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Replacement Research Reactor Project

SAR CHAPTER 11
REACTOR UTILISATION

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TABLE OF CONTENTS

11 REACTOR UTILISATION

End of Table of Contents

11 REACTOR UTILISATION

11.1 INTRODUCTION

The objectives of this chapter are:

1. To identify the safety requirements and safety design bases applicable to the utilisation devices (i.e. the irradiation facilities, target handling equipment, the neutron sources and beams, and other experiments).
2. To provide a summary description of the design and operation of the utilisation devices.
3. To identify the safety features of the utilisation devices that contribute to nuclear and personnel safety.
4. To evaluate the design and operation of the utilisation devices so as to demonstrate that they meet the identified safety requirements and safety design bases.
5. To identify faults that are subject to detailed safety analysis in Chapter 16.

This chapter describes design and operation of the irradiation facilities, including the handling and storage of rigs and targets, and the neutron beam facilities, including the Cold Neutron Source.

One major purpose of the Replacement Research Reactor Facility (Reactor Facility) is to sustain Australia’s nuclear expertise, knowledge levels, and nuclear competence. The reactor has been designed to be used for purposes which include the production of cold and thermal neutron beams with different energy ranges for scientific research, the production of radioisotopes, the neutron transmutation doping of silicon, and the irradiation of samples for elemental and isotopic analysis. None of the irradiation facilities, the neutron sources, the neutron beam assemblies or the neutron beam transport system are located in-core.

The different reactor irradiation and beam facilities are described and assessed in this chapter from a safety perspective, taking into account the possible influence of the facilities on the reactor, and also the possible incidents or accidents that may arise from the utilisation of the facilities themselves.

The utilisation of the Reactor Facility and its irradiation and beam facilities permits the performance of a wide variety of research programs. Furthermore, as the technology develops, the research program and parts of the specific research equipment are expected to change during the life of the reactor.

To cope with those changes without reducing the safety margins of the reactor and its facilities, a set of values for those parameters important to safety, are derived from design limitations and safety analyses described in Chapter 16. These parameters are identified in Chapter 17, Operational Limits and Conditions. This allows for changes in the utilisation facilities and procedures as described in this SAR, and allows evaluation of the safety impact of other uses not described in the SAR, that will not decrease the safety margin. Finally any new uses and modification to utilisation facilities are reviewed for compliance with the Operating Limits and Conditions and recommendations given in the IAEA Safety Series 35-G2, as stated in Section 11.6.

End of Section

11.2 REACTOR UTILISATION OVERVIEW AND BASIC SAFETY REQUIREMENTS

The primary use of the reactor is the production of neutron beams for research and the neutron irradiation of materials.

The reactor will be operated on a continuous basis at full power for several weeks followed by short shutdowns for refuelling and maintenance to be undertaken (see Chapter 5, Section 5.7). During these operating cycles, in-reflector facilities may be used to irradiate specimens and targets, and beam facilities used to extract neutrons at different energy levels. None of the irradiation or beam facilities are located in-core, rather they are located in the Reflector Vessel.

The irradiation facilities include:

a) Bulk Production Irradiation Facilities (BIF).

b) Long Residence Time General Purpose Irradiation Facilities (LRT).

c) Short Residence Time Irradiation Facilities (SRT).

d) Large Volume Irradiation Facilities (LVF).

e) Specific hot cells with pneumatic equipment for the delivery and retrieval of specimens and targets to and from the Reflector Vessel.

f) A series of installations for Irradiated Material Handling and Delivery.

The beam facilities include:

a) Neutron Beam Assemblies with shutters to extract neutron beams from the Reflector Vessel.

b) Cold Neutron Source (CNS) facility.

c) Hot Neutron Source provisions (to allow future installation of a hot neutron source).

d) Neutron Guide System.

All these facilities have been designed in accordance with internationally accepted safety standards (Chapter 2) and their operation does not pose a significant risk to the reactor operation.

Safety provisions have been made in order to cope with each of the possible failure modes that may arise from the operation of systems and components of each of the utilisation facilities.

No radioisotope processing is carried out in the Reactor Building. Targets are prepared at other ANSTO facilities in LHSTC and then sent to the Reactor Facility for irradiation. Once the irradiation is completed they may be left to decay for some time and then dispatched to the Radioisotope Production and Processing Facilities (RPPF) at ANSTO.

The Reactor Building layout has been organised to integrate operations, avoiding interference between radioisotope production activities and routine plant maintenance and operation activities and neutron beam research.

Appropriate, flexible and safe means are provided to handle and transport radioisotopes within the Reactor Building.

Adequate and safe means are provided to dispatch radioisotopes off the reactor site, including appropriate access for trucks, hoists, service lifts and an Interbuilding Pneumatic Transfer System.

End of Section

11.3 BRIEF DESCRIPTION OF THE FACILITIES

A brief description of the facilities for irradiation of targets, handling of irradiated specimens, and neutron beams for research purposes is included in this Section. Summary descriptions and safety consideration of the facilities are discussed in Sections 11.4 and 11.5.

11.3.1 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. These facilities are cooled by circulation of de-mineralised water by the Reactor and Service Pools Cooling System (RSPCS). 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 via an underwater elevator into a shielded hot cell. Irradiated targets are removed from the rig and are transferred to a loading hot cell from where the irradiated targets are dispatched, for processing in other buildings, by means of shielded transport flasks.

11.3.2 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 transport system is driven by nitrogen gas and the irradiation rigs have provision for cooling of the cans with this flow of nitrogen gas while they are being irradiated.

The pneumatic conveyors’ loading and unloading are carried out in two shielded hot cells, in which the main operations are automatic.

From the pneumatic system shielded 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.

11.3.3 Short Residence Time Irradiation Facilities

The Short Residence Time Irradiation Facilities (SRT) allow Neutron Activation Analysis (NAA) and Delayed Neutron Analysis (DNAA) to be undertaken. The target material is enclosed in a sealed irradiation can, which is sent for irradiation to rigs in the Reflector Vessel by means of a pneumatic transport system operated by nitrogen.

The transit time between the irradiation facility and the load/unload station at the Neutron Activation Analysis laboratory is approximately 3 seconds, thereby allowing analysis of short-lived radionuclides. The load and unload stations for DNAA are also located in the NAA Irradiation Laboratory.

Only one target at a time is allowed to be irradiated in each facility with the reactor at full power.

11.3.4 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. The transport to the NTD processing laboratory, and to the Silicon Pallet Room is done by means of the service lift incorporated in the Reactor Building.

11.3.5 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 and facilitate their delivery to the processing plants 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 Above Pool Hot Cell Complex (APHCC) has one Transfer Hot Cell (THC) for handling rigs from the Bulk Production Irradiation Facilities (BIF) and two Pneumatic Hot Cells (PHC) to handle targets irradiated in Long Residence Time (LRT) pneumatically operated irradiation facilities.

A Loading Hot Cell (LHC) serves for shielded flask loading operations.

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 (for further details see Section 11.4.5 and Sections 11.4.6)

11.3.6 Neutron Beams

The Reactor Facility provides the capability to perform both thermal and cold neutron beam research. For this purpose, several beam facilities are provided. These facilities include neutron beam assemblies, neutron guides, shutters, shielding, and Instrumentation & Control systems.

All neutron beams are provided with a double static barrier between the Reactor Pool and the area outside the reactor block.

All neutron beams have Primary Shutters installed at the reactor block face.

Primary shutters can be rotated from the closed position to a position enabling neutron beam transmission by the Neutron Beam Transport System. This operation is requested from a local control board enabled from the MCR. Either location can close the primary shutters.

Each of the thermal and cold neutron guides has 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

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

11.3.7 Cold Neutron Source

A liquid Deuterium type Cold Neutron Source (CNS), with an operating temperature of about 20 K, is located close to the peak thermal flux in the Reflector Vessel and has a high yield of neutrons with energy less than 5meV. Two neutron beam assemblies are focused directly at the source. A dedicated Preliminary Safety Analysis Report has been provided for the CNS. The main issues on its interaction with the reactor core are described in this SAR. The CNS SAR showed that the CNS does not affect reactor safety.

The CNS is cooled by an active cryogenic system that allows reliable and safe operation. Both the CNS system and the reactor are capable of independent operation.

Postulated failures of the CNS do not affect reactor safety as the CNS is isolated by a Vacuum Containment able to withstand a hypothetical Deuterium-Oxygen reaction inside it. The CNS is automatically monitored and controlled by the Facilities Control and Monitoring System (FCMS), and protection-related variables are monitored and protective actions are executed by the Cold Neutron Source Protection System (CNSPS), a dedicated Safety Category 2 system that prevents failures of the CNS Thermosiphon.

The “multiple barriers” concept is fully applied to the CNS design. The entire CNS Moderator System is double-walled, maintaining an inert gas blanket constantly monitored to provide early leak warning. In addition, the thermosiphon loop is fully contained by a zirconium alloy vessel, which acts as the boundary between the reactor and the CNS systems. Consistent with international practices this vessel is designed to withstand a hypothetical energy reaction should Deuterium and Oxygen reach critical explosion concentration ratios in its interior (Table 11.3/1).

Therefore, the Moderator System is isolated from the reactor core boundary by three successive engineered barriers having a continuous early leak detection system between them. In consequence, although close to the core, the CNS System can be considered effectively outside the Reactor System.

11.3.8 Hot Neutron Source

The Hot Neutron Source (HNS) is not provided at present. However the space for its location is provided, and the beam extraction device is installed, with its appropriate shutters, to allow incorporation of the HNS at a later stage.

When the HNS installation is planned, a specific Safety Analysis Report will be provided.

11.3.9 Neutron Beam Transport System

Neutron Guides are the main components of the Neutron Beam Transport System (NBTS). Their primary function is to transport neutrons from the high neutron density sources located in the Reflector Vessel to the research instruments placed in the Reactor Beam Hall and Neutron Guide Hall.

The Reactor Facility is provided with five Neutron Beam Assemblies.

The Thermal Neutron Beam Assembly #1 has provisions to hold three thermal neutron guides: TG-1, TG-2 and TG-3 in the same horizontal plane and is provided with two guides, with, initially the TG-2 guide plugged within the primary shutter. The Thermal Neutron Beam Assembly #4 has provision to hold one thermal guide: TG-4.

The Cold Neutron Beam Assembly #2 has provisions to hold three cold neutron guides in the same horizontal plane: CG-1, CG-2 and CG-3 and is provided with two guides, with, initially the CG-2 guide plugged within the primary shutter. The Cold Neutron Beam Assembly #3 holds one cold guide: CG-4.

The Hot Neutron Beam Assembly #5 has provisions to hold two hot neutron channels in the same horizontal plane: HB-1 and HB-2.

All neutron guides are of the supermirror type that ensure critical angles (θ_C) between 2 and 3 times that of Nickel.

The NBTS starts in the beam tube assemblies inside the Reflector Vessel. The neutron guides start inside the beam tubes and traverse the Reactor Primary Shutters through guide sections, to reach the reactor block face (outer face of the reactor biological shield). At this position, a metal window closes each guide and ensures a leak tight environment, constituting the second enclosure for preventing potential leaks from the Reactor Pool or Reflector Vessel. The first leak barrier is provided by the beam tube assembly inside the Reflector Vessel. (A full description of the leak tightness of the beam penetrations to the Reactor Pool is included in Chapter 4, Section 4.5)

From there, four guides (TG1, TG3, CG1 and CG3) run into and through the Neutron Guide Bunker until they reach the Secondary Shutters, located at the outlet of this bunker. These guides continue beyond the bunker into the Neutron Guide Hall where they are connected to experimental instruments. Along their entire trajectory into the Neutron Guide Hall and at their ends, dedicated shielding, that provides an adequate low-level radiation environment, encloses the neutron guides.

End of Section

Table 11.3/1 CNS International Practice

CNS Location, since (year)	**Moderator/working pressure**	**explosion safe vessel/design pressure**
FRM, Garching, 1996	H_2 / 450 kPa	Vacuum / 1 MPa
FRM-II, Garching, 2001	D_2 / 300 kPa	Vacuum / 1.3 MPa
SFV, ILL Grenoble, 1971	D_2 / 300 kPa	Vacuum / 1.3 MPa
SFV, ILL Grenoble, 1991	D_2 / 300 kPa	Vacuum / 1.3 MPa
BER-II, HMI Berlin, 1991	H_2 / 1.8 MPa	Gas liner / 3 MPa
Orphèe, CEA Saclay 2 units	H_2 / 200 kPa	Vacuum / 1.3 MPa
KFKI, Budapest, 2000 PNPI / BNC	H_2 / 200 kPa	Vacuum / 1.5 MPa
WWR-M, Gatchina, 1970-1986 several PNPI	H_2 / D_2 200 kPa	Gas liner / 1.5 MPa
JRR-3M, JAERI, Japan, 1990	H_2 / 160 kPa	Vacuum / 2 MPa
LANSCE, Los Alamos	H_2 / 1.8 MPa	Gas liner / 1.5 MPa
FRG-1, Geesthacht, 1988	H_2 / 1.8 MPa	Vacuum / 3 MPa
HFIR, ORNL Oak Ridge, 2001	H_2 / 1.8 MPa	Vacuum / 1.9 MPa
NIST, Gaithersburg, MD 1995	H_2 / 300 kPa	Gas liner / 7.6 MPa
RRR, Australia	D_2 / 300 kPa	Vacuum / 3.2 MPa

End of Tables

11.4 IRRADIATION FACILITIES

In this Section, each irradiation facility is described and assessed from a safety perspective. A number of general aspects are identified below.

General characteristics of the irradiation facilities are:

The irradiation facilities are located in positions inside the Reflector Vessel, outside the reactor core. This reduces the influence on the reactor core that might result from the normal operation, mishandling or failure of the irradiation facilities.

Radioisotope Containment: Targets are contained in sealed cans and are irradiated inside rigs of different types, depending on the irradiation facility.

Relation with the Reactor Control and Monitoring System (RCMS) (control rod movement): Irradiation facilities are designed so as not to cause substantial disturbance to the reactivity of the reactor core. Should a disturbance occur, the control rods automatically compensate for the effect. A limit on reactivity worth is imposed on those targets or rigs to be loaded/unloaded during reactor operation.

Cooling of rigs: Rigs are designed to allow the removal of the heat produced by the can/target and other structural materials during the irradiation without affecting their integrity and mechanical properties. The cooling is carried out with or without a can/target in the rig.

Relation with the Primary Cooling System (PCS): The PCS is physically and hydraulically independent of the irradiation facilities and it is not affected by their cooling systems (equipment, channels and circuits).

Total flow of the coolant and total pressure drop along the irradiation tubes is monitored from the Main Control Room.

Anchoring/fastening systems: Rigs and targets are properly located and held so that there is no significant risk of unwanted movement of components that are intended to be fixed.

Rigs are cooled by downward flow, which helps maintain them in their positions. Rigs and targets are designed not to float.

Handling of rigs and cans: The movement of rigs and cans between the Reactor and Service Pool is performed under well-defined procedures, and includes the use of handling devices to avoid the accidental dropping of these items. Protective structures prevent objects from falling onto rigs or into irradiation positions.

Rigs' materials: Rig and canning materials include aluminium, stainless steel, titanium and zirconium alloys. There is wide experience with these materials, which are also fully compatible with other reactor structural materials.

Design consideration has been given to the target cans' integrity and to the internal pressures reached through the expansion of the air contained in the can.

Effects due to potential target gasification produced by irradiation are assessed by ANSTO as part of the individual analysis to be performed prior to the approval for irradiation of each material/target can combination.

Perturbation of neutron flux readings due to manipulation of irradiation rigs: Sufficient perturbation could occur only in the case of removal of a silicon ingot and its replacement with the equivalent large volume of water. For this case, the design criteria require that at most only one nucleonic instrument be sufficiently perturbed to produce an alarm state. Spurious triggering of the RPS would be prevented since it acts on a Two-out-of-Three (2oo3) logic.

Core power peaking factor effects can be neglected because the facilities are not in-core.

Reactivity effects are discussed for each individual facility.

Maintenance and decontamination provisions: Especially those at the hot cells and radioisotopes manoeuvring areas, have been considered during the design stage and include:

a) The use of a tent or temporary partitioning to control contamination spread on the opening of cell doors.

b) The use of breathing air supplies close to the doors for connection to the suits.

c) The use of decontamination techniques and materials (e.g. demineralised water, paper).

d) The use of adequate in-line filters on the nitrogen return manifolds of the recirculating pneumatic system to prevent powder scattering throughout the pneumatic system in case of can rupture.

11.4.1 Bulk Production Irradiation Facilities

11.4.1.1 Description

These facilities allow the irradiation of targets contained in irradiation rigs that are placed vertically inside irradiation tubes provided in the Reflector Vessel.

Irradiation rigs are capable of containing multiple targets, each enclosed inside a suitable irradiation can.

Irradiation rigs are handled by operators standing at the Operation Bridge that moves above the Reactor Pool and Service Pool.

The removal and replacement of these rigs is permitted while the reactor is operating at full power except for those of reactivity worth greater than 200 pcm. The design allows more than three rig movements per day. Limitations to the number of rig movements arise only from scheduling considerations for ancillary equipment.

Rigs have a cover device to keep the targets safely inside and allow for rig cooling during the irradiation process. A specific tool is required to operate the cover.

Each rig has a locking system in the irradiation tube so as to avoid accidental removal. A specific tool is used to perform the locking task and to load and unload the rig. The combination of both of these features provides a safe system to avoid accidental removal.

Cooling of the rigs/targets is achieved by down-wards forced cooling

11.4.1.2 Normal Operation

The target preparation and canning is carried out at other facilities outside the Reactor Facility.

Targets are loaded to and from the rigs in the Transfer Hot Cell.

The Transfer Hot Cell (THC) is integrated into the Above Pool Hot Cell Complex (APHCC). Target loading to the rig inside the THC is performed using master-slave manipulators. Descriptions of the operating and safety aspects of the hot cells, and of the Irradiated Materials Handling and Delivering provisions are provided in Sections 11.4.5 and 11.4.6, respectively.

Once the fresh targets are loaded in the rig and the rig cover is in position, the rig is passed from the THC to the Service Pool. From there it is transferred to the Reflector Vessel, where the rig is placed into the irradiation tube with the aid of rig handling tools.

After irradiation, a reactor operator manually removes the rig from the irradiation tube with a specific tool. The rig removal operation is a simple operation. The rig is placed in a rack in the Reactor Pool for an initial decay period. This allows the initial decay of the rig activity to a level where it may be safely passed through the canal.

Auxiliary tasks such as visual confirmation of the rig identity may be carried out at the Service Pool position. Rigs are left to further decay for the required time before being taken to the THC.

When the decay period has passed, the operator transfers the rig into the THC for disassembly.

Section 11.4.5 presents a description of the facilities and the loading and unloading process at the THC and Loading Hot Cell (LHC).

11.4.1.3 Safety Design Provisions

The design of the BIF has been developed with attention to strict safety considerations. These considerations include inherent safety design features as well as operating principles, in order to avoid incidents or accidents caused in the facilities themselves and in the reactor as a result of operation of the facilities.

The relevant accident scenarios are specifically addressed in Chapter 16, Section 16.15 for Irradiation Facilities and Section 16.8 for reactivity insertion, which includes those due to irradiation facility events. The following evaluation is included for those incidents potentially compromising the rigs:

a) *Rig cooling*: As the irradiation rigs produce power during irradiation, the cooling system has been designed to cool the rigs by downward forced circulation from the Reactor Pool. The flow conditions guarantee that the heat flux, at the surface of the targets, is at least 30% lower than that required for the Onset of Nucleate Boiling (ONB). The ONB is often taken as a limit in steady state conditions although it does not actually correspond to any critical event.

b) *Rig Movements*: The rig cooling system allows loading and unloading of irradiation rigs and targets with the reactor at full power. The design is such that only slight perturbations of the overall hydraulic behaviour take place when a maximum of two medium flux and one high flux rig are extracted. This level of perturbation does not compromise the cooling capability for the remaining rigs.

c) *Rig caps*: For protection against falling objects the irradiation rigs are located inside a box that rests over the reflector vessel, with the following characteristics:

    (i) The upper steel face has openings to allow insertion and retention of rigs

    (ii) Fixation of the rigs to the upper plate is made by means of a cap that also prevents the entrance of foreign objects. The cap must be removed prior to removing the rig.

    (iii) The lateral walls are made of a fine mesh that allows the flow of cooling water to the rigs and prevents entrance of objects that may obstruct their cooling.

Due to the fact that special tools and a planned sequence of actions are required to load and unload the rigs, the inadvertent removal of a rig is not considered possible.

d) *Coolant flow path blockage:* In addition to the use of protective rig caps, administrative controls prohibit the entry of clear plastic to the reactor pool top area (this includes plastic bags and disposable plastic gloves). Administrative procedures and appropriate clothing ensure that loose objects do not fall into the pool or open irradiation positions. During rig exchange, the operator must check the coolant opening at the bottom of the irradiation channel with a special tool to verify that it is not blocked by a fallen object.

e) *Loss of flow*: In the event of a failure of the pumps, there is a signal on low flow for the First Reactor Protection System that triggers a reactor shutdown via the First Shutdown System.

f) *Loss of Coolant (LOCA)*: The PCS has Siphon Breakers located well above the core in order to preserve cooling capability in case of a loss of coolant event in the PCS circuits. Natural circulation cooling of the core takes place in case of a pipe break event at the primary or pool cooling circuits.

g) In the unlikely event of a total drainage of the Reactor and Service Pools, water is retained in the piping, the suction box and the reflector tank irradiation tubes. Further, a skirt above the Reflector Vessel (Irradiation Rig Coolant Container) would retain a head of cooling water above the rigs in the irradiation tubes.

h) *Incorrect rig positioning*: To prevent positioning of irradiation rigs in the wrong irradiation positions, the different irradiation devices are geometrically different, thus avoiding the irradiation of a certain device in an inappropriate position. In addition, administrative control including observance of procedures will also prevent the wrong positioning of rigs and targets.

i) Excessive power generation in a given rig is prevented by administrative control implemented under a suitable quality assurance system which controls the material type and mass of the targets prior to irradiation.

j) *Incidental radiation field*: To prevent the incidental irradiation of the operations personnel when handling irradiated rigs, all manual operations are performed with the rigs under water. The loading and unloading tools are designed to prevent the accidental extraction of an irradiated rig above a safe water level. The transfer wagon to the transfer cell is provided with the proper end-of-travel stops and interlocks such as to prevent an accidental drop of the irradiated rig.

k) *Target cladding failure/leakage*: The fission product detector and the active liquid monitor (ALMO) will indicate the leakage from the irradiation targets of fission products and other radioactive nuclides (Chapter 6).

l) *Layout characteristics*: Irradiation facilities are designed so that there is no interference with the safety functions of the First Shutdown System (FSS). No operation related to rig loading, unloading or irradiation has any physical, mechanical or electrical interference or inter-relation with the FSS. The inadvertent extraction of a rig that might produce unwanted reactivity insertion is analysed in Chapter 16, Section 16.8, in relation to the FSS capability to handle the event. The same considerations apply to the Second Shutdown System (SSS), since operation of BIFs does not interfere with its basic safety functions.

m) *Reflector Vessel drainage*: The drainage of the Reflector Vessel is addressed in Chapter 6 and it is shown to represent no hazard to the safety of either the core or the irradiation rigs.

n) *Materials compatibility (rig/irradiation tube/target)*: The materials used in the irradiation rig facilities are: aluminium and titanium and zirconium-alloy. These materials are used extensively in research reactor applications and are totally compatible. Analysis of reactor materials is included in Chapter 5.

Besides the possible incidents that may compromise the integrity of the rigs themselves, there are some incidents that may influence the reactor behaviour. These are the reactivity perturbations caused by the insertion or extraction of a rig, and the potential consequences of an accidental drop of an irradiation device during transfer operations. They have safety implications as indicated:

a) The potential for a reactivity perturbation on the reactor is analysed in Chapters 5 and 16 of the SAR, and even the worst case constitutes a reactivity insertion well within the capabilities of the RCMS. Therefore it poses no risk to the reactor behaviour.

b) To avoid accidental rig falling during loading and unloading manoeuvres the operating tools are provided with safety locks that prevent the rig disengagement at undesired positions. Furthermore, critical components inside the Reactor Pool are protected by grids that minimise or avoid damage from any falling heavy objects.

11.4.2 Long Residence Time General Purpose Irradiation Facilities

11.4.2.1 Description

The Long Residence Time General Purpose Irradiation Facilities (LRT) are aimed at irradiating samples transferred through the Pneumatic Conveyor System (PNCS), to their respective irradiation positions in the Reflector Vessel.

It is possible to use cans lined with cadmium in these facilities. Use of cadmium will result in a neutron flux perturbation level of less than 5% in any other facility. The maximum reactivity worth of a target including a cadmium liner is within limits specified in Operational Limits and Conditions.

All the targets are contained inside suitable sealed metal cans. Where necessary, inner cans, capsules or ampoules may be used within the outer can to provide higher levels of containment for targets (e.g. For powdered or fluid targets) and activation products.

Targets can be loaded and unloaded while the reactor operates at full power, and their reactor residence time ranges from one minute to one operating cycle.

Cans to be used in these facilities are designed to safely withstand the limiting conditions that are identified in target and canning specifications. The cans and isotopes to be used in all irradiation facilities require an approved Target & Canning Specification before they can be loaded for irradiation. In addition, each design of irradiation can requires an approved Canning Specification. The Target & Canning Specification ensures compliance with Operational Limits & Conditions and confirms that it is safe to perform a specific irradiation. This requirement applies to irradiations in all facilities, ie. Bulk, LRT, LVF, NAA and DNAA.

A pneumatic system is provided that both cools targets and transfers them to and from the irradiation positions provided.

The design allows soft loading and delivery of the cans to prevent can damage or opening on impact when transferred to/from the rigs. In the case of ampoules or other very fragile targets they are wrapped in aluminium foil to prevent damage.

The system also has the LRT Multiple Unloading Interlock, a hardwired interlock that prevents the simultaneous unloading of cans.

In the event of failure or routine maintenance of any rig component, the operation of the remaining rigs can continue normally.

These facilities are used to irradiate a very wide range of target materials, for both radioisotope production and irradiations for research purposes. Prior to the irradiation of any target type for the first time, analysis is carried out and a specification prepared defining limits for target material for irradiation and for canning methods. This is subject to a formal review and approval process. All targets irradiated shall be prepared under a suitable quality assurance system and shall conform to an approved specification for target and canning.

11.4.2.2 Normal Operation

No target opening operations are carried out in the facilities located at the Reactor Building. Conditioning, identification, controls, canning of samples as well as opening of irradiated cans are undertaken at the Radioisotope Production and Processing Facilities at ANSTO.

The On-Site Pneumatic Conveyors transfer cans between the Terminal Stations and the Rigs in the Reflector Vessel. To this end, the system has a pressure source for accelerating the cans.

The facility will have an integrated, automatic and programmable system aimed at loading the fresh cans to their irradiation positions in the Reflector Vessel from outside each PHC or via the IPTS from Building 23. The system also unloads the irradiated can into each PHC and sends it via the IPTS to the Building 23.

The facilities allow loading and unloading a can without affecting the cooling in other irradiation positions, and without moving other targets.

11.4.2.3 Safety Design Provisions

All system components are located within controlled areas to reduce radiation exposure during normal reactor operation.

An adequate ventilation system maintains the environment’s low activity and humidity levels.

Biological shields guarantee a gamma emission level below the maximum specified values to ensure compliance with applicable dose limits and to keep radiation doses as low as reasonably achievable.

All pressure vessels are protected with safety valves.

All safety valves discharge into the Reactor Containment Ventilation System through valve outlet pipes.

Dew point sensors verify water content inside the pneumatic circuit. Should there be a water leak, the dew point alarm value would be quickly reached, sending an alarm to the IFCMS. The operator must respond in accordance with this alarm and assess the magnitude of the leak.

Electrical connections between the three blowers prevent all of them being in operation simultaneously, i.e. a maximum of two blowers can be switched on together. This hard-wired restriction prevents an increase in flow-rate that may produce a non-controlled target movement when placed inside their irradiation position.

The Long Residence Time General Purpose Irradiation Facilities (LRT) have been designed with attention to strict safety considerations. These considerations include inherently safe design features as well as safe operating principles, in order to avoid incidents or accidents in the facilities themselves, and in the reactor as a result of operation of these facilities.

The relevant accident scenarios are specifically addressed in Chapter 16. The following evaluation is included for those incidents potentially compromising the pneumatic irradiation facilities:

a) *Target power*: The total power for each target including the can is limited to 145 W. If this power is exceeded, this will raise an alarm to the pneumatic system operator. If the temperature reaches a set limit, the system will automatically remove the can from its irradiation position.

b) *Target activity*: The activity for each target is limited to the equivalent of 100 GBq of sodium-24, The hot cells have shielded decay stations to allow for the decay of short-lived radionuclides before sending them for processing.

c) *Target opening and integrity*: The target cans will not be opened in any of the facilities provided in the Reactor Building. Also, in order to maintain the integrity of cans containing powdered or hazardous material, targets may be encapsulated in double cans.

d) *Can stuck in transit*: The cans will undergo a physical inspection and a check with a go/no go gauge prior to their introduction in the loading stations, in order to prevent any can becoming stuck in the pneumatic system. However, if a stuck can did occur, there are two position sensors to determine the target location. If during a transit operation, a can is stuck in a pneumatic tube, cooling is maintained, and the target position is indicated on the sensing instrumentation in order to guide appropriate recovery actions. This being the case, the radiation doses to the operating personnel during a recovery operation is kept to a minimum due to the shielding associated with the pneumatic tubes.

e) *Target mishandling*: Several target-mishandling operations were postulated, which include targets sent to incorrect irradiation positions, and targets sent to a position already occupied by another target. To prevent these events, several safety interlocks, which are software-based and constitute part of the pneumatic control system, have been included in the Terminal Station design.

f) *Loss of cooling*: In the event of a loss of cooling (either by the blower system failure or by electrical failure), several signals feeding the RCMS will initiate a reactor power reduction, in order to prevent thermal damage to any target.

g) *Pressure build-up in the can*: The design is such that it can safely withstand the maximum internal pressure generated from the expansion of air inside the can due to the temperature rise during irradiation. Prior to authorising a type of material for irradiation, ANSTO will evaluate the possibility of gas generation in a target material during irradiation. The can design will withstand the negative differential pressure applied should rig tube leakage allow a can to be exposed to the reactor pool hydraulic pressure.

h) *Materials compatibility*: The design of the LRT facilities employ various aluminium alloys that will present no compatibility issues with other structural and irradiation can materials.

i) *Leakage from can*: In case of a failure of a can during or after the irradiation the circuit or the hot cell system (depending on the location of can) will act as a containment barrier to prevent exposures to operating personnel. In such situations the contaminated rig is replaced and the design is such that there is access to the cells to perform decontamination tasks.

j) *Radiation beam through the tubes in the Reactor Pool*: The pneumatic tubes are provided with shielding at the Reactor Pool top to prevent radiation streaming and radiological hazard/exposure of operating personnel.

Besides the possible incidents that may compromise the integrity of the irradiation facilities themselves, there are other possible scenarios where operation of the facilities may affect the reactor. These are analysed in Chapter 16 and briefly described herein:

a) *Reactivity incident*: This incident is constituted by the fast extraction of an irradiation target, with its maximum reactivity worth. This case is analysed in Chapter 16, Section 16.8, and does not pose any significant risk to the reactor. This incident is bounded by the incident of a Control Rod withdrawal.

b) *Simultaneous withdrawal of two or more cans*. This event is prevented by a hard-wired inhibition for simultaneous withdrawal of two or more cans

c) *Pneumatic tube LOCA*: Loss of coolant through a failed pneumatic tube is prevented since all the tubes exit from the reactor pool above the water level. Should a tube fail, the inner region of the tube up to the pool water level would be flooded. Thus, a tube failure does not pose a significant risk to the reactor. (Small breaches are detected by a dew point sensor located at the main coolant stream that controls humidity contents).

11.4.3 Short Residence Time Irradiation Facilities

11.4.3.1 Description

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 with short exposure periods.

Only one target at a time can be transferred and irradiated in each facility. Irradiation times ranging from 3 seconds to several minutes are achievable. Each facility consists of one rig and one set of transfer tubes similar in design to those described in the On-Site Pneumatic Conveyors for the LRT rigs.

The irradiation Terminal Stations for NAA and DNAA are located in the Neutron Activation Analysis Laboratory. Transfer between the irradiation positions and each 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.

The pneumatic transfer system and cooling system of the NAA/DNAA facilities is integrated into the Long Residence Time General Purpose Irradiation Facilities (see Section 11.4.2). The transfer system is designed to transfer targets with mass up to 50 g via the NAA and DNAA Pneumatic Conveyors.

All target movements are possible with the reactor at full power. It is possible to irradiate only one target can at a time in each facility.

The facility is capable of handling up to 40 target cans per day. The flux perturbation level is less than 5%, which can be easily handled by the RCMS.

11.4.3.2 Normal Operation

The target loading and unloading stations for NAA and DNAA are located inside cabinets with localised air extraction in the NAA Irradiation Laboratory. A fume cupboard is located next to the unloading stations for can opening to extract possible active gases to the Reactor Containment Ventilation System.

The control system supplied is placed in the NAA Irradiation Laboratory. The control system will allow cans to be automatically transferred and irradiated for programmed periods. The instrumentation provided allows for analysis of gamma spectrometry following irradiation of targets loaded for multiple irradiation and counting cycles. A similar arrangement with neutron counting equipment is provided for DNAA.

Target cans are of High-Density Polyethylene (HDPE) and will have external dimensions of 35 mm OD and 90 mm in length. The design will maximise the internal volume as much as practicable, subject to mechanical constraints. The target can will have a snap close system or similar, which will allow fast opening and closing.

11.4.3.3 Safety Design Provisions

The design provisions for the Short Residence Time Irradiation Facility are similar to those for the Long Residence Time Irradiation Facilities. Safety aspects such as target power, activity, mishandling and loss of cooling have been considered in Section 11.4.2.3.

The evaluation of other aspects that concern the safety of this system include:

a) *Target opening and integrity*: The target cans have been designed from High-Density Polyethylene (HDPE) and with a fast open and closure device. These cans are opened inside a fume cupboard, which has its own active ventilation system. Fume cupboards within the reactor building share an active ventilation system, which discharges to the main stack and has provision for HEPA filtration. Therefore, any hazard resulting from a leak of radioactive gas or fine particulate material from the fume cupboard is prevented.

b) *Can stuck in transit*: This event is similar to the one discussed for the other pneumatic irradiation facilities. The transfer process is controlled by a dedicated control software-based system, which will control the transfer process, provide information on the facility status, and enable the loading and unloading of canned samples. Additionally, the pneumatic tubing for transfer of the polyethylene cans has 25 mm lead equivalent shielding, and the loading and unloading station 50 mm lead equivalent shielding.

A reactivity-related event is associated with the incorrect or inadvertent fast withdrawal of a target, and it is discussed in Chapter 16, Section 16.8. This reactivity incident is bounded by the incident related to the withdrawal of a CR.

11.4.4 Large Volume Irradiation Facilities

Six Large Volume Irradiation Facilities (LVF) are supplied for the Neutron Transmutation Doping (NTD) of single-crystal silicon ingots. These facilities may also be used for the bulk irradiation of other suitable samples.

The facilities are used to irradiate silicon ingots in an unsealed can on a rotating rig. The other samples are irradiated in these same rigs in sealed cans loaded into the unsealed cans.

Control valves on each hydraulic line allow water supply to the rig to be isolated during load/unload or maintenance operations. The silicon in its unsealed can is loaded into or unloaded out of the rig inner rotating element by a purpose built lifting head mounted to the operation bridge. The rig is fully removable from the Reflector Vessel for repair in the event of a system failure.

All in-pool transfers of the silicon or sealed bulk samples in their unsealed can are carried out by personnel. After irradiation, the silicon ingots are placed for temporary storage in the Reactor Pool and Service Pool in dedicated storage racks. Here they are left to decay.

After decay, irradiated silicon is transferred to a load and unload station located in the Service Pool. At the load and unload station, the silicon is unloaded from the unsealed cans under water. Unirradiated fresh silicon is loaded into the cans before they are returned to the storage rack. The irradiated silicon is cleaned and dried after removal from the pool before being transported to the Silicon Processing Room where additional cleaning if required and final packing is done. This room has integrated areas to perform the different tasks such as cleaning, packing and storage, and accommodation for a programming officer.

All receipt and despatch of silicon product occurs through the truck access area.

Fluxes within a silicon ingot over a 600mm length centred about the peak thermal neutron flux are axially uniform to better than ± 3% of the average, which are maintained throughout the operating cycle. Dummy silicon and graphite ingots may be placed above and below the required 600mm length, to achieve the specified flux uniformity. The silicon ingot is rotated to provide radial uniformity of dose within the ingot.

Cans containing silicon ingots do not require fastening devices because of the downward cooling flow.

It is possible to remove and replace cans containing silicon ingots within the rotating irradiation rigs when the reactor is at full power.

11.4.4.1 Normal Operation

Receipt and dispatch of new and irradiated consignments of silicon is performed in the truck access area.

This truck access area is also used for loading and unloading other radioisotope facility containers. It has a hoisting device to allow movement of heavy weights and pallets.

On one side of the truck access there is a room to store material belonging to the radioisotope handling facilities. Material may be stored temporarily in this room during loading and unloading tasks.

Fresh material is unpacked in this area and prepared for loading in the irradiation facility in the reactor hall.

11.4.4.1.1 Silicon Ingot Removal and Transfer to Service Pool

Silicon ingots in their irradiation cans will be removed from the rotating irradiation rigs using the Operation Bridge and lifting tools and placed into a nominated location in the Reactor Pool Storage Rack. The cans are then transferred from the Storage Rack to the storage facility located in the Service Pool by the operator. Any auxiliary handling tasks are carried out in the Service Pool.

The storage facility allows temporary storage of large volume irradiation rigs and components, silicon ingot irradiation cans, loaded or empty, and other sample target cans.

Silicon ingots are cleaned using demineralised water and dried using breathing quality compressed air above the wash station. Once dry, the silicon ingots are checked for contamination prior to release for transfer. From this position ingots are transferred to the silicon processing room

Once an ingot is cleared for release to the customer, it is subsequently repacked.

After being packed, the material is stored in another area within the NTD processing room.

After completion of these processes, material is delivered.

Silicon cans will be treated as solid waste if they exhibit excessive wear or are damaged during routine operations.

Since they are mainly made of aluminium, they will be left to decay for some days in the Service Pool to achieve a medium-low or low level activation before being processed.

An underwater cutting machine, located at the Service Pool, allows the reduction of the effective volume of waste to be transported in a special container. This container, of 72-litre capacity, is loaded under water with solid waste and is placed in a shielded flask to allow transport outside of the Reactor Building.

11.4.4.2 Safety Design Provisions

The design of the LVF and the related operations for silicon ingots have been developed with attention to strict safety considerations. These considerations include inherent safety design features as well as operating principles, in order to avoid incidents or accidents due to these facilities.

The relevant accident scenarios are specifically addressed in Chapter 16. Irradiation facilities in general are analysed in Section 16.15 and events associated with reactivity insertion in Section 16.8. The following evaluation is included for those incidents applicable to the LVF:

a) *Ingot cooling*: As the silicon ingots will produce some power during irradiation, the cooling system has been designed to cool the rigs by downward forced circulation of Reactor Pool water. This downward flow ensures cooling conditions to avoid the ONB along the surface of the samples.

b) *Can Movements*: The rigs cooling system has been designed to permit the load and unload of cans containing silicon ingots at full power. For this purpose, the design allows only slight perturbations to the overall hydraulic behaviour when one can is extracted, without compromising the cooling capability over the remaining rigs.

c) *Loss of flow*: In the case that a failure occurs, there is a signal on low flow for the Reactor Protection System (RPS), that will produce the reactor shutdown via the FSS. This is to protect the targets and is not needed to protect the reactor. After that, the ingots will be cooled by upward natural circulation.

d) *Pool LOCA*: The PCS and the RSPCS have Siphon Breakers located well above the core in order to preserve cooling capability, driven by natural circulation, for both reactor core and targets after a pipe break event at the primary or at the pool circuits.

e) *Incidental radiation field*: To prevent the incidental irradiation of the operations personnel when handling silicon cans, all manual operations will be performed with the cans under water.

f) *Ingots activity*: Following irradiation, cans containing silicon ingots will be left to decay for approximately 2 to 3 days.

g) *Materials compatibility:* Silicon, Graphite, Aluminium and Stainless Steel will be employed. These materials feature excellent compatibility under the operating conditions.

h) The potential for a reactivity perturbation on the reactor was analysed and is below the 200 pcm limit (Chapter 5, Section 5.7), and even the worst case constitutes a reactivity insertion well within the capabilities of the RCMS. Therefore, it poses no risk to the reactor behaviour.

i) Perturbation of readings of the nucleonic instrumentation: The magnitude of the perturbation of the flux, outside of the Reflector Vessel and behind NTD irradiation positions, due to the movement of the targets was evaluated. Thus the selected location of probes will minimise changes to nucleonic readings of the Automatic Reactor Power Regulation System (ARPRS) and Reactor Protection System (RPS). A description of the ARPRS is given in Chapter 8, Section 8.7.

Besides the possible incidents that may compromise the integrity of the irradiation facility itself, there is an incident that may influence the reactor behaviour. This is the accidental fall of a silicon ingot over the reactor core, structures, neutron beam assemblies or other elements located inside the Reactor Pool:

j) The possibility of an accidental drop of a silicon ingot on the reactor fuel or other structures (i.e. that may cause a breakage of a neutron beam tube) is addressed in Chapter 16, Section 16.15. To preclude such an event, however, the operating tools prevent can disengagement at undesired positions. Furthermore, the critical components inside the Reactor Pool are protected by grids that should reduce the likelihood of damage caused by the drop of an object.

k) Zoning of activities inside the Reactor Pool and minimisation of handling operations will reduce the likelihood of accidental situations.

11.4.5 Radioisotope Handling Facilities

The purpose of these facilities is to interface the production of radioisotopes with the processing and manufacturing operations, which are performed in the Radioisotope Production and Processing Facility outside the Reactor Building.

Typical operations to be performed are:

- reception of fresh targets,
- programming and control of irradiation cycles using Irradiation Facilities Scheduling System (IFSS),
- movement of samples (to and from irradiation positions at the Reflector Vessel),
- handling of rigs,
- control of irradiated samples and,

- conditioning of irradiated targets in containers or special packaging for transport to the Radioisotope Production and Processing Facility.

These operations will be performed at different areas of the Reactor Building by means of facilities designed to manage radioactive material in accordance with radiological protection standards. These areas are:

- Reactor Pool,
- Reactor Service Pool and Above Pool Hot Cell Complex,
- Silicon Ingot Processing Area,
- NAA Irradiation Laboratory and,
- Irradiated Material Dispatch Area and Loading Hot Cell area.

The facilities consist of four hot cells and a set of shielded tubes to allow the transfer of irradiated targets between the hot cells and between the Service Pool and the Loading Hot Cell. Special shielded Flasks will be used to allow the safe transfer of irradiated material outside the Reactor Building by truck, and a Pneumatic System allows the transfer of small cans between the pneumatic cells and the Radioisotope Processing Plant.

One Transfer Hot Cell (THC) and two Pneumatic Hot Cells (PHC) are integrated at the Above Pool Hot Cell Complex (APHCC). One Loading Hot Cell (LHC) for loading of irradiated targets into several types of shielded flasks.

The basic components of the Hot Cells are:

Heavy density concrete shielding

A shielded window

A shielded access door

A working table

One or two master-slave manipulators

A waste disposal system for liquids and solids

A set of accessories (mirrors, pliers, etc.)

A control console

An active ventilation system connection

A demineralised water supply

An electric power supply and lighting

A compressed air supply

A fire extinguisher system

One or more sample-conveying device stations

One or more through-wall posting port

Radiation monitor with interlock to the door control system

The hot cells have emergency lighting that will start automatically in the event of a loss of electric power supply.

Connections for breathing air beside the access door are provided to allow personnel to enter the cell under special circumstances.

11.4.5.1 Shielded Flask Containers

Two basic design types are used at the Reactor Facility for radioisotope handling similar to the ones universally used in the nuclear industry:

a) A Small Interbuilding Container (SIC) is used to transport small samples to the Radioisotope Processing Facility in Building 23. The SIC is shielded with 85 mm of depleted Uranium. A turntable containing three Small containers will be transferred to the truck access area by a fork lift truck transported through the service lift or by crane through a hatch.

b) 6 Tonne and 10 Tonne Bottom Loaded Flasks (BLF) will be loaded through a gate at the bottom of the flask. The flask has a cup, which holds the target that may be lowered into the LHC for target loading and unloading. The cup is tied to a cable that is handled from outside the flask. BLF are made of steel and lead allowing the transport of irradiated samples on-site by truck.

The Small Interbuilding Containers (SIC) and Bottom Loaded Transfer Flasks (BLF) will be loaded at the LHC to transfer radioisotopes to the Radioisotope Production and Processing Facility.

BLF (6 or 10 tonne) are brought into the Reactor Building through the truck access provided. A handling area provided with a hoisting device enables safe flask loading/unloading operations.

11.4.5.2 Safety Design Provisions

The different hot cells provided in the Reactor Building have been designed with attention to strict safety considerations, in order to avoid any possible incidents or accidents that may occur during their operations. These considerations include inherent safety design features, interlocks and a robust design.

The relevant accident scenarios are specifically addressed in Chapter 16. Section 16.15 discusses general events related with irradiation facilities. An overall evaluation of the safety characteristics is presented herein:

a) *Air circulation:* The hot cells are maintained at a nominal negative pressure in order to keep all possible airborne contamination within the cells. A dedicated ventilation system is provided with absolute filters for air intake, and absolute and charcoal filters for the exhaust.

b) *Radiation protection*: The radiation protection issues are specifically described in Chapter 12, Section 12.3. They include the construction of the cell walls in high-density concrete, the provision of master-slave manipulators, the provision of shielded storage inside the cell to provide for the decay of high energy short-lived radionuclides, the provision of a shielded glass window to protect the cell operators during normal operation, and the provision of area monitors in the vicinity of the cells to remotely monitor the dose rates.

c) *Spillage characteristics*: Can opening operations are not allowed in any hot cell. However, it is possible to have some spill of radioactive material in the case of can rupture, can leakage or fire. To cope with these situations, the hot cells have been designed to be easily cleaned. All the inner cell surfaces are painted with epoxy paint.

d) *Electrical Power failure*: To cope with incidences involving electrical power failures, the ventilation system for the cells and emergency internal lighting is supplied from the Standby Power System.

e) *Accessibility*: The hot cells cannot be accessed during normal use. However, for maintenance, cleaning or other needs, they may be accessed. To preclude any accidental access to the hot cells, the corresponding doors are provided with safety interlocks. Additionally, close to any access there is a source of breathing air to prevent any inhalation of contaminated air from inside the cell during these operations.

f) *Fire hazard*: Each of the hot cells is provided with embedded piping for fire fighting provisions (CO_2 Total Flooding System) that may be installed in the event of a future change on the usage of the cells. It would have the provision to activate the CO_2 flooding system from outside the cell.

g) *Sample Transfer Failures*: End of travel switches will give warning if targets do not arrive at the desired station. In case of power failure, all electric driven conveyors are designed to stop moving and a manual operating mode can be used to move samples out of the transfer ducts. Use of smooth curves along the path minimises the possibility of a stuck sample and also facilitates intervention when necessary.

11.4.6 Interbuilding Pneumatic Transfer System

The pneumatic transfer of irradiated samples to Radioisotope Production and Processing Facility will be described herein. These transfers take place through the Interbuilding Pneumatic Transfer System (IPTS).

11.4.6.1 Description

The IPTS is provided to transfer small irradiation cans between the Pneumatic 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 will be 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, at a distance from the Reactor Building.

Shielding along the path of this system is heavy density concrete or equivalent. Radioisotopes transferred in this system shall be limited to those giving rise to a radiation dose rate in uncontrolled access areas no greater than that from 40GBq of Co-60.

There is one IPTS tube and one spare tube connected to each Pneumatic Hot Cell.

The loading and unloading terminals in the Pneumatic Hot Cells have radiation monitoring equipment that will interlock with the transfer function if the radiation dose rate exceeds a pre-selected value that corresponds with the maximum activity limit.

One tube in each cell operates while the other is in stand-by mode.

The IPTS transfers irradiation cans and allows soft delivery and arrival of the cans.

The transfer time is estimated as 70s.

One control terminal is provided in Radioisotope Production and Processing Facility, which has a database function to keep track of irradiated and fresh targets in the IPTS, Bulk and Pneumatic Conveyor Systems. This terminal allows viewing of IPTS system status, operation and certain process parameters.

One terminal in each Pneumatic Hot Cell control panel will allow the viewing of system status and operation.

The IPTS tubes are placed inside a below ground concrete conduit between the reactor facility and the processing facilities in Radioisotope Production and Processing Facility. This conduit will provide suitable shielding to persons at ground level.

11.4.6.2 Safety Design Provision

The Interbuilding Pneumatic Transfer System has been designed with attention to strict safety considerations. These considerations include inherently safe and robust design characteristics as well as safe operating principles, in order to avoid incidents or accidents in the facility.

The relevant accident scenarios that may arise from the use of the IPTS are bounded by the events relating to excessive target activities (above design value) and can stuck events during transfer of targets. A brief description of the safety characteristics is indicated herein:

a) *Target activity*: The target activity to be transferred in the IPTS is limited to that equivalent to 40 GBq of Cobalt-60. The equivalent dose rate is instrumented as the set point of an interlock valve, which will prevent the use of the IPTS for targets with a higher activity.

b) *Can stuck in transit*: The transfer tube from the Reactor Building to Radioisotope Production and Processing Facility is below ground level, with protection by concrete-slab shielding and/or earth cover to avoid exposure of people standing above the ground in case a can is stuck inside the transfer line. In the unlikely event that the stuck target cannot be recovered by compressed air action, the transfer tube can be accessed through shielded inspection bays, the tube cut, and the specimen safely removed. At the cell interface, the tubes are embedded in the block and will be inaccessible from outside. In the event of a can stuck in this region, releasing the can will be by passing a flexible tool through an open end of the tube.

All pumps and blowers associated with the IPTS are located within the containment. Air flowing through the IPTS is returned to the containment, minimising the potential for the IPTS to constitute a containment bypass route.

End of Section

11.5 NEUTRON BEAM FACILITIES

The reactor is provided with a thermal and an advanced Cold Neutron Source (CNS) to produce neutrons in specific spectral ranges. These neutrons travel from their sources along specially designed neutron beam guides with high technology super-mirror inner walls. Neutrons entering the neutron guides can be transported long distances without significant losses.

The CNS will use the well-proven natural-circulation liquid deuterium (LD_2) thermosiphon concept. CNS parameters are:

a)	Moderator material	Liquid Deuterium (LD_2)
b)	Moderator volume	20 litres
c)	Heat Removal capacity	5000 W
d)	Average temperature of the moderator	23° K

The Hot Neutron Source will not be included within the present facilities, but provisions are included in the design for a future installation. The provision includes a Hot Neutron Beam Assembly (Assembly #5 described below) able to supply neutrons to two independent beams (HB1 and HB2) that terminate in the Reactor Beam Hall. These beams will be of thermal neutrons until the Hot Neutron Source is installed.

The Neutron Beam Transport System basically consists of super-mirror neutron guides. Depending on the neutron spectral requirement, the reflecting surfaces will be $2\theta_C$, $2.5\theta_C$ or $3\theta_C$. Neutron guides will be placed into a dedicated vacuum containment. This gives the minimum number of neutron guide windows and, at the same time, an exceptional mechanical behaviour of the neutron-optics components.

All these systems will be properly interfaced and optimised to maximise the performance for neutron-related science.

11.5.1 Neutron Beam Assemblies

Neutron beam assemblies are used to lead neutrons from the neutron sources, through the reactor block and the primary shutters, to the Reactor Face in the Reactor Beam Hall, or the Neutron Guide Bunker.

A Beam Assembly consists of three main sections, namely:

a) The Neutron Beam Tube, from the neutron source up to the Reflector Vessel external wall.

b) The Neutron Beam Structure, from the Reflector Vessel’s external wall up to the Reactor Face. It is the embedded metallic structure designed to hold the Primary Shutter and the internal section of the Neutron Beam Transport System.

c) The Primary Shutter located in the outer part of the Neutron Beam Structure extending to the Reactor Face. It allows neutron transport when the shutter is open.

The internal part of the Neutron Beam Transport System (NBTS) is described in Section 11.5.2.

The design of the Beam Assemblies has been developed with attention to strict safety considerations. These considerations include inherent safety design features as well as operating principles, in order to avoid incidents that may cause harm to personnel or the public.

All the assemblies are designed to withstand postulated seismic events (See Chapter 2, Section 2.5.2 for Seismic Design Requirements and Chapter 4, Section 4.5 for seismic protection of beam tubes and neutron cover plate detail analysis). The combination of static stress (own weight plus load) and dynamic stress (seismic loads) does not exceed the material's yield stress.

From a radiation protection viewpoint, the design provides similar dose rate levels at the reactor face to those at the surface of the reactor's biological shield.

An auxiliary system provides the cooling capacity to remove the gamma heating in the shielding.

The use of removable shields and purpose designed tools, as well as special hoists to facilitate the removal of heavy parts during maintenance or replacement are considered in the design which complies with the ALARA criteria for doses to personnel during such tasks.

The Reactor Facility has five Assemblies for the Neutron Beam Facilities:

a) Assembly #1: supplying thermal neutrons to three neutron guides: TG1, TG2 and TG3. Two of them (TG1 and TG3) extend into the Neutron Guide Hall while TG2 ends at the Reactor Face with, initially, a plug provided within the primary shutter.

b) Assembly #2: supplying cold neutrons to three neutron guides (CG1, CG2 and CG3); two of them (CG1 and CG3) extend into the Neutron Guide Hall while CG2 ends at the Reactor Face with, initially, a plug provided within the primary shutter.

c) Assembly #3: supplying cold neutrons to one neutron guide (CG4) that terminates at the Reactor Face.

d) Assembly #4: supplying thermal neutrons to one neutron guide (TG4) that terminates at the Reactor Face.

e) Assembly#5: supplying neutrons to two independent beams (HB1 and HB2) that terminate at the Reactor Face.

The design of Thermal and Cold Assemblies (#1 and #4, #2 and #3 respectively) are basically the same except for their location, relative position to the core and the quantity of the beam channels (3 or 1) at each assembly.

A metal support contains the channels for the neutron guides and the carbon steel body. The body of the Assemblies surrounding the guides acts as shielding.

CG4 and TG4 are installed in the centre of the Assembly #3 and #4 respectively. The spaces for additional guide components are replaced by solid steel shielding integrated into the inner and shutter sections of the assembly. To upgrade from a single to multiple guide assembly will require replacement of both these assembly sections. This is a planned operation as it is required whenever the inner sections of the guides need replacing.

11.5.1.1 Beam Tube and Structure

The neutron beam tube is a rectangular-section zirconium alloy structure immersed in the heavy water Reflector.

Neutron beam tubes are passive components and form part of the boundary of the Reflector Vessel acting as part of the first containment barrier. They are welded to the external Reflector Vessel's wall and are an integral part of this.

Neutron Beam Structures are also passive components and are made of stainless steel. Their design allows, with minor changes to components, the use of different collimator/neutron guides of the internal sections of the Neutron Beam Transport System. Intermediate metallic components surrounding the neutron guides provide the required compensating shielding.

Neutron Beam Structures provide the supporting structure to contain the internal part of the Neutron Guide System.

All components located in the Neutron Beam Structure are removable, because of the limited lifetime (more than 10 years) of the internal (near core) components of the Neutron Guide Transport System.

11.5.1.2 Primary Shutters

The outer section of the Neutron Beam Structure consists of a device for closing the beams, known as the Primary Shutters. These shutters are massive shields containing centrally located neutron guide sections.

Primary Shutters are a stainless steel structure specially designed to hold a homogeneous array of high-density and high-hydrogen content shielding materials around the neutron guides.

These shutters are the only movable part of the Beam Assemblies.

To minimise waste production, both structural and shielding materials are specifically qualified to have a low content of isotopes that may be activated.

The Primary Shutters can be dismounted from their position to allow the replacement of the internal part of the Neutron Guide System, if required.

Every Primary Shutter simultaneously closes or opens all the guides contained within that shutter.

The shutters have a neutron absorbing cover on their outer diameter, on the area exposed to radiation when they are closed and during rotation.

The primary shutters of Assembly #5 have a different design from the rest of the assemblies. The device contains two independent rotating shutters,

The mechanism will allow each shutter to rotate by 90-degrees, moving the neutron channels to the vertical position and interposing heavy and hydrogenous material to shield the ducts.

The instrumentation is the same for all shutters, and it has been designed to prevent any hazardous situation of the shutter.

The shutter control unit is identical for all Primary Shutters. The mechanism rotates the shutter through 90 degrees, with consequent positioning of shielding along the beam lines.

11.5.1.3 Safety Design Provisions

11.5.1.3.1 Beam Assemblies

The relevant accident scenarios are specifically addressed in Chapter 16, Section 16.15. An evaluation is included here for those incidents potentially compromising the neutron beams:

a) *Pool water leakage into the beam assembly:* A metallic seal is provided in the inner part of the beams. Should this barrier fail, the operators will be warned by a moisture detector.

b) *Moderator heavy water leakage into the beam assembly:* Leakage from the moderator water inside a beam assembly would be stopped by the sealed closure at the reactor face. This closure is a metallic plate on the reactor block.

c) *Loss of Neutron Beam Cooling System:* A failure of the cooling system has no impact on reactor safety. The only components that can be damaged are the Neutron Guides in the internal part of the NBTS.

d) *Corrosion and Materials compatibility:* No specific corrosion problems are foreseen. All materials used are compatible.

e) *Seismic response:* The beam tube design has been developed taking into consideration the seismic loads postulated in Chapter 2, Section 2.5.2. Water retaining boundaries and shields for beam tubes are designed to Seismic Category 1 and other components of beams are designed to Seismic Category 2.

Among the possible incidents that may challenge the integrity and/or the proper functioning of the beams, some are related to reactor safety since neutron beams are part of the Reactor Pool boundary at the same level as the core. Thus, issues related with the rupture of the beam tubes, have been considered during design by applying the “defence in depth” philosophy in order to reduce the probability of a Loss of Coolant Accident (LOCA) and to ensure that a fast loss of coolant is incredible. (Chapter 4, Section 4.5 describes the Reactor Pool protections against the loss of coolant through the beam penetrations and Chapter 16, Section 16.11 assesses the LOCA event).

a) *Early leakage detection:* Each beam assembly has two independent systems to detect breaches at the beam boundary. These systems provide alarm signals to the RPS that allow early detection and monitoring of the fault.

b) *Multiple barriers:* The beam system has two independent and passive barriers to prevent leakage from the Reactor and Service Pool.

Since the beam boundary is a passive device, designed to be corrosion resistant, free of mechanical stress and capable of withstanding seismic events, the effect of accidental dropping of a heavy object during transfer operations in the reactor pool has been considered (i.e. rigs, silicon ingots, etc.). The following engineering safeguards have been used:

a) *Weight limit:* To limit the weight of a potential object that could possibly damage the neutron beam assemblies, the Reactor Hall Bridge Crane has interlocks that prevent the movement of excessively heavy objects above the Reactor Pool.

b) *Safe-locked tools and administrative procedures:* The movement of rigs or any other heavy object at the Reactor and Service Pool must be performed in compliance with well defined procedures which include the use of tools provided with safety locks to prevent the undesired dropping of loads.

c) *Mechanical protections:* The part of the beams located inside the Reflector Vessel is protected from a falling object by the top of the Reflector Vessel. The part of the beams located outside the Reflector Vessel in the Reactor Pool is protected with an upper metallic grid that will minimise the effects of any falling object on the beam. This protection will preserve the integrity of the beam even if the heaviest object at the irradiation facilities should fall onto them.

11.5.1.3.2 Primary Shutters

The relevant accident scenarios are specifically addressed at Chapter 16, Section 16.15. A brief description is included herein for those safety aspects considered relevant:

a) *Loss of power:* In case of a loss of power, the primary shutter will remain in its existing position. An alternate operation mode is provided which allows manual closing of the shutter using a local crank should this situation be required to place the facility in a safe condition or for maintenance or other purposes. Also a Secondary Shutter is provided at the exit of the Neutron Guide Bunker as described in Section 11.5.2.1.

b) *Shutter position:* Personnel near the primary shutter will have a clear indication of the shutter position, in order to alert them to a potential radiological hazard.

c) *Shutter opening:* Each shutter will be provided with spring actuated anti rotation locks. The pneumatic movement control system has interlocks and alarms to ensure safe operation of the shutters. The interlock prevents opening of the shutter unless authorisation for shutter opening is given from the Reactor Control Room (password protected action).

d) *Shutter Bunker interlock:* Appropriate administrative procedures will be provided to ensure the bunker is vacated before the shutters are opened.

e) *Maintainability:* The design of shutters and associated equipment takes into account the long-term activation of structural components. The facilities provided (including hoists, rail-towing devices and shielded casks) can be used for manoeuvring heavy structural components both during construction and replacement at the end-of-life, under radiologically safe conditions.

f) *Seismic response:* The shutters are designed to resist static stresses and postulated seismic loads without exceeding the material yield strength at any part of the structure and also not to overturn during severe seismic events (Chapter 2, Section 2.5.2 describes the seismic criteria).

11.5.2 Neutron Beam Transport System

11.5.2.1 Description

The function of the Neutron Beam Transport System (NBTS) is to transport neutrons, from the neutron sources located in the Reflector Vessel, to defined positions in the Neutron Guide Hall, where experimental equipment is placed.

The internal part of this system has two components clearly identified:

a) An Inner part, located between the Neutron Beam Tube and the Primary Shutter.

b) An Outer part located within the Primary Shutter.

In the inner part a supporting plug contains three rectangular channels one for each neutron guide.

Each neutron guide section has its own independent channel, which provides mechanical protection for the glass based neutron guides. The channel also contains all neutron guides into a unique block and serves as a supporting structure for the assembling of the neutron guide elements.

In the outer part, all components are contained within a single component called Neutron Guide Cassette, which is contained within the primary shutter.

From the Reactor Face (where the NBTS is interrupted by metallic windows), four neutron guides (TG1, TG3, CG1 and CG3) run into and through the Neutron Guide Bunker till reaching the Secondary Shutters, located at the outlet of this bunker. The metallic windows are safety category 1 items that form part of the secondary LOCA barrier. No other parts of the NBTS have any significance to nuclear safety.

These guides continue beyond the bunker into the Neutron Guide Hall where they will be connected to experimental instruments. To minimise losses, neutrons travel in the guide in a specially designed Vacuum Jacket along the entire trajectory from the Reactor Face, through the Neutron Guide Bunker, and into the Neutron Guide Hall. In this way it is possible to keep the neutron transmission path air-free and, additionally, provide mechanical protection to the guides.

A dedicated Neutron Guide Vacuum System (NGVS) provides the required vacuum in the Vacuum Jacket. Malfunctioning of this system does not impact on reactor safety, but only affects the neutronic performance of the NBTS.

At the exit of the Neutron Guide Bunker the Secondary Shutters interrupt each line of the NBTS again. They are devices whose main function is to cut the neutron supply in each neutron guide. Their design is such that, when shut, they allow unrestricted access to the downstream sections of the corresponding neutron guide.

Until the installation of the guides TG2 and CG2 their channels are blocked off inside the primary shutter and concrete shielding blocks will be provided at their bunker exit positions to provide safe working conditions in the Neutron Guide Hall.

11.5.2.2 Safety Design Provisions

The incidents postulated for these facilities are related to radiation protection actions and provisions, and are described in Chapter 12. A brief description of the radiological safety characteristics of the neutron guide system is provided here.

a) *Neutron Guide Bunker:* A dedicated bunker to provide biological shielding will be constructed from the reactor face to the neutron guide hall

b) *Bunker Access:* A locked door and administrative control prevents access to the bunker by unauthorised personnel.

c) *Secondary Shutter* Indication: These shutters are instrumented to indicate their positions and warn of malfunctions to beam users and reactor operators.

d) *Radiation protection:* Along the entire trajectory within the Neutron Guide Hall, the neutron guides have dedicated shielding around and at each end position, to provide the required low-level radiation environment.

The possibility of guide component fracture does not pose a risk to reactor safety. The guide components are not required to hold a pressure differential. Fracture would only impact on the neutronic performance of the NBTS. All guide components are designed to be replaceable.

11.5.3 Cold Neutron Source Facility

This document presents the main characteristics of the CNS and its operation, and the main safety aspects of this facility in relation to reactor operation. A separate Preliminary Safety Analysis Report for the Cold Neutron Source has been presented to ARPANSA. This report will be updated to reflect the ‘as built’ design and incorporated as an Appendix into this SAR.

11.5.3.1 Description

The Cold Neutron Source consists of a liquid Deuterium (LD_2) moderator, 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 Neutron Guide Hall, where research facilities are located.

The use of Deuterium instead of Hydrogen as neutron moderator is a safety feature by ensuring a negative reactivity change in any event leading to sudden deuterium evaporation. Although the reactivity changes anticipated from the CNS operation are low, this feature leads to a safer design.

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. The liquid deuterium is sub-cooled at all points in the loop under normal operating conditions thus ensuring maximum moderation efficiency.

The moderator was designed to operate at liquid state and is refrigerated by a natural circulation loop. This design feature simplifies the design, avoiding the use of pumps for forced convection (as the ones used in some horizontal CNSs designs) and avoiding active components that may act as single points of failure.

A space defined by the Vacuum Containment and the CNS Flange, which is kept in vacuum conditions by a connection to the CNS Vacuum System, contains the CNS Thimble. The CNS Thimble is fixed to a vertical support tube that is part of the Reactor Reflector Vessel.

The main safety function of the Vacuum Containment is to be a physical barrier between the CNS Moderator and the reactor core, strong enough to cope with all events originating within the CNS. The Vacuum Containment walls, as a boundary towards the Reflector Vessel, are designed to withstand any accidental condition of the CNS, including the hypothetical case of a Deuterium reaction with air. The Vacuum Containment is made of Zr-alloy and is cylindrical. The Vacuum Containment has a flange at its upper end (Vacuum Containment Flange) by means of which it is fixed to a vertical support tube, which is part of the Reactor Reflector Vessel. The Vacuum Containment Flange is joined with double gaskets to the flange on the top of the support tube. Additionally, the Vacuum Containment Flange is joined with blanketed double gaskets to the CNS Flange. Therefore, there is a double flange involving the flange on the top of the support tube, the Vacuum Containment Flange and the CNS Flange.

The CNS Flange locates all the piping penetrations to the CNS Thimble, and it is a boundary towards the reactor pool. Its safety requirement is limited to withstanding any accidental condition without detaching from the Vacuum Containment flange although leakage and/or distortion is permitted.

The CNS operates in two steady state modes, namely: the “Normal Operation” (NO) mode and the “Standby Operation” (SO), and in the transient states between them. Both allow normal reactor operation. An additional Mode, namely Halt Operation (HO), is compatible with the reactor and CNS RCS shutdown. Although not actually an operating mode, it is defined to allow for maintenance and loading operations of the CNS.

In the NO mode, the CNS Thermosiphon (Moderator Cell, tubing and He/D_2 heat exchanger) is filled with liquid deuterium that is kept sub-cooled by heat exchange with the cryogenic Helium from the CNS-RCS.

The SO mode is an alternative mode that allows for continued normal reactor operation in the event of unavailability or failure in some CNS systems.

In the SO mode, warm Helium is circulated from the CNS-RCS to remove the heat load induced in the CNS Moderator Chamber material. In this operation mode, the Moderator Cell is filled with gaseous Deuterium and consequently, energy deposition mainly takes place in the Moderator Chamber material.

Switching between CNS operation modes is possible during any reactor operating state.

11.5.3.1.1 Cold Neutron Source Thimble

The CNS moderator chamber consists of a double-walled vessel. The Moderator Cell is filled by the CNS-Moderator System with cold liquid Deuterium that provides neutron moderation functions. Cooling Helium flows through the outer chamber (or gap) where it also fulfils a Moderator Cell gas blanketing function.

Two pipelines connect the upper part of the moderator cell with the inlet and the outlet of the primary side of the CNS-Cryogenic Heat Exchanger, located above the cell, in a lower neutron flux zone. The secondary side of the heat exchanger is fed with cryogenic helium by the CNS- Refrigerator Cryo-System, whose main function is to remove the heat deposited in the deuterium.

The sections of the CNS thimble are made of appropriate materials, which can withstand cryogenic conditions, radiation fields, minimise radiation heating and have adequate processing and welding characteristics. Alloys of zirconium and aluminium meet these requirements in the high radiation region, and also stainless steel in the upper (lower radiation) region.

Electron beam and/or electric arc welding will be used for the manufacture of the moderator cell, pipelines, cylinders and torospherical top and bottom sections.

11.5.3.1.2 Layout of the CNS within the Reflector Vessel

The Vacuum Containment constitutes the most significant of the engineered safety features associated with the CNS. It mitigates any incident within the CNS, isolating its effects to the reactor and safety systems even in the event of a hypothetical deuterium reaction with air. The Thermosiphon loop is the heart of the CNS providing the neutron moderation functions and thus, producing the cold neutrons.

The Vacuum Containment is placed within the Reflector Vessel before the latter is filled with heavy water. The thermosiphon loop is placed within the Vacuum Containment and attached with its own flange. Finally, all flexible supply pipes are connected to the loop’s flange. In this way, the CNS Thimble is vertically placed within the Reflector Vessel, close to the thermal neutron flux peak. There are two horizontal beam tubes pointing towards the CNS thimble. These beam tubes hold the neutron guides, providing cold neutron transport functions.

11.5.3.1.3 Instrumentation & Control

The CNS system will be controlled, operated and monitored through an automatic and computerised (computer or Programmable Logic Control) Facilities Control and Monitoring System (FCMS).

The CNS systems instrumentation will allow detection and indication of the departure from acceptable operating conditions, including the leakage of deuterium from the moderator system and the loss of integrity of any of the multiple barriers. The instrumentation will include:

a) deuterium boundary failure detection mechanisms;

b) deuterium pressure sensors;

c) deuterium temperature sensors;

d) helium refrigerant temperature sensors;

e) a vacuum system gas analyser (vacuum containment); and

f) a helium jacket gas analyser

11.5.3.1.3.1 Facilities Control and Monitoring System

The CNS is automatically kept within the operational range in any of the operating modes by the FCMS. Additionally, this system controls the transients between operating modes, according to pre-defined cooling/ warming strategies that are dependent on the current operating conditions. This system provides information to the main control room operators.

11.5.3.1.3.2 Cold Neutron Source Protection System

The CNS will have a Protection System aimed at protecting the integrity of the Thermosiphon loop. The Cold Neutron Source Protection System does not perform any nuclear safety function. The CNSPS is classified as Safety Category 2 and will:

Monitor protection related variables

Provide protection interlocks

Provide appropriate links to the reactor protection system

In abnormal operating conditions, the Cold Neutron Source Protection System (CNSPS) will request a reactor Trip 1 or isolates the He lines, in order to prevent the Thermosiphon being exposed to non-acceptable conditions. Actions are taken when the Thermosiphon cooling cannot be guaranteed or its mechanical integrity is being threatened.

11.5.3.2 Normal Operation

The CNS is able to operate in two modes, namely: the “Normal operation” (NO) mode and the “Standby operation” (SO) mode, both allowing normal reactor operation. There is an additional mode, called Halt Operation (HO), which is compatible with the reactor shutdown and allows having the CNSRCS turned off.

In the NO mode, the thermosiphon is filled with liquid deuterium, and cold neutrons from the CNS enter neutron guides CG1, CG3 and CG4. The deuterium temperature in the cell is below boiling temperature. Liquid deuterium moves by natural circulation in the low temperature loop. Cryogenic helium is used to remove the radiation heat load induced in the moderator cell from both the construction material and the liquid deuterium. Cryogenic helium enters by two separate lines, one of them supplying the heat exchanger and the other going to the outer gap of the moderator chamber. In principle both lines have similar flows.

To reach the NO mode operating parameters in the CNS:

a) The reactor may be shut down or operating at any power level. The time to reach the NO mode depends on the heat load induced in the CNS moderator cell. The lower the heat load, the faster the NO mode is reached.

b) The operating parameters of the CNS cooling system will change smoothly until they reach full capacity. The helium inlet temperature to the CNS Thimble will change smoothly from initial SO values down to around 20 K.

c) The pressure in the Deuterium Buffer Tank will change smoothly.

There is an alternative mode “Standby Operation” (SO) which allows normal reactor operation without cryogenic conditions in the CNS (without producing cold neutrons), or in the case of unavailability or failure in some part of the CNS systems.

In the SO mode, warm helium is circulated through the helium jacket of the moderator chamber.

This helium mass flow removes the heat generated in the moderator cell material.

Returning from the SO to the NO mode is possible from any reactor operating state.

11.5.3.3 Safety Design Provisions

The safety characteristics of the CNS and associated systems are fully analysed. SAR Chapter 16, Section 16.15.6 addresses the issue of CNS-related accidents and the risk of damage in the reactor core.

This section provides a brief description of the key safety features of the CNS design.

The CNS Vacuum Containment is designed to withstand a hypothetical energy reaction should Deuterium and Oxygen reach critical explosion concentrations in its interior, even though such an event is considered in practice to be so unlikely as to be beyond design basis. The following component of the CNS is classified as Safety Class 1 and Seismic Class 1:

a) CNS Vacuum Containment, which will be designed to Class 1 Pressure Vessel standard.

The main safety features of the CNS design are:

a) *Moderator boundary:* The CNS moderator system has a closed and passive pressure boundary that minimises the possibilities of leakage. There are neither pumping devices nor operational valves. The system has a buffer tank that retains the complete inventory of deuterium under all operating conditions within allowable pressure limits without the use of any active components. Furthermore, the system has an overpressure protection.

b) *Moderator self-regulation:* The moderator within the closed loop flows by natural circulation, and has a self-regulating trend: any increase in the heat load leads to an increase in circulation and therefore to an increase in heat removal. Moreover, if there is a heat imbalance that stops the normal sub-cooling of the thermosiphon (for example as a result of an accidental initiating event), the system becomes self-pressurised, and any deuterium evaporation tends to maintain the pressure and to increase the circulation and the heat removal.

c) *Multibarrier provided by the Moderator blanketing:* The moderator system is completely surrounded by a blanketing system that provides a second barrier which includes all the deuterium cryogenic pipelines. The space between the first and second barriers is filled with pressurised helium or nitrogen depending on location, and the pressure is monitored. The cooling helium is considered as part of the helium blanket for all the in-pile parts of the moderator system.

d) *Multiple barrier provided by the Helium blanketing and vacuum containment:* The in-pile part of the CNS is contained within a high integrity boundary that also provides a vacuum insulation. The vacuum level and residual gas concentration are monitored. Considering that the most demanding conditions of the moderator system are within the in-pile part (that is completely surrounded by cooling helium and blanketing), the vacuum system of the containment may be considered as a third barrier to potential releases

The vacuum system is in turn surrounded by a fourth blanket (the heavy water of the Reflector Vessel), that also excludes air from reaching the CNS and therefore preventing ignition.

e) *Vacuum containment:* The thermal-siphon loop is fully contained by a zirconium alloy vessel placed within the reactor's Reflector Vessel. The Vacuum Containment is attached by a flange to a tube extending a substantial distance above the Reflector Vessel. This Vacuum Containment is designed to withstand a hypothetical energy reaction should deuterium and oxygen reach critical stoichiometric concentration within it.

f) *Helium relief tank:* In order to assure the moderator cell integrity when subjected to external pressure (mechanical stability) the maximum pressure obtainable in the cooling helium system is passively limited by the use of a relief tank. This tank is connected to the helium loop in such a way that even mishandling operation of valves would not hinder the tank's function as a pressure relief.

End of Section

11.6 REVIEW AND APPROVAL OF MODIFICATIONS IN UTILISATION AND EXPERIMENTAL FACILITIES

11.6.1 General

IAEA Safety Series 35-G2 provides practical guidance on safety related aspects of utilisation and modification of research reactors such that these projects can be implemented without undue risk to personnel, public, the environment or the reactor. The review and approval of modifications in reactor utilisation and experimental facilities (modification projects) in the Reactor Facility will be done in accordance with 35-G2.

An independent means of review and approval, such as an on-site safety committee, which can provide judgement on the adequacy of the safety of the facilities and which may endorse proposals for action, will be available within ANSTO.

Approved arrangements to control utilisation and modification projects will be established and implemented before the commencement of reactor operations. This will include written procedures to ensure compliance with regulatory requirements.

ANSTO will be responsible for ensuring that:

a) appropriate safety analyses of the proposed modifications are undertaken,

b) approved categorisation criteria are applied,

c) relevant safety guidelines are followed and associated requirements for review and approval are met.

Adequate quality assurance will be applied at all stages in the preparation and implementation of a modification project in order to ascertain that all agreed safety principles and criteria have been satisfied. This will include the proper identification, evaluation and approval of QA non-conformances, changes to designs etc.

All persons who will be involved in a modification project will be suitably trained and qualified and have experience in such work.

The Reactor Manager has the overall responsibility for modification projects, and the responsibilities of all other personnel involved will be defined in the appropriate procedures, instructions and project documentation.

Since separate organisational groups (e.g. operators and users) will be involved in a modification project an appropriate organisational structure for the project will be implemented to ensure full co-operation between the parties involved.

Procedures for handling irradiated equipment or material will be established before a modification project is approved. Equipment for the safe handling of such material will be procured and tested before the operational phase of the modification project starts.

11.6.2 Significant Modification Projects

Significant modification projects are those which present a potential hazard which could have major safety significance and those involving new experimental facilities which are outside the scope of the facilities discussed in the current SAR

A project manager will be responsible for the implementation of the project objectives through the development of a project definition, adherence to established safety criteria, evaluation of the options, and the management of the detailed design, project implementation, commissioning and decommissioning, if relevant.

These projects will be subjected to safety analyses and design, construction and commissioning procedures in order to ensure that they satisfy the same requirements as the existing facilities, including appropriate review and approval by the regulatory body. Such projects will be documented in detail in a safety analysis report which will include justification for requesting the change and which will follow the guidance given in IAEA Safety Series 35-G1 and sections 5, 6, and 7 of IAEA Safety Series 35-G2.

Special attention will be given to:

a) the determination of the impact of the project on the existing safety analysis report and on the operational limits and conditions;

b) preparing proposals for the safety categorisation of the project;

c) ensuring that adequate precautions are in place to provide protection against radiological hazards; and

d) providing the safety documentation to obtain the necessary reviews and approvals from the on site review committee and the regulatory body.

The project manager may use outside specialists and consultants as appropriate.

11.6.3 Out-of-reactor Installations

There are two categories of out-of-reactor installations:

a) those which utilise the radiation produced by the reactor but which are outside the reactor shielding (e.g. neutron spectrometer) and

b) those which do not use the radiation produced by the reactor but which are at or near the reactor and constitute a potential hazard (e.g. parts of a cryogenic system).

For such out-of reactor installations, the hazards which they present to the reactor and its associated systems will be assessed. If necessary a safety assessment will be prepared and reviewed by the on-site safety committee, using the procedures for review and approval of modifications of reactor utilisation and experimental facilities, prior to approval for their installation or modification.

The users of such installations will observe the limits and conditions agreed upon in the safety review and will follow the operating instructions for the installation.

It is intended that the neutron beam instrumentation will be covered by the Bragg Institute Source Licence.

End of Section

11.7 RESTRICTION ON MATERIALS ASSOCIATED WITH REACTOR UTILISATION

The following materials (in significant amounts) other than those incorporated into the facility design, are not allowed to be used in practices in or near the reactor core:

Corrosive liquids and gasses

Flammable solids, liquids or gasses materials

Explosive materials

Organic peroxides

Oxidising agents

Structural material able to be corroded by the primary cooling system water

Spontaneous fuels

The following materials will require specific safety assessments, which must be suitably documented and approved prior to their use in the reactor facilities:

a) materials able to be significantly activated while exposed to the core radiation fields

b) materials able to produce significant changes in the moderation capability of the reactor like deuterium and graphite (excluding the cold and hot neutron sources).

End of Section