INTRODUCTION

The Philippine Research Reactor (PRR-1) is an open-pool-type nuclear research reactor owned and operated by the Philippine Nuclear Research Institute (PNRI), an agency of the Philippine government under its Department of Science and Technology (DOST). The reactor was obtained from the government of the United States of America under the Atoms for Peace program. The PRR-1 attained first criticality and began operation at its original rated power of 1 MW (thermal) in 1963.

The reactor was operated regularly without any serious problem until the late 1970s, when its instrumentation system became unreliable because of aging. The instrumentation system was completely replaced in 1980. The PRR-1 was converted to a TRIGA-type reactor from 1984 to 1988, when its fuel elements, cooling system and instrumentation system were replaced, raising its rated power to 3 MW (thermal). The reactor was successfully tested at full rated power, but a leak in the pool liner, problems with other aging reactor components and problems with the reactor site prevented the resumption of operation.

The pool liner leak and some of the reactor components were repaired, but the PNRI eventually ran out of funding in the late 1990s to finish reactor rehabilitation. All of the reactor's spent fuel elements were shipped back to the U.S.A. in 1999. The PNRI decided in 2005 to decommission the reactor.

This document is a living record of the decommissioning of the PRR-1. Chapters and sections will be added and revised as work progresses. This document will eventually be complete when the facility has been released from regulation.

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Chapter 1

REACTOR DESCRIPTION

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1.1 SITE

The PRR-1 is located in the PNRI Compound in the campus of the University of the Philippines (U.P.) in the Diliman area of Quezon City, a part of Metropolitan Manila in the island of Luzon, the Philippines. See the following figures:

a. Fig. 1. The PRR-1 in the PNRI Compound

b. Fig. 2. The PNRI Compound in the U.P. Diliman Campus

The PNRI Compound is a 7.5-hectare fenced plot of land. The PNRI Compound is in the 100-hectare mostly-vacant northwest section of the U.P. campus that is separated from most of the academic buildings by Commonwealth Avenue, a wide highway running northeast. The PNRI Compound is bounded at the north by Central Avenue, at the west and southwest by a wooded area (the U.P. Arboretum), at the south and southeast by empty brush land up to Commonwealth Avenue (currently undergoing development into a Science and Technology Park), and at the east by another fenced compound occupied by the Engineering Research and Development Center of the Philippine National Oil Corporation.

Aside from the PRR-1, the PNRI Compound contains three large buildings: the Atomic Research Center Building, the Co-60 Multipurpose Irradiation Facility and the PNRI Administrative and Training Building. There are also numerous small buildings housing laboratories and various workshops. The southwest corner of the compound is fenced apart and contains the Radioactive Waste Management Facility of the PNRI.

1.2 REACTOR BUILDING AND GROUNDS

The Reactor Building is made of reinforced concrete, with a central cylindrical structure topped by an approximately-ellipsoidal dome and two attached wings. The space enclosed by the central cylindrical structure is called the Reactor Bay and contains the Reactor Pool. The two wings are called the East Wing and the West Wing.

See the following drawings:

a. Fig. 3. The Basement-Floor Plan of the Reactor Building

b. Fig. 4. The First-Floor Plan of the Reactor Building

c. Fig. 5. The Second-Floor Plan of the Reactor Building

d. Fig. 6. The ESE-WNW Vertical Section of the Reactor Building

e. Fig. 7. The NNE-SSW Vertical Section of the Reactor Building

The Atomic Research Center (ARC) Building is built as a detached semicircular arc around the Reactor Building but is not considered part of the reactor facility. However, the basement and first floors of the ARC Building are connected by covered hallways to the Reactor Building.

The reactor's cooling tower and small auxiliary structures are located in the northeast space between the Reactor Building and the ARC Building

1.2.1 Reactor Bay

The Reactor Bay has an internal diameter of 20.7 m (68 ft), has walls 0.46 m (1.5 ft) thick, and rises 29.8 m (97.8 ft) from its floor to the top of the dome. The floor of the Reactor Bay is 3.8 m (12.3 ft) below ground level. A polar crane spanning the full width of the building is mounted on a circular rail 14.0 m (45.8 ft) above the floor. The Reactor Bay has a truck entrance door, which opens into a tunnel that slopes up to ground level. There are personnel doors into the Reactor Bay from the East and West Wings, and a small hatch into the West Wing.

1.2.1.1 Reactor Bay Location Codes

The following codes will be used to refer to locations and items in the Reactor Bay. (The prefix RB means Reactor Bay.) Refer to Figures 3 to 7.

RB-1	Floor.
RB-2	Alcove for sliding truck entrance door.
RB-3	Truck Entrance Ramp.
RB-4	Fuel Storage Tank. This tank is a free-standing cylindrical tank made of stainless steel, 4.9 m (16 ft) high and containing up to 51.1 m^3 (13,500 gal) of demineralized water. The tank was intended to be a temporary storage location for irradiated nuclear fuel elements and other radioactive material that were removed from the Reactor Pool while the pool liner was being repaired in the 1990s. The spent fuel were all shipped out in 1999, but the fuel from the TRIGA core and the other radioactive material are still in the tank. There is a demineralizer attached to the Fuel Storage Tank.
RB-4a	Large Portable Demineralizer (beside RB-4).
RB-4b	Small Portable Demineralizer (beside RB-4).
RB-4c	Co-60 Source (in lead cask inside RB-4).
RB-4d	TRIGA Fuel Elements (inside RB-4).
RB-4e	Cf-252 Neutron Sources (inside RB-4).
RB-4f	Sb-Be Neutron Source (inside RB-4).
RB-4g	Pu-Be Neutron Source (inside RB-4).
RB-4h	Neutron Source Holder (inside RB-4).
RB-4i	Old Regulating Rod (inside RB-4).
RB-4j	Various Storage Racks and Tanks (inside RB-4).
RB-5	Stairway. This stairway connects the Reactor Bay floor to the Control Room, East Wing second floor.
RB-6	Stairway. This stairway connects the Reactor Bay floor to the West Wing first floor.
RB-7	Interior surfaces of the wall and dome of the Reactor Bay.
RB-8	Storage Holes. These holes, set horizontally into the wall of the Reactor Bay, were used for storage of the beam tube plugs and some irradiated material.
RB-9	Air-Conditioning Ducts.
RB-10	Polar Crane.
RB-11	Co-60 Source. This source is inside a shipping cask on the floor of the Reactor Bay.
RB-12	Seed Neutron Irradiation Facility (SNIF). The SNIF is stored on the floor of the Reactor Bay.
RB-13	Various Fuel Storage Racks. These racks, which originally held spent fuel, were removed from inside the Reactor Pool and stored on the Reactor Bay floor.
RB-14	Various Shielded Containers. These containers are stored on the floor of the Reactor Bay. At least one of them contains radioactive material.

1.2.2 East Wing

The East Wing, including underground spaces, occupies almost two quadrants outside the Reactor Bay, to about 11 m (36 ft) beyond the wall of the Reactor Bay. The East Wing has three floors, two above ground level and one below. The East Wing houses the reactor control room and ventilation equipment in the second floor; a laboratory room and a mechanical/electrical equipment room in the first floor; and another laboratory room, an equipment room, tank rooms and various utility rooms in the basement floor.

The East Wing rises about 8.1 m (26.5 ft) above ground level, with most of its basement floor at the same level as the floor of the Reactor Bay. The basement floor in the tank rooms is 1.4 m (4.7 ft) below the floor of the Reactor Bay.

The East Wing has five doors into the Reactor Bay, one in the control room in the second floor, one each in the laboratory and isotope rooms in the basement floor, and two in the equipment room in the basement floor. The East Wing connects to the ARC Building through a hallway at the first floor level and another hallway directly underneath at basement level. Aside from the connections through the ARC Building, the East Wing has two doors to the outside, one at the first floor and another at the second floor opening to the roof deck.

The locations in the East Wing are described below. (The prefixes have the following meanings: E0 - basement floor; E1 - first floor; E2 - second floor.) Refer to Figures 3 to 7.

1.2.2.1 Basement Floor Location Codes

E0-1	N-16 Decay Tank Room. Contains the N-16 decay tank.
E0-1a	N-16 Decay Tank. This 11.4 m^3 (3,000 gal) tankwas used to delay primary coolant as it flows from the reactor core, reducing the radiation level around the rest of the primary coolant equipment during operation. The tank is carbon steel with a chemical-resistant phenolic coating.
E0-2	Drain Storage Tank Room. Contains the drain storage tank.
E0-2a	Drain Storage Tank. This 37.8 m^3 (10,000 gal) tank was meant to temporarily store waste water before being discharged. The tank is carbon steel with a chemical-resistant phenolic coating. Nevertheless, the tank rusted out and was replaced with a stainless-steel tank in the 1990s. The new tank has never been used.
E0-3	Retention Tank Room. Contains the retention tank and a transfer pump.
E0-3a	Retention Tank. This 56.8 m^3 (15,000 gal) tank was used to hold water from the Reactor Pool when the pool water level was lowered. The tank is carbon steel with a chemical-resistant phenolic coating and is still full of ex-pool water at present.
E0-3b	Transfer Pump.
E0-4	Suspect Tank Room. Contains the suspect tank and a small transfer pump.
E0-4a	Suspect Tank. This 1.9 m^3 (500 gal) tank was meant to hold liquids that are suspected to contain radioactivity. The tank is carbon steel with a chemical-resistant phenolic coating. This tank was used mainly during regeneration of the ion-exchange resin of the clean-up demineralizer.
E0-4b	Transfer Pump.
E0-5	Hot Resin Tank Room. Contains the 1.9 m^3 (500 gal) tank meant to store ion-exchange resin that has been discharged from the clean-up demineralizer. The tank is carbon steel with a chemical-resistant phenolic coating.
E0-6	Process Equipment Room. Contains the reactor’s heat exchanger, primary pump, make-up softener and demineralizer, clean-up demineralizer, clean-up pump and the sump pit.
E0-7	Sump Pit. All the floor drains in the Reactor Bay and in the East Wing laboratories discharge into the Sump Pit.

E0-7a	Sump Pump. This submerged pump in the Sump Pit moved waste water into the drain storage tank or directly into external discharge piping.
E0-8	A shielded alcove in the Process Equipment Room containing the clean-up demineralizer.
E0-8a	Clean-Up Demineralizer. The clean-up demineralizer has a discharge connection through the wall to the hot resin tank in room E0-5.
E0-9	Storage Room.
E0-10	Office.
E0-11	Storage Room.
	E0-9, E0-10 and E0-11 were used by radiation protection personnel. The storage rooms were used for equipment and supplies, not for radioactive materials.
E0-12	Toilet.
E0-13	Toilet.
	The sanitary drains of E0-12 and E0-13 discharge into a septic tank outside the Reactor Building.
E0-14	Stairwell. This stairwell connects the basement, first and second floors of the East Wing.
E0-15	Change Room for Isotopes Laboratory Room (E0-17).
E0-16	Hallway. This hallway connects various rooms in the basement of the East Wing, and also connects to the basement of the ARC Building through an underground corridor. The hallway has a door to the Reactor Bay at one end. The stairwell to the first and second floors of the East Wing opens into this hallway.
E0-17	Isotopes Laboratory Room. Radiochemical processing of targets irradiated in the reactor was done in this room. The room also contains one of the two terminals of the reactor's pneumatic irradiation system. The room was decontaminated in the early 1990s and new equipment (a hot cell for the production of I-131) was installed, which was never used because the reactor never resumed operation.
E0-18	Counting Room. A shielded alcove of the Isotopes Laboratory Room, meant to house counting equipment.
E0-19	Vertical Shaft. Originally meant to contain an elevator (lift) to the first and second floors. The elevator was never installed, and the shaft was closed off.
E0-20	Isotopes Storage Room. This room contains vaults for the storage of radioactive material.

1.2.2.2 First Floor Location Codes

E1-1	Mechanical/Electrical Equipment Room. This room contains the switchgear of the building's electrical power supply, the chiller of the building's air-conditioning system, a compressor for the building's compressed-air supply, and a booster pump for the building's water supply.
E1-2	Hallway. This hallway connects the various rooms in the first floor of the East Wing. The stairwell to the basement and second floors opens into this passageway.
E1-3	Office. This room was used by laboratory personnel. This room was later used for storage only.

E1-4	Foyer. This room was originally the reception room to the Reactor Building. The reception area was later moved to the lobby at the first floor of the ARC Building. A hallway connects E1-4 to the first floor lobby of the ARC Building.
E1-5	Stairwell. This stairwell connects the first and second floors of the East Wing. This stairwell was originally meant to be used only by visitors. E0-14 is an adjacent but separate stairwell for reactor and laboratory personnel.
E1-6	General-Purpose Laboratory. This room was originally used for general laboratory work and some radioactivity counting. In the 1980s, the room was partitioned into an office space and a space for the terminus and counting electronics of a Delayed Neutron Activation Analysis system that was installed in the reactor. The DNAA system had an automated pneumatic system for irradiating samples and transporting them to the counter. The remains of the DNAA system is still in the room. The room also has a terminus for the reactor's original pneumatic irradiation system.
E1-7	Vertical Shaft. Continuation of E0-19 in the basement floor. Also closed off.

1.2.2.3 Second Floor Location Codes

E2-1	Ventilation Equipment Room. This room was originally an open deck containing the blowers for the ventilation system of the Reactor Building. The original ventilation system was removed and replaced with an air-conditioning system in the 1990s. Most of the roof deck was then enclosed and roofed to hold the emergency exhaust system of the Reactor Building. The unenclosed part of the deck contains the cooling tower of the Reactor Building's air-conditioning system.
E2-2	Visitor's Gallery. This room was originally meant as a viewing room into the Reactor Bay, with glass windows looking into the Reactor Bay and into the control room. The room has its own entrance and stairwell (E1-5), separate from the reactor personnel's entrance and stairwell. The room was later merged with the control room and converted into office space for reactor operations personnel.
E2-3	Control Room. This room contains the operator console and instrumentation cabinets of the reactor. It has a door and a glass window into the Reactor Bay.
E2-4	Toilet. The sanitary and floor drains of this toilet discharge into a septic tank outside the Reactor Building.
E2-5	Storage Room. This is actually the upper portion of the abandoned vertical shaft E1-7 in the first floor. Unlike the similar spaces in the basement and first floor, this room was provided with a concrete floor and was used for storage of control-room supplies.

1.2.3 West Wing

The West Wing occupies almost a quadrant and extends to about 13.9 m (45.5 ft) beyond the wall of the Reactor Bay. The West Wing is of the same height as the East Wing, and also has three floors, two above ground level and one below. The second floor houses laboratory and office rooms, and the basement floor is used for storage. The first floor was originally intended to be a large laboratory for radioisotope processing, but the necessary equipment were never installed and the first floor was used only for storage of non-radioactive materials (except for a special room set aside for fresh nuclear fuel). The first floor still has two rooms shielded with heavy concrete that were to be the hot cells.

The West Wing has one personnel door opening into the Reactor Bay, and one room extending into the Reactor Bay with a ceiling hatch originally meant for irradiated targets headed for the hot cells. The West Wing has two doors leading to the outside.

The locations in the West Wing are described below. (The prefixes have the following meanings: W0 - basement floor; W1 - first floor; W2 - second floor.) Refer to Figures 3 to 7.

1.2.3.1 Basement Floor Location Codes

W0-1	Storage Room. This was originally just a single room, but was later partitioned into several storage areas. Spare mechanical and electrical equipment for the reactor were stored here. The PNRI property and procurement unit also stored office and laboratory supplies for the whole institute here.
W0-2	Stairwell. This stairwell connects the basement and first floors of the West Wing.

1.2.3.2 First Floor Location Codes

W1-1	Transfer Room. This room is actually inside the Reactor Bay, but enclosed by the Reactor Pool concrete. The room has a ceiling hatch that opens into the platform around the top of the Reactor Pool. Irradiated material was intended to be transferred to the West Wing though this room. The room was never used for this purpose, and was only used to store fresh and near-fresh nuclear fuel.
W1-2	Transfer Corridor. Heavy doors on wheels at the back of the hot cells (W1-4 and W1-5) were supposed to open into this corridor, through which the radioactive materials to be processed can enter the hot cells. The doors were never installed.
W1-3	Decontamination Room. Never used as such; used only for storage.
W1-4	Hot Cell 1. Never used as such; used only for storage.
W1-5	Hot Cell 2. Never used as such; used only for storage.
W1-6	Stairwell. This stairwell connects the first and second floors of the West Wing. There is also a door to the Reactor Bay. A door connecting this stairwell to the outside was opened in the 1980s.
W1-7	Operating Room. This room was intended to contain the operator ends of manipulators installed in the hot cells, and would have had lead-glass windows looking into the hot cells. The equipment were never installed, and this room was used only as a hallway. This room originally opened overhead directly into the second floor, but a ceiling was installed in the 1980s.
W1-8	Decontamination and Service Area. Never used as such; used only for storage.
	W1-9 and W1-10 were supposed to be the women's change and locker rooms:
W1-9	Women's Contaminated Room. Never used as such; used only for storage.
W1-10	Women's Clean Room. Never used as such; used only for storage.
	W1-11 and W1-12 were supposed to be the men's change and locker rooms:
W1-11	Men's Contaminated Room. Never used as such; used only for storage.
W1-12	Men's Clean Room. Never used as such; used only for storage.
W1-13	Storage Room.

1.2.3.3 Second Floor Location Codes

W2-1	Ventilation Equipment Room. This room originally contained blowers for the ventilation system of the West Wing, which was separate from the reactor’s ventilation system. The ventilation equipment was removed in the 1980s, when this room was converted into office space for regulatory personnel. This room also contains hatches into rooms W1-4 and W1-5 in the first floor below.

W2-2 to W2-5	Offices and laboratories. These rooms were used as offices and laboratories by reactor, research and regulatory personnel. Some radiation counting and light use of radioactive material were done in these rooms.
W2-6	Hallway. This hallway connects the various rooms in the second floor of the West Wing. The stairwell to the first floor (W1-6) connects to one end of this hallway.
W2-7	Women's Toilet.
W2-8	Men's Toilet.
	The sanitary drains of W2-7 and W2-8 discharge into a septic tank outside the Reactor Building.
W2-9	Storage Room.

1.2.4 Reactor Pool

The Reactor Pool is a monolithic free-standing reinforced-concrete structure sitting on the Reactor Bay floor. The Reactor Pool was designed to hold about 200 m^3 (7000 ft^3) of water, with the waterline about 8.5 m (27.9 ft) above the floor. The pool water and concrete serve as the reactor's biological shield. The Reactor Pool is shown in the drawings of the Reactor Building (Figures 3 to 7) and in cut-away view in Figure 8.

1.2.4.1 Pool Sections

The Reactor Pool has three sections: the high-power section, the intermediate section and the low-power section. The intermediate and low-power sections are connected to the high-power section in that sequence going from east to west. The sections are open to each other down to their bottoms.

The high-power section is circular with an internal diameter of 2.6 m (8.6 ft) and a depth of 9.5 m (31 ft), and is concentric with the Reactor Bay. The intermediate section is rectangular, with internal dimensions of 1.6 m (5.2 ft) by 2.4 m (8.0 ft), and is 8.7 m (28.4 ft) deep. The low-power section is almost square, with internal dimensions of 2.6 m (8.5 ft) by 2.4 m (8.0 ft), and is also 8.7 m (28.4 ft) deep.

The reactor core is suspended inside the Reactor Pool, and can be moved to any of the pool sections. The reactor's primary cooling system has 8-inch pipe stubs in the Reactor Pool that connect when the core is in the high-power section; in that location, the availability of forced cooling allows the reactor to be operated at its maximum power, hence the name of the pool section. There is no provision for forced cooling in any of the other two sections, but the reactor can still be operated up to about 100 kilowatts using natural convection cooling in either section. In practice, the core was operated in the high-power section most of the time, occasionally in the low-power section, and never in the intermediate section. The intermediate section was used for storage of spent fuel.

1.2.4.2 Pool Stages

The Reactor Pool rises from the floor of the Reactor Bay in four stages. The first to third sections are approximately octagonal in outline around the high-power and intermediate sections but changes to a rectangular outline around the low-power section, while the fourth stage is completely rectangular enclosing all three sections. The first stage is 4.2 m (13.9 ft) high and is about 3 m (10 ft) thick around the high-power and intermediate sections, and 2.3 m (7.5 ft) thick around the low-power section. The second stage stands 1.1 m (3.8 ft) above the first stage and is about 2.1 m (6.8 ft) thick around the high-power and intermediate sections and 0.9 m (3 ft) thick around the low-power section. The third stage stands 1.1 m (3.8 ft) above the second stage and is about 1.3 m (4.3 ft) thick around the high-power and intermediate sections and 0.6 m (1.8 ft) thick around the low-power section. The fourth stage stands 2.4 m (7.9 ft) above the third stage and is at least 0.6 m (1.8 ft) thick all around. The top of the pool is 8.9 m (29.3 ft) above the floor of the Reactor Bay and is at the level of the second floor of the East Wing of the Reactor Building.

1.2.4.3 Pool Penetrations

There are several penetrations in the Reactor Pool for irradiation facilities. All the penetrations are at the elevation of the reactor core, which is centered at 0.89 m (2.9 ft) above the floor of the Reactor Bay.

The thermal column fills an opening about 1.8 m (5.9 ft) square through the east face of the high-power section's octagonal outline (directly opposite where the intermediate section is connected). The thermal column has an aluminum casing that juts into the pool's high-power section, touching the reactor core. The external end of the thermal column is closed with a wheeled concrete and steel door that is 0.6 m (2 ft) thick.

There are six radial beam port penetrations at reactor core level, one through each of the north, northwest, northeast, south, southwest and southeast faces of the high-power section. The north and south beam ports are 8-inch aluminum tubes, and all the others are 6-inch aluminum tubes. The tubes are flanged where they leave the pool concrete. Aluminum extensions were bolted on to the tubes to extend them to the core at the center of the high-power section. These extensions were removed in the 1990s during the repair of the pool liner. All of the beam ports have an internal shutter and removable end plugs for radiation shielding.

There is a 0.6 m (2 ft) square window in the Reactor Pool concrete at core level at the west end of the low-power section. Only the pool liner covers this opening. The window opens into the dry gamma room, a shielded irradiation facility 2.4 m (7.8 ft) deep by 3.4 m (11 ft) wide by 2.4 m (8 ft) high. The reactor core can be moved flush against the window. The core (when shut down) was originally intended as the gamma irradiation source, but a rack of Co-60 pencils was actually exclusively used for irradiation. The dry gamma room has a concrete and steel door 0.9 m (3 ft) thick.

1.2.4.4 Pool Liner

The inside of the Reactor Pool is completely lined with welded aluminum plates 6 mm (0.25 inch) thick. The liner was installed after the pool concrete was poured. The liner was welded on a framework of aluminum I-beams bolted to the pool concrete. The 150 mm (6 inch) gap between the liner and the concrete was filled with grout as the liner was assembled from the bottom up.

Originally, the liner was not successfully welded to the thermal column casing because of accessibility problems with the joints. The joints were packed with epoxy to make them watertight. A leak in an epoxied joint caused the shutdown of the reactor in 1988, about 25 years after the liner was constructed. The liner was repaired in the 1990s by cleaning out and modifying the epoxied joints to allow full re-welding. While the repair was being performed, corrosion was discovered in many places in the pool liner. To delay the eventual penetration of the corrosion, the thickness of the pool liner was doubled in 1997 by welding another set of 6-mm aluminum plates over all of the pool liner below about 3.6 m (12 ft) below the top of the Reactor Pool.

1.2.4.5 Piping Embedded in the Pool

Pipes embedded in the concrete of the Reactor Pool carry the primary cooling water, air for the ventilation of irradiation facilities (thermal column, beam tubes and dry gamma room), and capsules of the pneumatic irradiation facility. There are also embedded conduits for instrumentation and electrical power cables.

1.2.4.6 Pool Platform

The pool platform is a walkway around the upper part of the Reactor Pool, at the same level as the second floor of the East Wing, and connecting to the Control Room (E2-3). The western end of the pool platform is also the ceiling of room W1-1 of the West Wing. The Pool Platform is surrounded by safety railing. Trays for reactor instrumentation and power cables run under the pool platform, as well as the piping for the pneumatic irradiation system.

1.2.4.7 Bridge, Suspension Frame and Core Box

The top of the Reactor Pool is spanned by a steel bridge, at the center of which is attached an aluminum framework that supported the reactor core box under water. See Figures 9, 10 and 11. The bridge is mounted on rails, allowing the bridge to be moved to any of the pool sections, carrying the core box with it. The core box contained the reactor's fuel elements, reflector elements, control elements, start-up neutron source, irradiation baskets and two vertical irradiation tubes. (Except for the control elements and baskets, all these contents of the core box have been removed.) The drive motors of the control elements are mounted on the bridge. The framework also supports ducting that carried the primary coolant around the core and connected with the pipe stubs in the high-power section of the Reactor Pool.

1.2.4.8 Reactor Pool Location Codes

The following codes will be used to refer to locations and items in the Reactor Pool. (The prefix RP means Reactor Pool.) Refer to Figures 3 to 7.

RP-1	Interior of High-Power Section
RP-2	Interior of Intermediate Section
RP-3	Interior of Low-Power Section
RP-4	Dry Gamma Room
RP-5	Thermal Column
RP-6	Beam Tubes
RP-6a	Beam Tube Plugs.
RP-7	Exterior Surfaces of the Pool
RP-8	Pool Platform
RP-8a	Irradiation Capsule Stringers. These irradiated parts are stored behind lead shielding at the west end of the pool platform.
RP-8b	DNAA Irradiation End. This item was removed from the reactor core and placed in a rack at the north side of the pool platform.
RP-8c	Spare Neutron Detector. This item may have been installed in the core box for a short time. It is stored in a rack at the north side of the pool platform.
RP-8d	Various Fuel Handling Tools. These items are stored in racks at the south side of the pool platform.
RP-9	Bridge and Core Suspension Frame
RP-10	Core Box
RP-10a	Control Elements (Blades and Rods). These items are still installed in the core box but are easily removable.
RP-10b	Irradiation Baskets. A few irradiation baskets are still in the core box.

RP-10c Neutron Detectors. Some neutron detectors are installed inside the corner posts of the core suspension frame, and some are installed in irradiation baskets in the core box.

1.2.5 Reactor Grounds

There are a few auxiliary structures in the grounds northwest of the Reactor Building that are considered part of the PRR-1. See Figure 1.

1.2.5.1 Hallways to ARC Building

The basements and first floors of the Reactor Building East Wing and the ARC Building are connected by separate enclosed hallways, one atop the other. The hallways run west-to-east and are each about 3.2 m wide.

1.2.5.2 Reactor Office

The office of the reactor personnel is a single-floor concrete building adjoining the north side of the first-floor hallway to the ARC Building. The area of the building is about 6.1 m by 16.8 m. This building was constructed in the 1980s.

1.2.5.3 Large Powerhouse

The reactor's 500 kW diesel generator is in a detached concrete powerhouse on the north side of the reactor's office building. The single room of the powerhouse has an area of about 4 m by 6 m. This powerhouse and diesel generator were added to the reactor in the 1990s.

1.2.5.4 Small Powerhouse

A 10 kW diesel generator and an Uninterruptible Power Supply (UPS) for the reactor's control and instrumentation system are installed in a small concrete powerhouse a few meters north of the large powerhouse. The area of the building is about 3.6 m by 6.6 m. This powerhouse and diesel generator were added to the reactor in the 1980s.

1.2.5.5 Diesel Fuel Tank

Diesel fuel for the reactor's generators is stored in a steel tank in a concrete pit close to and north of the powerhouses. The pit is covered with a concrete slab and is 3.5 m in diameter and 3.5 meters deep. The tank in the pit that can hold up to about 11,000 liters (3,000 gal) of diesel fuel. This fuel tank was constructed in the 1990s.

1.2.5.6 Cooling Tower

The reactor's cooling tower sits on a concrete pad 5.8 m (19 ft) square, about 7.5 m (24 ft) north of the Reactor Bay wall. Pipes run in trenches from the underground equipment room E0-6 to the cooling tower. The pipes carry secondary cooling water between the cooling tower and the reactor's heat exchanger. The pumps of the secondary cooling system are installed outdoors, in a pit beside the cooling tower.

The cooling tower was originally installed in 1963 but has been rebuilt twice. The original tower had a concrete basin and wooden fill The first rebuild in the 1970s replaced the wooden fill. The second rebuild during the 1980s replaced the cooling tower entirely with a new one with a steel basin and PVC fill.

1.2.5.7 Utility House

A small concrete shed stands beside the cooling tower, originally intended to house a softener for water in the secondary cooling system. The softener was later found unnecessary and was never installed. The structure was then used as a general utility building.

1.2.5.8 Raw Water Tank

An above-ground cylindrical concrete tank that can hold up to 56.8 m^3 (15,000 gal) of water is located near the utility house and diesel fuel tank. The tank holds the reactor's reserve of unprocessed water. The raw water tank was constructed in the 1980s.

1.2.5.9 Underground Waste Water Discharge Piping

Waste water from the reactor, excluding sanitary waste, is discharged through a single underground concrete pipe running from the basement of the East Wing to the western boundary of the PNRI Compound. The pipe runs under the pump pit at the side of the cooling tower and under the truck entrance ramp, where it is accessible through manholes and vertical shafts.

The original pipe run from the second manhole to the site boundary collapsed and was blocked during the 1980s. A new underground pipe run was dug at that time, and the old pipe run was abandoned.

1.2.5.10 Underground Septic Tanks

The toilets in the East Wing and the West Wing are connected to buried septic tanks, whose digested liquid effluents are diffused to the subsoil by perforated overflow pipes.

1.2.5.11 Reactor Grounds Location Codes

The following codes will be used to refer to locations in the grounds around the Reactor Building. (The prefix RG means Reactor Grounds.)

RG-1	Earth, Subsoil and Rock
RG-2	Underground Waste Water Pipes
RG-3	Septic Tanks
RG-4	Basement-Level Hallway to ARC Building
RG-5	First-Floor Hallway to ARC Building
RG-6	Reactor Office
RG-7	Large Powerhouse
RG-8	Small Powerhouse
RG-9	Diesel Fuel Tank
RG-10	Raw Water Tank
RG-11	Cooling Tower
RG-12	Utility House

1.3 REACTOR SYSTEMS AND EQUIPMENT

Reactor operation was supported by several mechanical/electrical systems that are described below. Some of these will remain operational to support the decommissioning of the PRR-1.

1.3.1 Irradiation Facilities

1.3.1.1 Thermal Column

The thermal column is a graphite-filled horizontal cavity in the high-power section of the reactor pool that provided neutrons in the thermal range. The penetration has been described previously. The thermal column abuts the east face of the core box, being separated from the latter by a water-cooled lead gamma shield.

1.3.1.2 Beam Ports

The beam ports are air-filled aluminum tubes, described previously, that provided neutrons which were primarily above the thermal range. Three beam ports were fed by the north face of the core box, and three by the south face. The three northern beam ports were used to irradiate capsules that were manually inserted in the tubes. Two of the southern beam ports were connected to neutron spectrometers, and one was connected to a time-of-flight experiment rig. These rigs were dismantled in the 1990s when the fuel storage tank (RB-4) was constructed in the Reactor Bay.

1.3.1.3 Pneumatic Tubes

The pneumatic tubes are air-filled aluminum tubes that rapidly transported 1-1/2-inch-diameter, 6-inch long polyethylene capsules (“rabbits”) to near the reactor core. There were two tubes, one terminating at the north face of the core box and one at the south face. The other ends of the tubes, where the capsules were inserted and retrieved, were at the laboratories in the East Wing, one at location E0-17 and another at location E1-6. The turbo-compressor powering the facility was located at the mechanical/electrical equipment room (E1-1). The pneumatic irradiation facility was deactivated and partially dismantled in the 1990s.

1.3.1.4 Dry Pipes

The dry pipes were two 2-inch-diameter air-filled vertical aluminum tubes inserted in the core box, in the grid but outside the fuel element array. The tubes were bent and offset to prevent radiation streaming. Small aluminum capsules containing target material were manually lowered down the dry pipes in stringers for irradiation. The dry pipes were removed when the reactor core was defueled.

1.3.1.5 DNAA System

A delayed-neutron activation analysis (DNAA) system was installed in the 1970s to analyze geological samples for uranium content. The system used compressed air to drive small 1/2-inch-diameter polyethylene capsules containing the samples to an irradiation tube vertically inserted in the core box. After irradiation, a capsule was driven to a counting system in location E1-6 in the East Wing that detected the delayed fission neutrons produced by uranium in the sample. Plastic tubing was used to transport the capsules between the irradiation and counting locations. The system was automated and accepted a number of capsules loaded in a magazine. The DNAA system was dismantled in the 1990s, although there are still remains of the system in location E1-6.

1.3.1.6 Seed Neutron Irradiation Facility

The Seed Neutron Irradiation Facility (SNIF) was provided by the IAEA in the late 1960s, primarily for the fast-neutron irradiation of seeds. The SNIF was basically a barrel-shaped gamma and thermal-neutron shield, with a diameter of about 43 cm (17 inches) and a height of about 40 cm (15.75 inches), with a central cavity to accommodate the irradiation target. The SNIF was floor-mounted on a pedestal at the low-power section of the Reactor Pool. The core box was moved alongside when the SNIF was to be used. The SNIF was removed from the pool in the course of pool liner repair in the 1990s.

1.3.1.7 Dry Gamma Room

The Dry Gamma Room has been described previously as a penetration in the Reactor Pool. This was a Co-60 gamma irradiation facility that shared the Reactor Pool but was utilized independently of the reactor.

1.3.2 Reactor Cooling System

The reactor was cooled by water in a system that delivered reactor heat to a heat exchanger. The primary coolant loop pumped water through the reactor core, passing hot water through a 3,000-gallon N-16 delay tank, through the 75-hp primary pump, through the tube side of the heat exchanger, and back to the reactor core as cooled water. The N-16 delay tank is in room E0-1 while the primary pump and heat exchanger are in room E0-6 of the East Wing. The all-aluminum primary piping within those rooms are accessible in bolted-together sections that can be taken apart. However, the piping from those rooms to the Reactor Pool are embedded in concrete under the floor of the Reactor Bay and in the concrete of the Reactor Pool. The primary coolant within the pool is guided but not completely isolated from the pool water by flow channels built into the suspension frame supporting the reactor core.

The hot water in the secondary coolant loop was routed from the shell side of the heat exchanger to the top of the cooling tower, sprayed down to the cooling tower basin, collected from the basin by two 40-hp pumps, and returned to the shell side of the heat exchanger as cooled water. The all-aluminum secondary loop piping are accessible in bolted-together sections.

The current reactor cooling system was installed in the 1980s during TRIGA conversion. The original heat exchanger, pumps and exposed piping were replaced, but the N-16 delay tank and all of the embedded piping were retained.

1.3.3 Water Supply and Purification System

The reactor's water is supplied by the city's water mains, except for a few years during the 1960s when the reactor used deep ground water pumped up to a water tower. (The water tower still exists, no longer directly connected to the reactor. It is now used as an emergency supply for the entire PNRI compound.) Reserve raw water is stored close to the Reactor Building in a tank (RG-10). A booster pump is installed in room E1-1 for those times when the city water pressure is not adequate.

Make-up water that was to be added to the reactor pool was purified using a softener column and a mixed-bed ion-exchange demineralizer column in room E0-6. The make-up purification system handled only incoming raw water, never pool water. The purity of the pool water was maintained by a separate clean-up demineralizer column in location E0-8. Both of these purification systems are the original equipment installed in the 1960s.

The water in the secondary coolant loop was not treated, except for the addition of a biocide to control the growth of algae. The purity of untreated city water was considered sufficient for use in the secondary coolant loop.

1.3.4 Air Conditioning and Ventilation System

The Reactor Bay and East Wing were originally ventilated by blowers that provided 2.5 air changes per hour. The air was not conditioned and was often hot and humid in the tropical environment. Uncontaminated air was discharged at the level of the second floor of the East Wing, while air from the irradiation facilities was filtered and discharged at the top of the dome. During an emergency, the normal ventilation system was shut down and a separate blower discharged air at the top of the dome through a filter, supposedly keeping the interior of the building at a negative air pressure and preventing radioactive contamination from escaping. However, in practice the air leakage through the ducting of the normal ventilation system did not allow much negative pressure to build up inside the Reactor Bay.

The original ventilation system was removed during the 1990s. Discarding the old ventilation ducts and sealing the wall penetrations allowed a single blower to maintain negative pressure inside the Reactor Bay at all times, not just during an emergency. A new separate ventilation system was installed for the isotopes laboratory E0-17 in the East Wing. A large air-conditioning system was installed to control the humidity and lower the temperature in the Reactor Bay, although it was not fully tested before the reactor was shut down.

The West Wing had a ventilation system that was separate from that of the East Wing and Reactor Bay. This ventilation system also did not supply conditioned air. The West Wing ventilation system was removed in the 1980s, by which time all the rooms in the West Wing that were in use as offices or laboratories had individual room air-conditioners.

1.3.5 Control and Instrumentation System

The central node of the reactor's control and instrumentation system is in E2-3, the control room. From there, cables run under pool platform RP-8 to cable towers, and then to the bridge RP-9. The control rod drive motors are on the bridge. Cables for instrumentation run from the bridge down the suspension frame to the core.

Many other control and instrumentation cables are installed in electrical conduits that terminate in the control room. These cables are for the reactor's radiation monitoring system, process control system, motor control system, fire alarm system, door monitoring system, public-address system, and warning lights and alarms.

The control and instrumentation system has been shut down since the 1988 and is probably mostly non-functional by this time.

1.3.6 Electrical Power Supply System

The reactor's electrical power is supplied by the city's electrical utility company, although the reactor has generators capable of supplying its entire operational load for back-up. Electrical power is carried by high-voltage cables from the utility company that enter a power room at the basement of the ARC Building. That room contains a large step-down transformer that converts the power to three-phase 220 V, 60 Hz. Until the 1990s, the entire PNRI Compound was supplied with power from this single source. The PNRI Administrative and Training Building is now supplied with 220 V power directly by the utility company, but the Reactor Building is still supplied with power from the ARC Building transformer. Electrical power enters the Reactor Building in room E1-1.

The reactor has a 500 kW diesel generator (RG-7) with an 11,000-liter fuel tank (RG-9). This generator was installed in the 1990s and was not much used until the reactor was shut down. However, it is still functional.

The reactor also has a 10 kW diesel generator and UPS (RG-8) that is connected only to the control and instrumentation system. This emergency electrical supply system was installed in the 1980s. This system can supply essential power even if the city power and the large generator both fail. However, the UPS has become non-functional in the years after the reactor was shut down.

1.3.7 Polar Crane

The polar crane in the Reactor Bay has a rated lifting capacity of 9 metric tons. However, its mechanical parts date back to the 1960s, and it has never been used to lift more than 5 tons in recent years. The crane was refurbished in the 1990s, and is still functional.

1.4 OPERATING HISTORY

1.4.1 Authorized Activities

1.4.1.1 Reactor Operation

The PRR-1 first attained criticality on 26 August 1963 and was first operated at 1 MW on 26 October 1964. The reactor was then operated regularly, usually at 1 MW for a few hours a day until 30 March 1977, accumulating a total burn-up as of that date of 570 MWd. Problems with aging instrumentation caused the reactor to be operated at no more than 500 kW from then to 14 July 1980, increasing the total burn-up to 604 MWd. The instrumentation was replaced, but problems with the reactor building's ventilation system caused the reactor power to be reduced further to 100 kW until 24 October 1984. The total burn-up had reached only 617 MWd by that date. The reactor was then shut down for conversion to a TRIGA-type reactor.

The reactor originally had 30 plate-type fuel elements in the core in 1963, each containing 134 g of U-235 at an enrichment of 20%. The reactor was partially refueled several times during the 1970s and early 1980s, eventually replacing 10 of the original fuel elements with similar fuel elements containing 137 g each of U-235 at 93% enrichment, and another 10 with fuel elements containing 155 g each of U-235 at 93% enrichment. The core size was reduced to 26 fuel elements, with 6 of the original fuel elements still in service in 1984.

All of the irradiated plate-type fuel elements were eventually shipped back to the U.S.A. on 14 March 1999.

1.4.1.2 TRIGA Conversion

The cooling system, instrumentation system and electrical power supply system were reconstructed with new components during 1984-1987. The original plate-type fuel elements were replaced with 115 rod-type TRIGA elements, housed in 30 shrouded 4-rod clusters that approximated the external dimensions of the plate-type fuel elements in order to fit into the original grid. (Five rod positions were occupied by control rods or irradiation tubes.) Other components of the reactor were not replaced or rebuilt at the time, although it was planned to repair or upgrade some aging components (primarily the ventilation system) before the reactor would be put back into regular operation.

The PRR-1 was successfully tested as a TRIGA reactor during 9 to 30 March 1988. First criticality with the TRIGA core was achieved on 11 March 1988. Testing was completed with a five-hour run at 3 MW on 28 March 1988.

The PRR-1 never resumed regular operation. The pool liner leak that begun its unplanned shutdown appeared on 18 April 1988.

1.4.1.3 Gamma Irradiation

Gamma irradiation was done in the dry gamma room independently of the reactor using a 20 kCi (as of May 1970) Co-60 source. The source was placed in the storage tank (RB-4) in the Reactor Bay in the 1990s in the course of pool liner repair. There is another 19 kCi (as of September 1978) Co-60 source in a lead cask stored in the Reactor Bay.

1.4.1.4 Radionuclide Processing

Targets irradiated in the reactor were processed in the isotopes laboratory room (E0-17) for the production of radionuclides. The radionuclides that were routinely produced were in small amounts and generally were short-lived. These included Br-82, Cr-51, Co-58, Co-60, Cu-64, Au-198, I-128, Ir-191, Mn-56, Ni-65, P-32, Na-24 and S-35.

Most of the processing was moved out of the Reactor Building into a separate building in the 1970s. The isotopes laboratory room was gutted and decontaminated in the 1990s and a new hot cell for I-131 was installed. The new equipment has never been used except for some testing.

1.4.2 License or Authorization History

The PNRI, the owner/operator of the PRR-1, is also the national nuclear regulatory body of the Philippines. Philippine law has been interpreted by the PNRI as exempting its own facilities from the formal licenses required of other nuclear facilities in the Philippines. The PRR-1 was never issued an official license during its operational lifetime from 1963 to 1988, but its operation was always subject to review and approval by a Reactor Safety Committee. The head of the PNRI regulatory division traditionally was also the chairman of the Reactor Safety Committee.

In 2004, the PNRI decided to implement a formal internal licensing process for its own facilities, called an "authorization" process to differentiate it from the licensing imposed on externally-owned facilities. The PNRI's regulatory division was given formal authority over the PNRI's facilities, which will be subject to the same regulations imposed on external facilities. The PNRI facilities were required to obtain official authorizations from the regulatory division in order to continue operating. The PRR-1 was already shut down at time, but was required to obtain authorization for the possession of the remaining radioactive materials in the facility, and future decommissioning activities will also be subject to the authorization process.

1.4.3 Spills and Occurrences Affecting Decommissioning

There is no known major spill or other major release of radioactivity during the operational life of the reactor. There may have been minor unrecorded spills (e.g., of activated ion-exchange resin or fluids while regenerating the reactor's demineralizer, or small mishaps in the laboratories).

The pool liner leak in 1988 released water continuously until the pool was completely dewatered in 1992, but fortunately there had never been a fuel cladding failure in the PRR-1 and the water did not carry a significant amount of contamination. However, the water did completely saturate the concrete under the liner, and could have diffused activation products deeper than their places of formation.

1.4.4 Previous Decommissioning Activities

During TRIGA conversion in the 1980s, all of the components of the reactor cooling system except the pipes embedded in concrete were removed and replaced. The instrumentation system, including the control element drives and the neutron detectors, was also completely replaced.

Also in relation to TRIGA conversion, the old equipment in the isotopes laboratory room (E0-17) in the basement floor of the East Wing was removed and the room was decontaminated, in preparation for the installation of a new hot cell for the production of I-131. The new hot cell was installed and tested, but never used for production because the reactor was shut down.

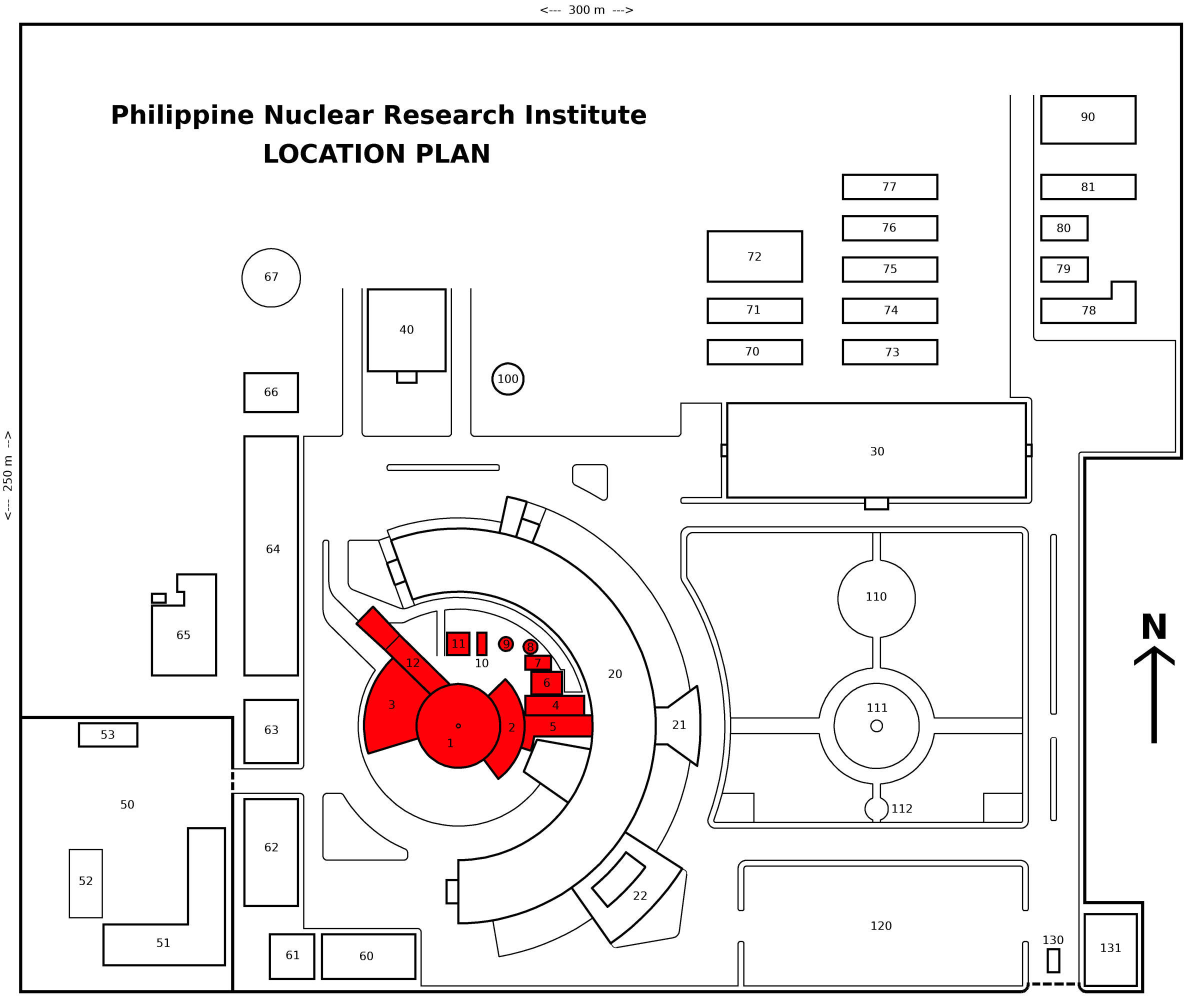
Also in the 1980s, the old buried waste water discharge piping became blocked and was abandoned. A new buried pipe run was installed.

The reactor pool was dewatered and decontaminated during the 1990s in the course of repairing the pool liner leak. A new layer of aluminum plates was welded over the old liner in the bottom half of the Reactor Pool.

At about the same time as the pool liner was being repaired, the rusted-out drain storage tank (E0-2) in the basement floor of the East Wing was dismantled and replaced with a new tank. The new tank has never been used.

All of the reactor's spent plate-type fuel elements were shipped out of the site in 1999. The TRIGA fuel elements remain in the fuel storage tank (RB-4) in the Reactor Bay.

FIGURES



LEGEND:

	PRR-1:
1	Reactor Building Dome
2	Reactor Building East Wing
3	Reactor Building West Wing
4	Office
5	Hallway to ARC Building
6	Large Powerhouse
7	Small Powerhouse
8	Diesel Fuel Tank
9	Water Tank
10	Utility House
11	Cooling Tower
12	Truck Entrance
20	Atomic Research Center Building
21	Entrance Canopy
22	Poolside
30	Administrative and Training Building
40	Co-60 Multipurpose Irradiation Facility
50	Radioactive Waste Management Facility
51	Waste Processing Building
52	Waste Storage Trenches
53	Utility House
60	Irradiation Services Lab
61	Warehouse
62	Industrial Applications Lab
63	Radiography Facility
64	Machine Shop
65	Nuclear Materials Lab
66	Carpentry Workshop
67	Gamma Garden
70	Agriculture Lab 1
71	Agriculture Lab 2
72	Greenhouse
73	Biomedical Lab 1
74	Biomedical Lab 2
75	Entomology Lab
76	Seed Processing Lab
77	Animal House
78	Health Physics Lab
79	Tritium Lab
80	Environmental Lab
81	Cytogenetics Lab
90	Motor Pool
100	Water Tower
110	Bronze Sculpture
111	Flagpole
112	Gen. Medina Memorial
120	Parking Lot
130	Guard House
131	Guard Barracks

Fig. 1. The PRR-1 in the PNRI Compound

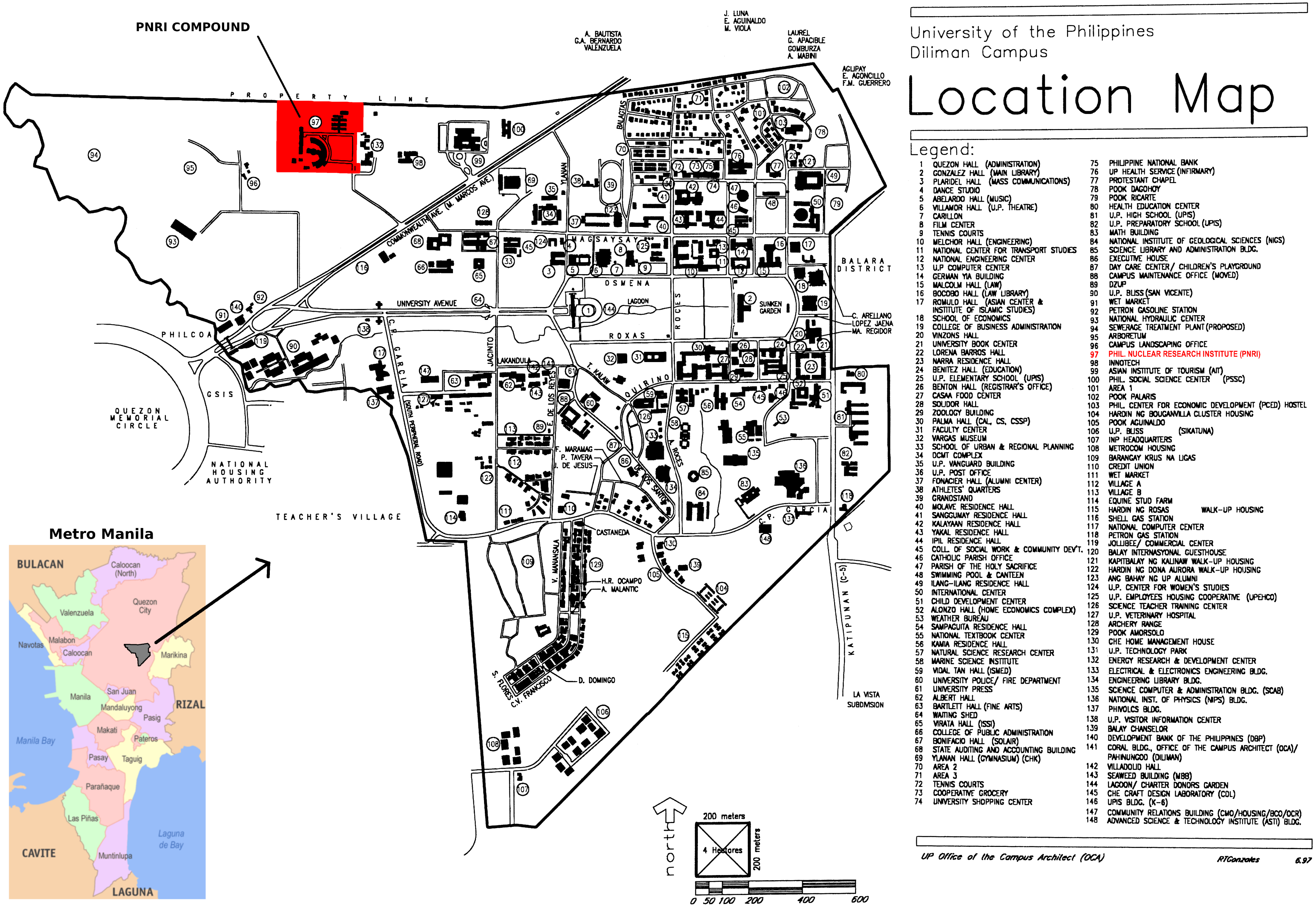


Fig. 2. The PNRI Compound in the U.P. Diliman Campus

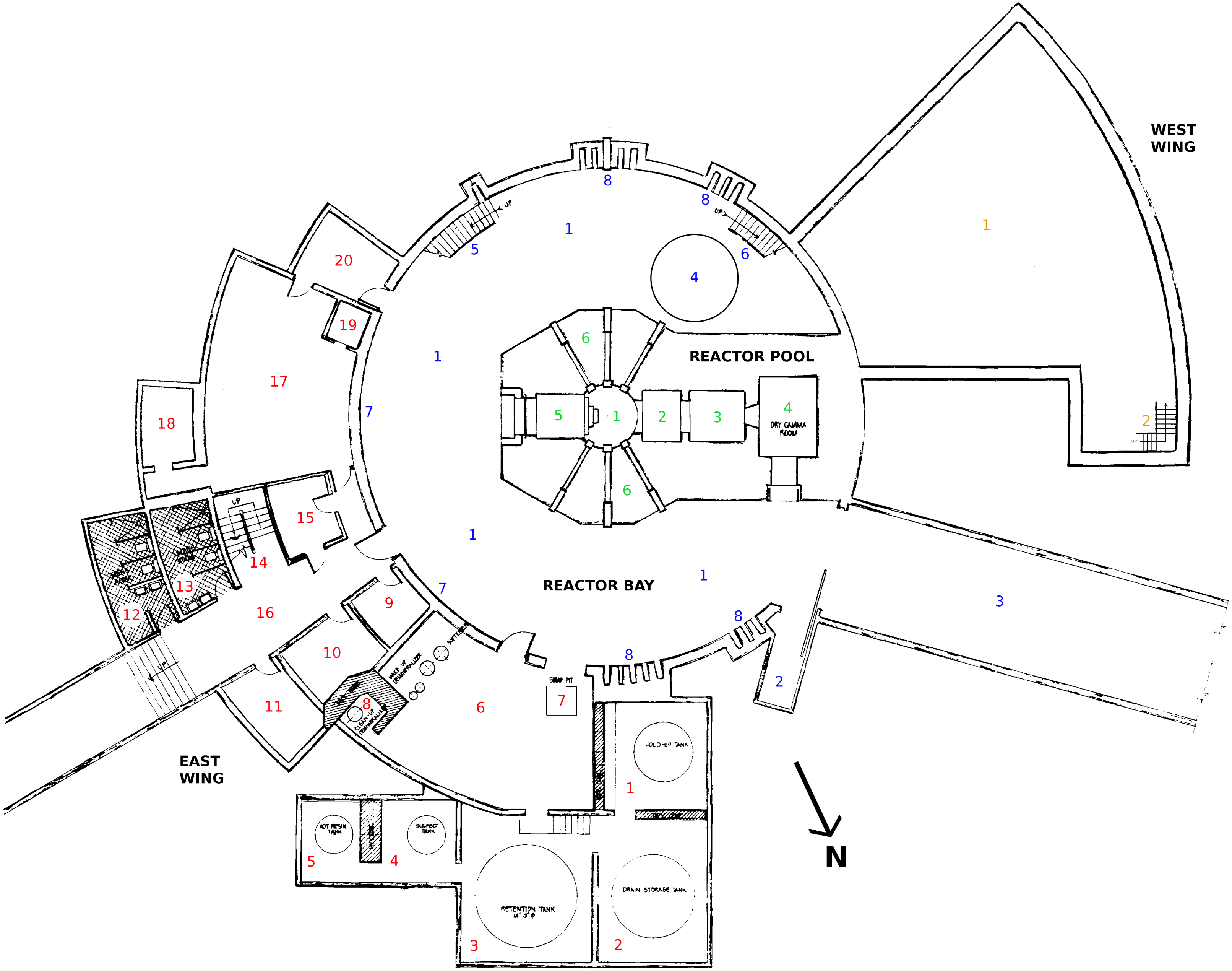


Fig. 3. The Basement-Floor Plan of the Reactor Building

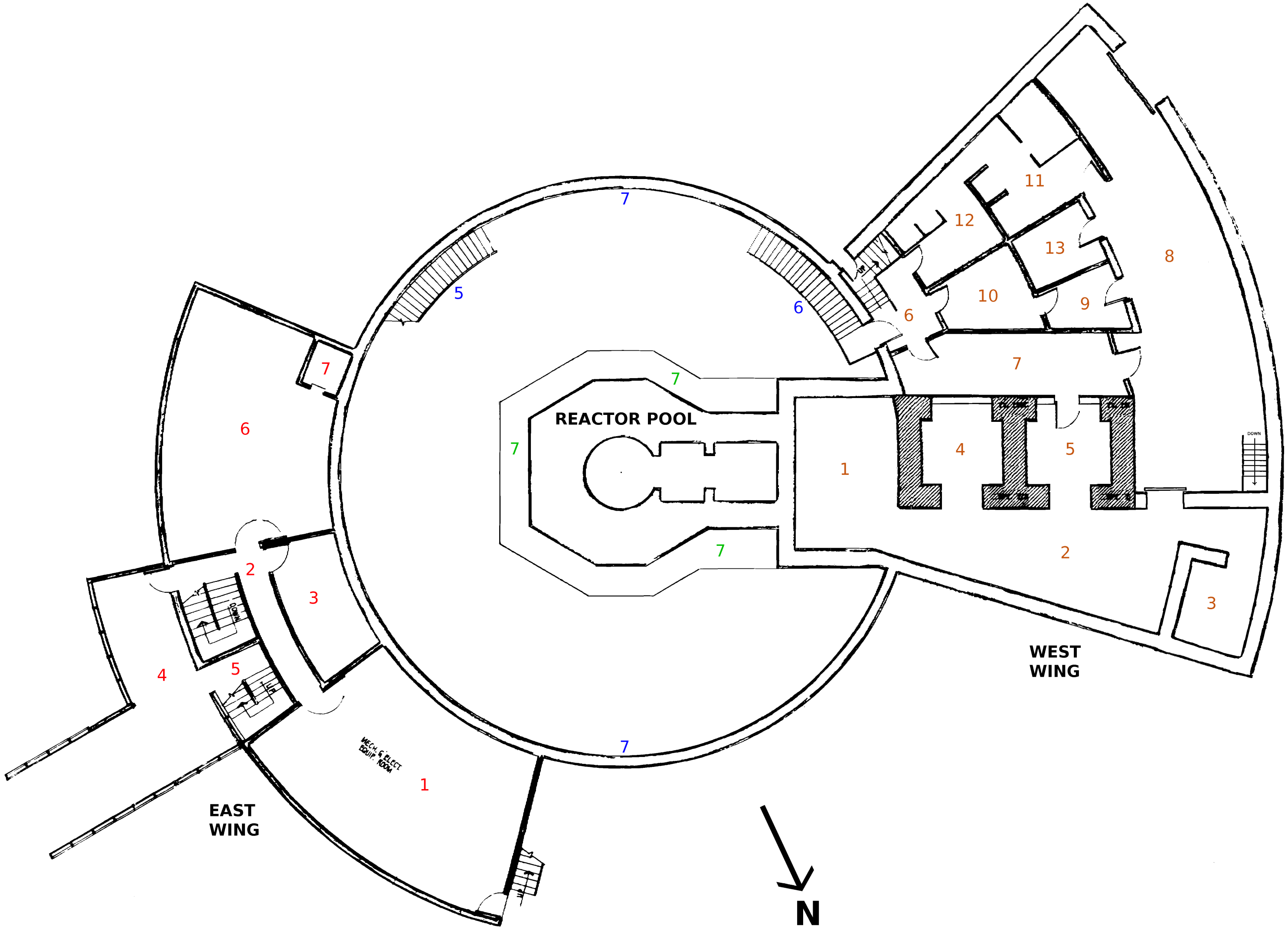


Fig. 4. The First-Floor Plan of the Reactor Building

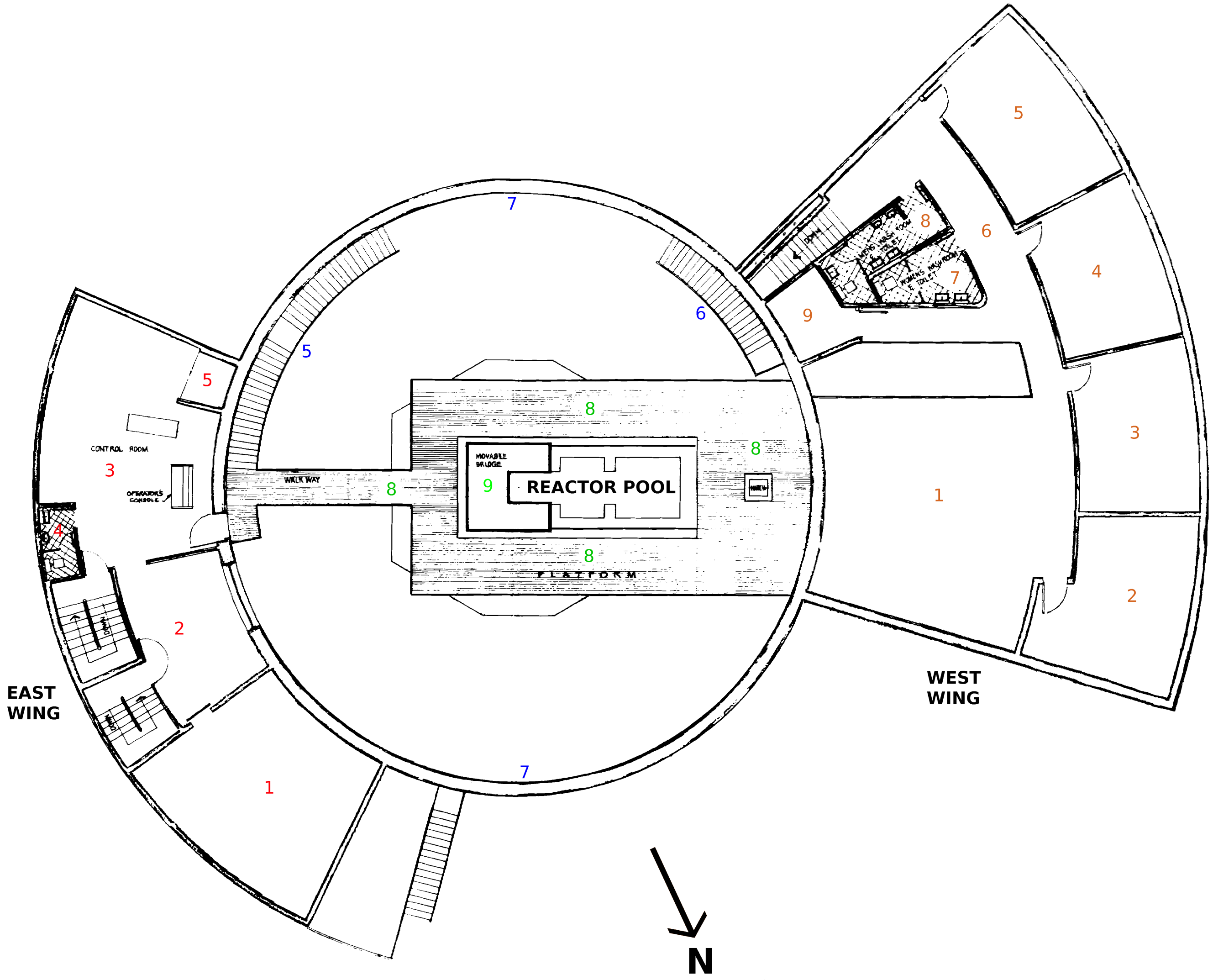


Fig. 5. The Second-Floor Plan of the Reactor Building

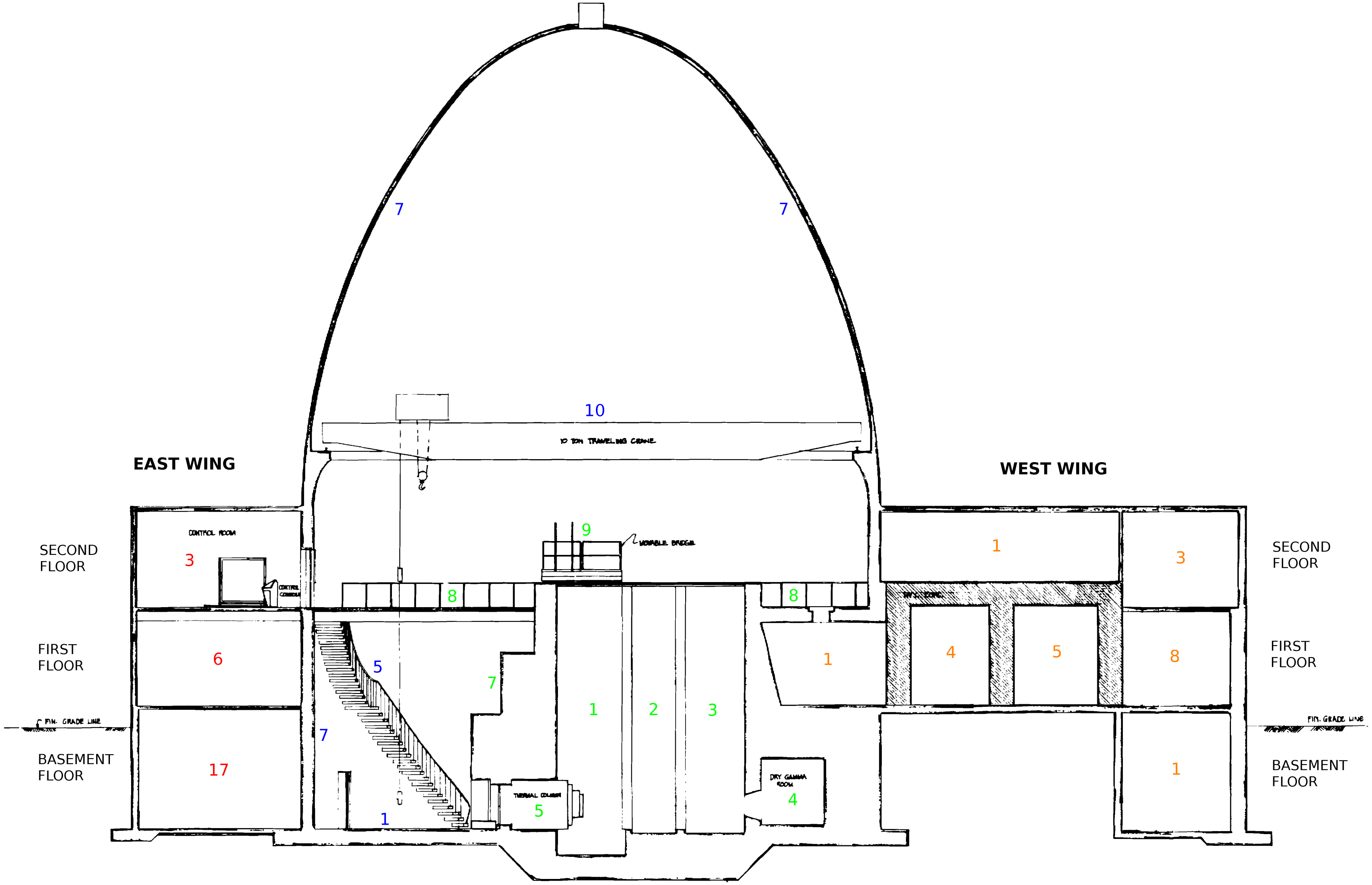


Fig. 6. The ESE-WNW Vertical Section of the Reactor Building

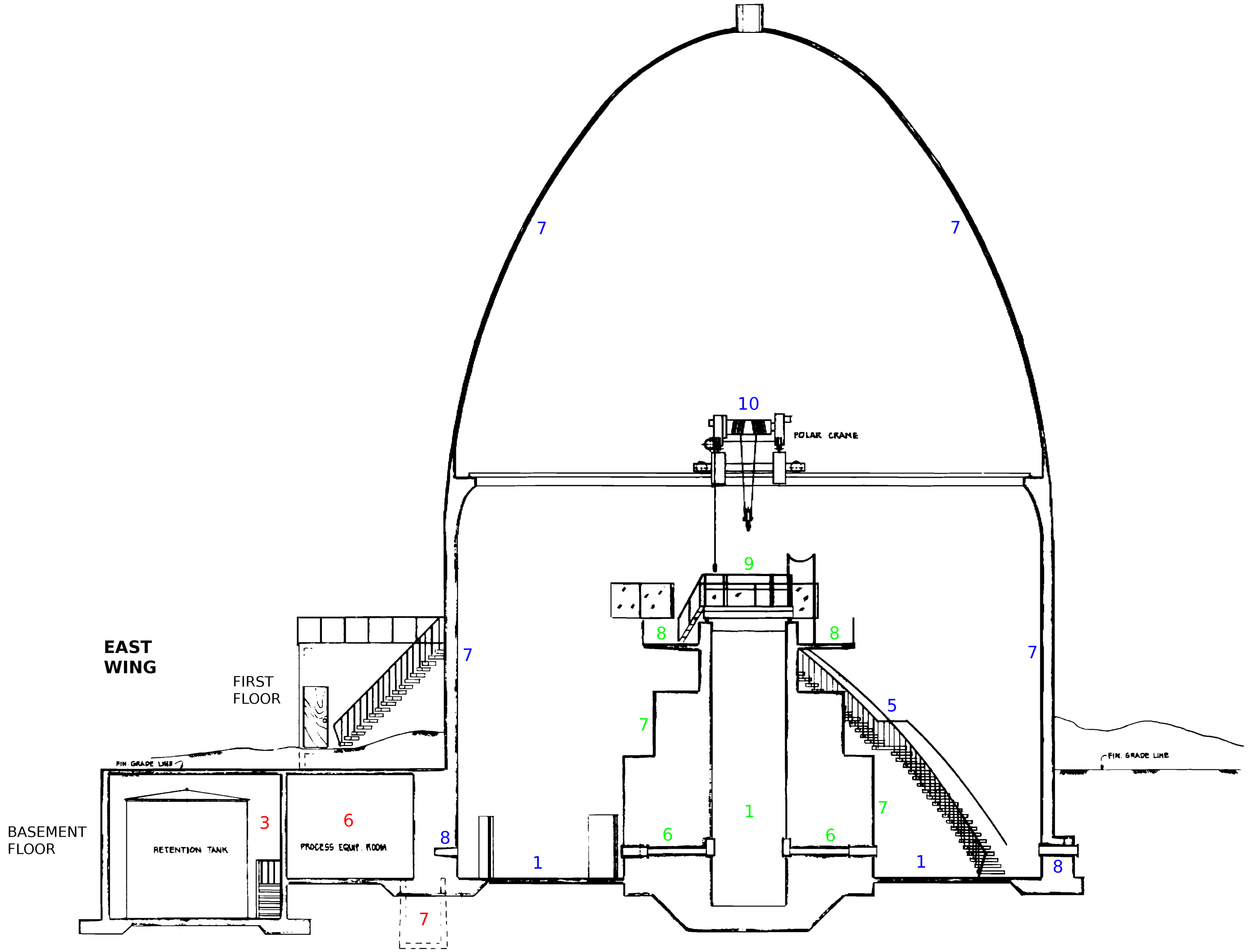


Fig. 7. The NNE-SSW Vertical Section of the Reactor Building

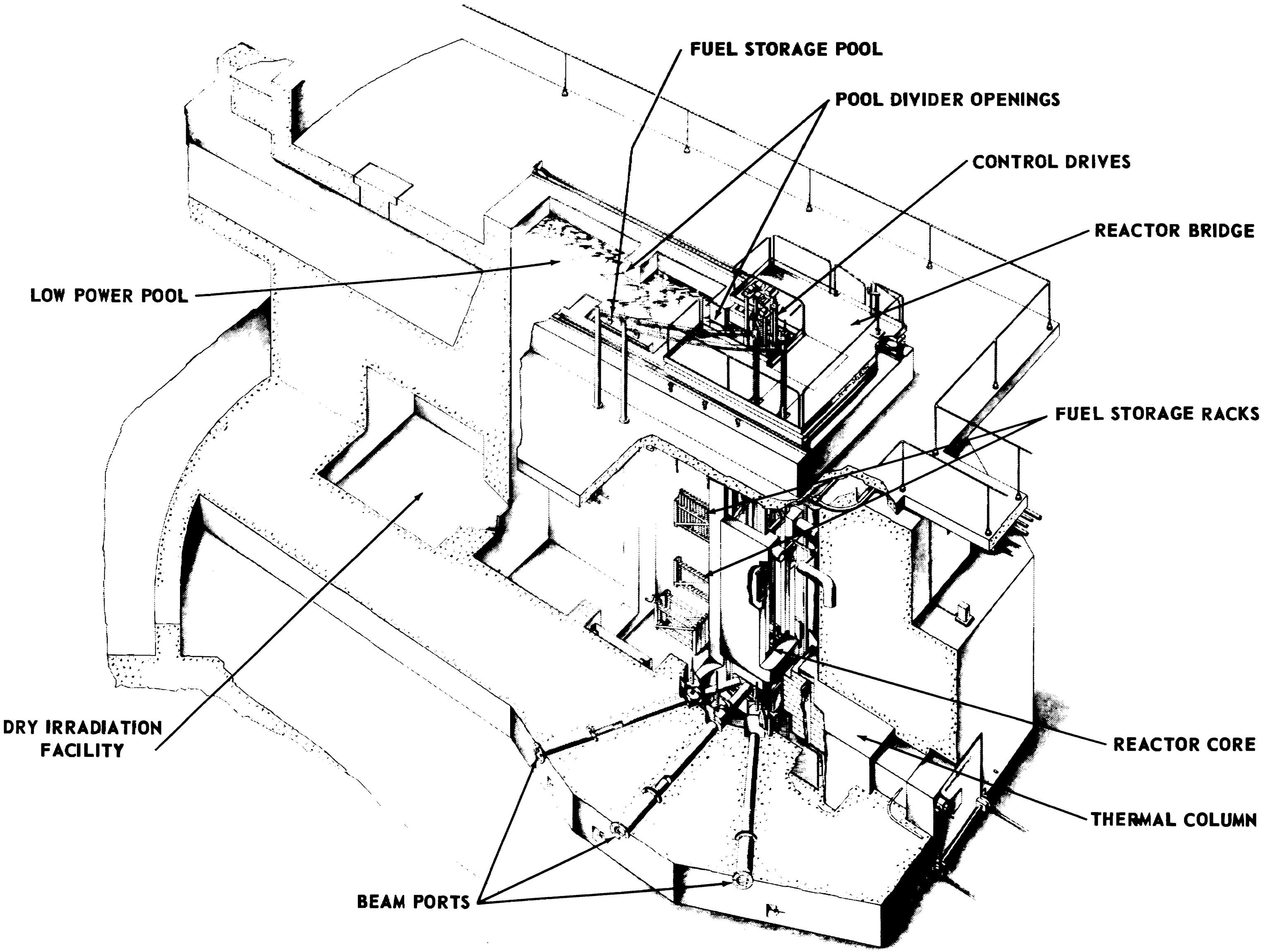


Fig. 8. A Cut-Away View of the Reactor Pool

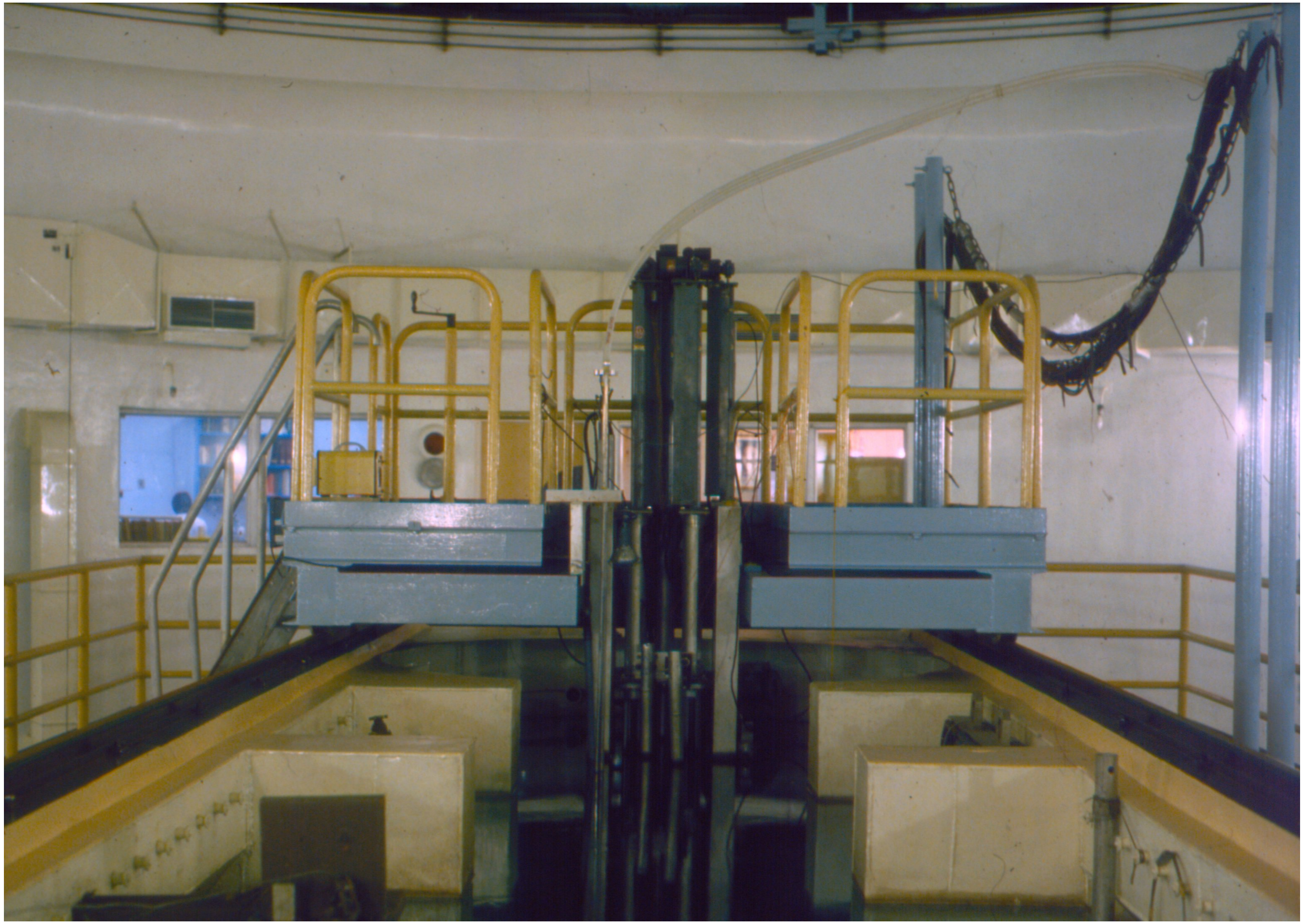


Fig. 9. The Reactor Bridge

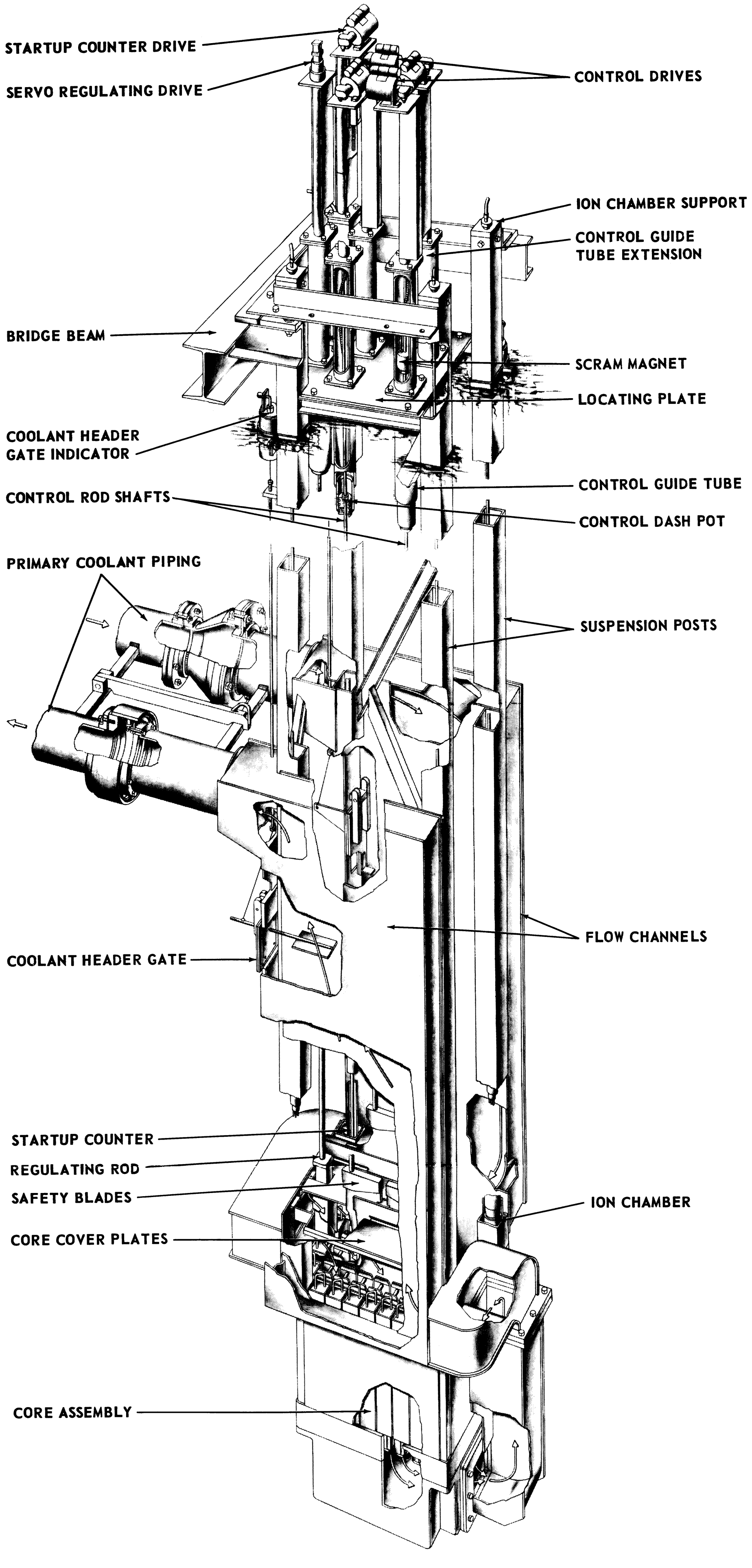


Fig. 10. A Cut-Away View of the Core Suspension Frame

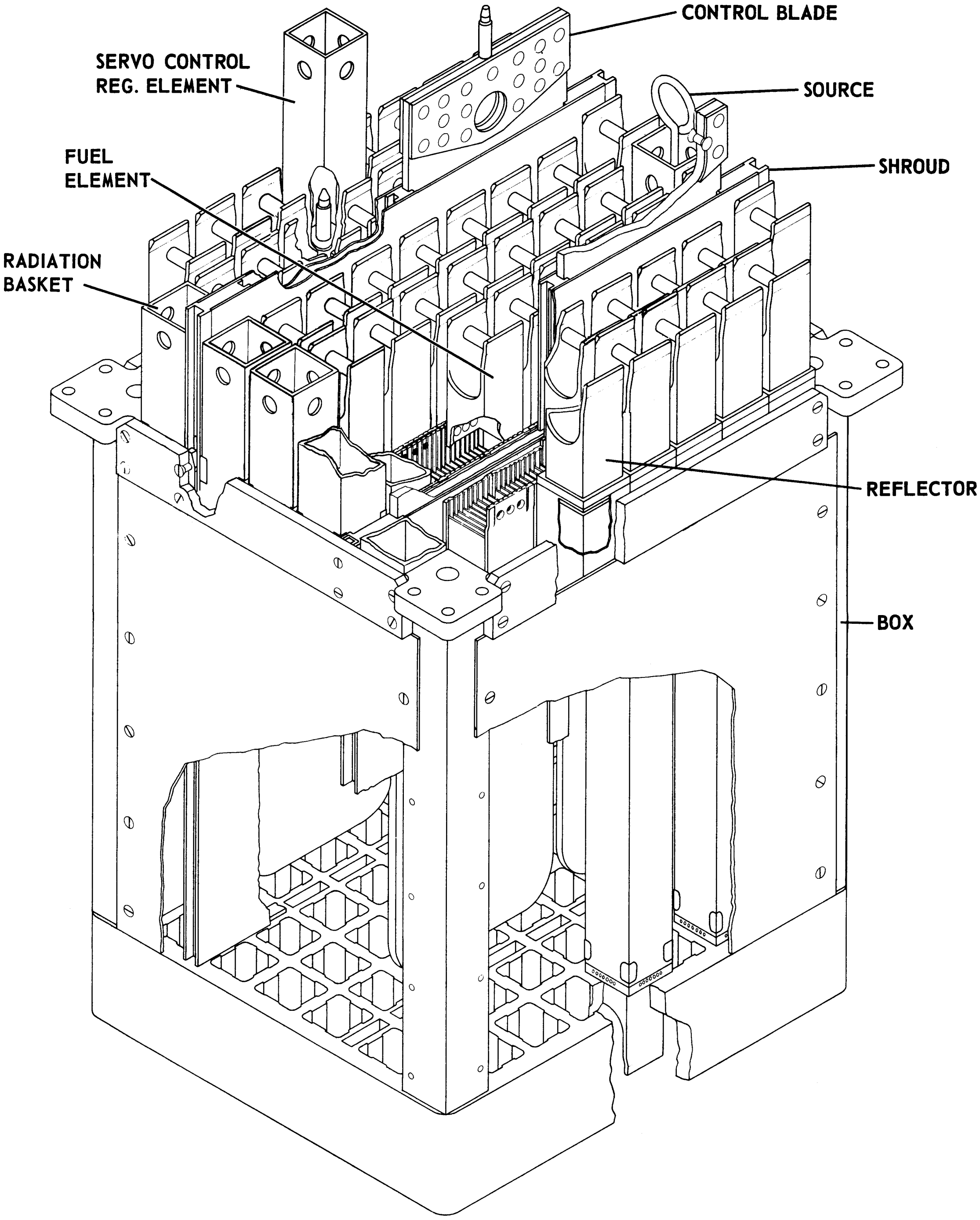


Fig. 11. A Cut-Away View of the Core Box

Chapter 2

HAZARDS CHARACTERIZATION

Table of Contents

2.1 THE HAZARDS CHARACTERIZATION PLAN

2.1.1 Objective

The objective of performing a hazards characterization of the PRR-1 is to obtain reliable data on the quantity, type, location, distribution, and physical and chemical states of radionuclides and other hazards in the facility. The data should be appropriate for use in planning the decommissioning of the facility such that decontamination and dismantling procedures and techniques may be properly delineated, the safety of the workers and the public may be properly provided for, hazardous waste may be properly disposed of or managed, regulatory requirements may be met, and costs may be properly estimated.

Although radiological hazards are expected to dominate in the PRR-1, other non-radiological hazards that may be encountered during decommissioning will also be characterized.

2.1.2 General Work Flow

The general steps that will be taken to perform the hazards characterization of the PRR1 are:

a. Prepare layout drawings and descriptions of past use of the facility in sufficient detail. (See Chapter 1.)

b. Prepare the instruments and sampling tools that will be used in the survey (see Survey Methods and Techniques). The instruments should be appropriate for the radioactive contamination in the facility (see Radionuclides of Interest) and of sufficient sensitivity and discrimination to make measurements that can be compared with guideline values (see Guideline Radiological Values). Write appropriate procedures for using these instruments and tools in order to have high confidence in the measurements (see Quality Assurance).

c. Based on a historical review of the operation of the facility, divide the facility into survey locations and items. Classify the locations and items according to a scale of possible radiological contamination. (See Document and Historical Review, Graded Approach, and Initial Classifications.)

d. Identify non-contaminated locations and items that are otherwise similar to those in the facility in consensus with the regulatory body. Measure radiation levels in those locations and items using the same methods and techniques that will be used to measure contamination in the facility. Obtain approval from the regulatory body to use those measurements as reference values for natural radiation.

e. Obtain approval from the regulatory body to do the survey. (The present facility authorization does not allow any activity beyond safety maintenance and periodic safeguards inspection.)

f. Systematically survey every identified location and item in the facility for radiation:

   1. Perform an initial radiation protection survey of the location or item. This survey should be used to reveal radiation fields, removable surface contamination, and airborne contamination that could be significant in terms of the exposure limits for radiation workers. This survey will determine the radiation protection measures (if any) that will be used with the location or item.

   2. Perform an *in-situ* wide-area gamma survey. If the location was initially designated as Category 1 (see Graded Approach and Initial Classifications), compare the result with the natural radiation reference. If there is no significant difference, the location is considered not contaminated and no further test is necessary; otherwise the location will be reclassified as Category 2.

3. In locations that are Category 2 or higher, examine spots where contamination is likely to be concentrated by manual scanning with portable alpha, beta and gamma detectors and by taking smear samples for analysis in a gross radiation counter. If no radiation is found to be above the natural radiation reference in a Category 2 location, the location is considered not contaminated and no further test is necessary; otherwise the location will be reclassified as Category 3.
4. In locations that are Category 3 or higher, examine the entire surface area in a grid, using portable contamination detectors and smear sampling. In a Category 3 location, no further test is necessary if no radioactivity is found above the clearance level and there is no reason to believe that there could be contamination below the surface; otherwise the location will be reclassified as Category 4.
5. In locations that are Category 4 or higher, delineate the extent of contamination, identify the radionuclides, and precisely determine the amount of radioactivity of each. Both surface and subsurface (core) samples should be taken for laboratory analysis. A profile of radioactivity shall be plotted where subsurface contamination is deep, *e.g.*, in neutron-activated concrete.
6. Category 5 mainly applies to radioactive items that will not be decontaminated but will be removed whole after some minimal dismantling. Category 5 items will be radiologically characterized for the design of appropriate containers, shielding and removal techniques, and for for waste storage purposes.
7. Whatever the category of a location, the laboratory analysis of samples shall be done when *in-situ* methods and techniques are not possible or appropriate, *e.g.*, in characterizing subsoil.
8. The data gathered by the survey will be numbered and cross-referenced and placed in a a computerized database such that all measurements will be traceable to location, time, instrument, and measurer. Instrument calibration and performance tests shall be recorded and also placed in the database. *In-situ* surveys will be recorded photographically in electronic images cross-referenced with the measurements whenever possible. Raw electronic data from the instruments will be stored in archival media and samples will be physically preserved whenever possible.
9. A survey plan for each particular location or item that anticipates the specifics of the above steps will be prepared and approved in advance, based on the physical and historical characteristics of the location or item. Deviations from the plan will be recorded and reported.

g. Simultaneously with the *in-situ* radiological survey, note the location and nature of nonradiological hazards in the facility. Industrial hazards will be identified by sight and hazardous materials will be identified by taking samples for laboratory chemical analysis.

h. Prepare a hazards characterization report presenting the results of the survey. The report should describe the location, extent, physical and chemical form, and radionuclide components of all of the radioactivity found above clearance level in the facility.

2.1.3 Guideline Radioactivity Values

This section specifies the sources of numerical values of radioactivity levels that will guide the design of procedures that will be used to implement the characterization survey.

2.1.3.1 Clearance Levels

The decommissioning of the PRR-1 is required to comply with the Code of PNRI Regulations and with the IAEA safety standards. (The former are the Philippine nuclear regulations, and are themselves largely based on the IAEA safety standards.) The characterization survey will therefore assume that the requirements for clearance levels of radionuclides in the facility are given by the following documents:

a. Code of PNRI Regulations: CPR Part 3, *Standards for Protection Against Radiation*. 6 September 2004.

b. IAEA Safety Requirement: Safety Series No. 115, *International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources*. February 1996. STI/PUB/996.

c. IAEA Safety Guide: Safety Standards Series No. RS-G-1.7, *Application of the Concepts of Exclusion, Exemption and Clearance*. August 2004. STI/PUB/1202.

2.1.3.2 Radiation Protection Exposure Limits

The requirements of CPR Part 3 and IAEA Safety Series No. 115 regarding radiation exposure limits will also be assumed to apply to the decommissioning of the PRR-1. In addition, the characterization survey will assume that the radiation exposure limits given by Appendix D, Administrative Limits, of the Application for Authorization of the PRR-1 are applicable to the public and to the radiation workers who will perform the survey.

2.1.3.3 Natural Radioactivity Reference

Certain procedures will involve comparison of measured values with natural radioactivity. Reference values of natural radioactivity will be defined in consensus with the regulatory body. *In-situ* surveys will be done on locations with similar construction as the locations to be inspected for contamination, but which could not have been contaminated. Laboratory analysis will be done on sample materials similar to the samples to be taken in the facility, but which could not have been contaminated.

2.1.4 Document and Historical Review

The following existing historical documents are being used to support the planning of the hazards characterization survey:

a. Drawings of the building and reactor systems (updated as necessary to reflect present conditions)

b. The reactor's original safety analysis report, with updates to include later modifications

c. Operating manuals

d. Operating logbooks and reports

e. Incident reports

f. Research papers and reports by reactor users

g. Reactor fuel usage reports and neutron flux mapping reports

h. Irradiation records (whatever still exist)

i. Personnel exposure dose records (whatever still exist)

j. Records of previous radiation surveys (whatever still exist)

k. Environmental survey reports (whatever still exist)

A number of people who have worked in the reactor or in the laboratories in the Reactor Building are still available for interview, to provide information that may not be in official documentation. Many have retired but a few are still employed by the PNRI.

2.1.5 Survey Methods and Techniques

This section specifies the methods and techniques that should be available to perform the characterization survey.

2.1.5.1 *In-Situ* Measurements

The following portable instruments will be used for *in-situ* measurement of radioactivity:

a. Coarse-resolution gamma spectrometer with sensitive NaI(Tl) detector for wide-area radiation measurements;

b. Scaler/rate meters with appropriate detectors for scanning for alpha, beta and gamma contamination of surfaces.

2.1.5.2 Laboratory Measurements

Samples taken in the field will be analyzed in the laboratory using the following instruments:

a. High-resolution gamma spectrometer with HPGe detector for the identification and measurement of gamma emitters;

b. Liquid scintillation counter for the measurement of alpha and beta emitters and low-energy gamma emitters;

c. Alpha/beta/gamma counter for the measurement of gross radioactivity in smear/swipe samples.

Some chemical and physical processing may be done on samples before counting.

2.1.6 Radionuclides of Interest

Reactor operation produced numerous radionuclides as fission and neutron activation products, but only a small number are expected to be significant because of the particular materials and construction of the PRR-1, the relatively low operating power, the absence of any known fuel cladding failure or contamination incident, and the long decay time since the reactor was last operated. The radionuclides of interest are given in Table 1, as well as information important to their detection and characterization. The basic reference for this table is Section 5 of IAEA Technical Reports Series No. 389, *Radiological Characterization of Shut Down Nuclear Reactors for Decommissioning Purposes*. The single-nuclide clearance levels are from Table 2 of IAEA Safety Guide RS-G-1.7.

Table 1. Information on Radionuclides of Interest

Radio-nuclide	Half-Life	Decay Mode	Analytical Technique	Production Mode	Likely Locations	Single-Nuclide Clearance Level (Bq/g)
H-3	12.32 y	β-	liquid scintillation	neutron activation	concrete	100
C-14	$5.7x10^3$ y	β-	liquid scintillation	neutron activation	thermal column graphite, bioshield concrete	1
Na-22	2.6 y	β+, γ	gamma spectrometry	neutron activation	bioshield concrete, ion-exchange resin	0.1

Radio-nuclide	**Half-Life**	**Decay Mode**	**Analytical Technique**	**Production Mode**	**Likely Locations**	**Single-Nuclide Clearance Level (Bq/g)**
Cl-36	3.01×10^5 y	β-	liquid scintillation	neutron activation	bioshield concrete, stainless steel and aluminum core parts, ion-exchange resin	1
Ar-39	269 y	β-	liquid scintillation	neutron activation	bioshield concrete and rebars, stainless steel core parts	
Ca-41	1.02×10^5 y	EC, weak x-rays	liquid scintillation	neutron activation	bioshield concrete, ion-exchange resin	
Fe-55	2.737 y	EC, weak x-rays	x-ray spectrometry, or correlation with Co-60	neutron activation	stainless steel core parts, bioshield rebars, ion-exchange resin	1000
Co-60	5.27 y	β-, γ	gamma spectrometry	neutron activation	stainless steel core parts, bioshield rebars, ion-exchange resin	0.1
Ni-59	7.6×10^5 y	EC, weak x-rays	x-ray spectrometry, or correlation with Co-60	neutron activation	stainless steel core parts, ion-exchange resin	100
Ni-63	100 y	β-	liquid scintillation, or correlation with Co-60	neutron activation	stainless steel core parts, ion-exchange resin	100
Sr-90	28.9 y	β-	beta spectroscopy	fission product	ion-exchange resin	1
Nb-94	2.03×10^4 y	β-, γ	gamma spectrometry	neutron activation	stainless steel core parts	0.1
Mo-93	4.0×10^3 y	EC	x-ray spectrometry of daughter products	neutron activation	stainless steel core parts	10
Tc-99	2.111×10^5 y	β-	beta counting	fission product	ion-exchange resin	1
Ru-106	373.59 d	β-	gamma spectrometry (of daughter Rh-106)	fission product	ion-exchange resin	0.1
I-129	1.57×10^7 y	β-	x-ray or gamma spectrometry or correlation with Cs-137	fission product	ion-exchange resin	0.01
Cs-134	2.0652 y	EC, β-, γ	gamma spectrometry	neutron activation, fission product	bioshield concrete, ion-exchange resin	0.1
Cs-137	30.03 y	β-, γ	gamma spectrometry	fission product	ion-exchange resin	0.1

Radio-nuclide	Half-Life	Decay Mode	Analytical Technique	Production Mode	Likely Locations	Single-Nuclide Clearance Level (Bq/g)
Ba-133	10.5 y	EC, γ	gamma spectrometry	neutron activation	barytes concrete (might not be present in the PRR-1)	
Eu-152	13.506 y	EC, β-, γ	gamma spectrometry, beta counting	neutron activation	bioshield concrete, ion-exchange resin	0.1
Eu-154	8.59 y	β-, γ	gamma spectrometry, beta counting	neutron activation	bioshield concrete, ion-exchange resin	0.1
Eu-155	4.753 y	β-, γ	gamma spectrometry, beta counting	neutron activation	bioshield concrete, ion-exchange resin	1
Ho-166m	1.2x10^3 y	β-, γ	gamma spectrometry	neutron activation	bioshield concrete, thermal column graphite	
U-235	7.04x10^8 y	α	alpha spectrometry	fuel component	ion-exchange resin	
U-238	4.468x10^9 y	α	alpha spectrometry	fuel component	ion-exchange resin	
Pu-239	2.411x10^4 y	α	alpha spectrometry	fuel irradiation	ion-exchange resin	0.1

2.1.7 Graded Approach

There are many locations in the facility, but only a few are expected to have radioactive contamination above clearance levels. To avoid wasting survey effort on clean areas, the various locations or items in the reactor will be classified into categories according to their potential level of radioactive contamination. The characterization goals and approach will vary depending on the category a location or item belongs to.

Each location or item will be initially assigned to a category based on the document and historical review of the facility. A location or item may be reassigned to a higher category based on the first results of the characterization survey. Reassignment to a higher category will usually mean that additional surveys appropriate to the higher category will have to be done on the location or item.

2.1.7.1 Category 1 - Low Likelihood of Contamination

The locations under Category 1 are those in which radionuclides are not known to have been produced, processed, conveyed or stored, and into which there is very little likelihood of migration of radionuclides from contaminated areas. Category 1 locations include spaces that were used exclusively as offices or for the storage of non-radioactive materials. The characterization approach in a Category 1 location is to verify that there is indeed no contamination in the location. Only a wide-area radiation scan will need to be done. However, if the survey shows the possible presence of radionuclides above the reference levels of natural radioactivity, the location will be promoted to Category 2.

2.1.7.2 Category 2 - Some Likelihood of Contamination

The locations under Category 2 are those that are not definitely known to be contaminated but where radionuclides were processed, conveyed, or stored, or which have some likelihood of having been contaminated by migration of radionuclides. Category 2 locations include laboratory rooms now believed to be clean but where radionuclides were used in the past, passages through which radionuclides were carried out of the reactor, and places where liquid spills could have spread.

The characterization approach in a Category 2 location is to look more closely for contamination than in a Category 1 location. A wide-area radiation survey of the type done in a Category 1 location will also be done in a Category 2 location. However, those specific places in a Category 2 location where contamination (if it exists) is more likely shall be hand-scanned and samples will be taken for gross radiation counting. If any radioactivity is found that is above the natural radioactivity reference, the location will be promoted to Category 3.

2.1.7.3 Category 3 - High Likelihood of Contamination

The locations and items under Category 3 are those that were not directly irradiated by neutrons, but into which neutron activation products have a direct migration path, or otherwise have a high probability of being contaminated. Category 3 locations include the parts of the concrete biological shield that were remote from the core but were reached by leaking water, the interior of the primary coolant piping that may have deposits, and the underground piping that drains the sump of the Reactor Building. The primary objective of the characterization survey in a Category 3 location is to determine whether there are places in the location where radionuclides exceed the clearance level. All of the location shall be scanned and sampled on a grid. If any place is found where the clearance level is exceeded, the location will be promoted to Category 4.

2.1.7.4 Category 4 - Known to be Contaminated

The locations and items under Category 4 are those that are assumed or known to be contaminated above clearance level. Category 4 locations include those that were irradiated with neutrons from the reactor core, those containing known radioactive sources and the locations of known spills. The parts of the biological shield that are closest to the core, the entire thermal column, the beam tubes, and the ion-exchange column of the pool water purification system are all Category 4. The primary objective of the characterization survey in a Category 4 location is to provide input data for the decisions to be made on how to remove the contamination. The survey must therefore identify the radionuclides and quantitatively determine their spatial distribution, including possible migration along cracks. In addition to the surveys done in a Category 3 location (perhaps in a tighter grid), core samples will be taken for detailed laboratory analysis where subsurface contamination could exist.

2.1.7.5 Category 5 - Known Occupational Hazard

The items under Category 5 are those that are assumed or known to produce radiation doses that are significant in comparison with limits on occupational exposure, or were part of the reactor core. The entire core box, the fuel elements, the neutron sources, in-core irradiation rigs and baskets, and Co-60 gamma irradiation sources that were stored in the reactor pool are Category 5. The primary objective of the characterization survey on a Category 5 item is to provide data for radiation protection during the dismantling and removal of the item (or decontamination on-site, although less likely). Radiation fields will be accurately measured and the possible mobilization of contaminants shall be assessed to provide input data for the delineation of procedures, protective equipment and shielding.

2.1.8 Initial Classifications

This section specifies the initial classifications of the locations and items that will be surveyed according to the graded approach that will be used. Refer to Chapter 1 for the location codes and layout drawings.

2.1.8.1 Category 1 Locations

W0-1 (Storage Rm.)	W0-2 (Stairwell)		
W1-6 (Stairwell)	W1-7 (Operating Rm.)	W1-8 (Decon. Rm.)	W1-9 (Contam. Rm.)
W1-10 (Clean Rm.)	W1-11 (Contam. Rm.)	W1-12 (Clean Rm.)	W1-13 (Storage Rm.)
W2-1 (Vent. Eqpt. Rm.)	W2-6 (Hallway)	W2-7 (Toilet)	W2-8 (Toilet)
W2-9 (Storage Rm.)			
RG-7 (Large Powerhse.)	RG-8 (Small Powerhse.)	RG-9 (Diesel Fuel Tank)	RG-10 (Raw Water Tank)
RG-12 (Utility House)			

2.1.8.2 Category 2 Locations

RB-3 (Truck Entr. Ramp)	RB-7 (Wall Surfaces)	RB-9 (Air-Cond. Ducts)	RB-10 (Polar Crane)
E0-9 (Storage Rm.)	E0-10 (Office)	E0-11 (Storage Rm.)	E0-12 (Toilet)
E0-13 (Toilet)	E0-14 (Stairwell)	E0-16 (Hallway)	E0-19 (Shaft)
E1-2 (Hallway)	E1-3 (Office)	E1-4 (Foyer)	E1-5 (Stairwell)
E1-7 (Shaft)	E2-2 (Visitor's Gallery)	E2-3 (Control Rm.)	E2-4 (Toilet)
W1-1 (Transfer Rm.)	W1-2 (Transfer Corridor)	W1-3 (Decon. Rm.)	W1-4 (Hot Cell 1)
W1-5 (Hot Cell 2)			
W2-2 (Lab.)	W2-3 (Lab.)	W2-4 (Lab.)	W2-5 (Lab.)
RG-1 (Earth)	RG-4 (Hallway)	RG-5 (Hallway)	RG-6 (Office)
RG-11 (Cooling Tower)			

2.1.8.3 Category 3 Locations and Items

RB-1 (Floor)	RB-2 (Alcove)	RB-4 (Fuel Storage Tank)	RB-4a (Lrg. Prt. Demin.)
RB-4b (Sml. Prt. Demin.)	RB-4j (Racks and Tanks)	RB-5 (Stairway)	RB-6 (Stairway)
RB-8 (Storage Holes)	RB-13 (Fuel Sto. Racks)		
RP-7 (Ext. Surfaces Pool)	RP-8 (Pool Platform)	RP-8d (Fuel Hand. Tools)	RP-9 (Bridge)
E0-1 (Decay Tank Rm.)	E0-1a (Decay Tank)	E0-2 (Drain St. Tank Rm.)	E0-2a (Drain Sto. Tank)
E0-3 (Reten.Tank Rm.)	E0-3a (Retention Tank)	E0-3b (Transfer Pump)	E0-4 (Suspect Tank Rm.)
E0-5 (Resin Tank Rm.)	E0-6 (Proc. Eqpt. Rm.)	E0-7 (Sump Pit)	E0-7a (Sump Pump)
E0-8 (Demin. Alcove)			
E0-15 (Change Rm.)	E0-17 (Isotopes Lab.)	E0-18 (Counting Rm.)	
E1-1 (M/E Eqpt. Rm.)	E1-6 (Gen. Purpose Lab.)	E2-1 (Vent. Eqpt. Rm.)	
RG-2 (Und. Pipes)	RG-3 (Septic Tanks)		

2.1.8.4 Category 4 Locations and Items

RB-10c (Neutron Dets.)	RB-12 (SNIF)		
RP-1 (Int. H.P. Section)	RP-2 (Int. I.P. Section)	RP-3 (Int. L.P. Section)	RP-4 (Dry Gamma Rm.)
RP-5 (Thermal Column)	RP-6 (Beam Tubes)	RP-8c (Neutron Detector)	
E0-4a (Suspect Tank)	E0-4b (Transfer Pump)	E0-5 (Resin Tank)	E0-8a (Clean-Up Demin.)
E0-20 (Isotopes Sto. Rm.)			

2.1.8.5 Category 5 Items

RB-4c (Co-60 Source)	RB-4d (Triga Fuel)	RB-4e (Cf-252 Source)	RB-4f (Sb-Be Source)
RB-4g (Pu-Be Source)	RB-4h (Source. Holder)	RB-4j (Old Reg. Rod)	RB-11 (Co-60 Source)
RP-8a (Irr. Cap. Stringers)	RP-8b (DNAA Irr. End)	RP-10 (Core Box)	RP-10a (Cntrl. Elements)
RB-10b (Irrad. Baskets)			

2.1.9 Characterization of Non-Radiological Hazards

The usual industrial materials that are considered very hazardous in a non-radiological sense (such as asbestos and PCBs) are not believed to be present in the PRR-1. Nevertheless, samples of suspicious materials (such as paint that may contain lead) will be taken and analyzed.

Common industrial hazards such as electrocution and falls do exist in the facility. These will be identified and included in the hazards characterization report.

2.1.10 Health and Safety

The administrative limits on radiation exposure defined by the Radiation Safety and Security Board of the PNRI as well as regulations that are imposed under the internal regulatory control program of the PNRI will apply to radiation workers and the public during the characterization survey.

During the performance of the characterization survey, precautions will be taken for safety against non-radiological hazards such as falls, electrocution and exposure to toxic materials.

2.1.11 Quality Assurance

The data to be produced by the characterization survey should have sufficient completeness and reliability for the purposes that it is to be used, namely the planning of the decommissioning of the facility and providing for the safety of the workers and the public. The characterization survey will include a quality assurance program to assure that it is so. The decommissioning clearance levels and the administrative limits for radiation exposure will be the bases for the design and implementation of the quality assurance program.

The quality assurance program of the characterization survey will be designed to ensure that:

a. All significant hazards will be identified and characterized;

b. The methods and techniques used will be appropriate and will be performed according to plan;

c. The instruments used will be appropriate, in good working order and accurate during use; and

d. The safety of the workers and the public will be always preserved.

In advancement of the above goals, the quality assurance program will have the following features:

a. Policies will be stated in writing unambiguously;

b. All work will be done according to written procedures;

c. The procedures will have a clear preparation, review, approval and revision path;

d. The performance of procedures will be documented; and

e. All numerical data produced will be traceable to a certified calibration standard.

2.2 PERSONNEL, WORK ITEMS AND SCHEDULE

2.2.1 Personnel

The hazards characterization survey will be performed by the PRR-1 Decommissioning Task Force that has been created by the PNRI. The Task Force Leader has been appointed by the PNRI Director. The members of this task force are all the remaining operations personnel of the PRR-1 and specialists in radiation protection, radiation detection and laboratory analysis assigned to the task force from other PNRI units (approximately 20 people in total). Additional personnel will be assigned to the task force as the need arises.

A Quality Assurance Manager will be assigned within the PRR-1 Decommissioning Task Force. The Quality Assurance Manager will also be in charge of records. The Task Force Leader will perform the function of the Quality Assurance Manager until he assigns a separate task force member to the post.

Work teams, each with its own leader, will be created within the task force to perform the following tasks:

a. *In-situ* survey (more than one team to take advantage of multiple portable instruments);

b. Sample-taking;

c. Laboratory analysis (one for each laboratory instrument);

d. Instrument maintenance;

e. Radiation protection (could be integrated with *in-situ* survey teams).

2.2.2 Preparatory Work Items

This section specifies the work items that need to be done prior to the physical implementation of the characterization survey on the facility.

2.2.2.1 Creation of a Quality Assurance Program

The Quality Assurance Manager will be in charge of the creation and documentation of a quality assurance program (see Quality Assurance). The Quality Assurance Manager will ensure that policies and procedures are properly documented and that all procedures are written, reviewed, approved and performed in accordance with the quality assurance program.

2.2.2.2 Creation of Procedures

This section specifies the work procedures to be created.

2.2.2.2.1 *In-Situ* Survey Procedures

These are the procedures that will be used to perform the characterization survey with portable instruments taken to the actual locations in the facility. The radiological procedures will be written by the specialists in radiation contamination detection, while the non-radiological procedures will be written by the reactor staff.

Procedures will be written for:

a. Wide-area gamma survey;

b. Surface contamination survey;

    1. Gamma;

    2. Beta;

    3. Alpha;
- c. Non-radiological hazard identification.

2.2.2.2.2 Sample-Taking Procedures

These are the procedures that will be used to take samples for laboratory analysis. The procedures will be written by the reactor staff, with some advice from the specialists in radiation detection and laboratory analysis.

Procedures will be written for:

- a. Surface samples;
    1. Smear / Swipe;
    2. Paint / Coatings / Surface deposits;
- b. Subsurface samples;
    1. Cracks and cavities;
    2. Cores (using diamond coring equipment);
        - i. Concrete;
        - ii. Metal;
        - iii. Wood;
- c. Liquids;
- d. Ion-exchange resin;
- e. Soil;
- f. A generic procedure for other materials.

2.2.2.2.3 Laboratory Analysis Procedures

These are the procedures that will define the use of laboratory instruments for the analysis of samples for radioactivity. The procedures will be written by the specialists in laboratory analysis.

Procedures will be written for:

- a. Radionuclide identification and quantification using gamma spectroscopy with the HPGe system available to the task force;
- b. Radionuclide identification and quantification using the liquid scintillation systems available to the task force;
- c. Gross counting of smear/swipe samples using the counters available to the task force;
- d. Sample preparation (as required by specific instruments);
- e. Preparation and use of calibration standards (separate procedures for each instrument type).

2.2.2.2.4 Radiation Protection Procedures

These are the procedures that will be used to assure compliance with the radiation exposure administrative limits of Appendix D of the Application for Authorization. The procedures will be written by the radiation protection specialist in the task force.

Procedures will be written for:

- a. Initial workplace radiation survey;
- b. Personal dose monitoring;

c. Workplace dose monitoring;

d. Workplace access control.

2.2.2.2.5 Equipment Maintenance and Calibration Procedures

These are the procedures that will be used to assure that equipment will be in working order and that measuring instruments will produce reliable data. Maintenance procedures will be written by the work teams that will use the equipment, in consultation with the manufacturers' manuals. Calibration procedures will be written by the specialist concerned with the particular instrument.

Procedures will be written for:

a. Portable radiation-detection instruments;

b. Laboratory instruments;

c. Core-drilling equipment;

d. Radiation protection equipment.

2.2.2.2.6 Record Management Procedures

These are the procedures that will be used to assure that records are created and managed according to the Quality Assurance Program. The procedures will be written by the Quality Assurance Manager. The Quality Assurance Manager should also ensure that proper records creation is incorporated in the procedures written by others.

2.2.2.3 Equipment Preparation

This section specifies the work items related to the preparation of equipment that will be used in the characterization survey.

2.2.2.3.1 Portable Equipment

Work will be done by the specialists in radiation detection in the task force to obtain, assemble, test and calibrate the following instruments to perform *in-situ* radiation measurements:

a. NaI(Tl) gamma spectrometer. A portable gamma spectrometer will be assembled from a 3-inch NaI(Tl) scintillation detector and a computer equipped with a multi-channel analyzer card. The spectrometer will be used to measure the wide-area coarse-spectrum gamma radiation in various locations in the facility. Some partial lead shielding may be used around the detector to provide rough directionality. The shielding and NaI(Tl) detector are already available. The multi-channel card will be obtained through IAEA technical assistance and the host computer will be obtained through local DOST-GIA assistance.

b. Portable scaler/rate meters with appropriate detectors. These instruments will be used to measure gamma, beta and alpha contamination on surfaces and also radiation fields for radiation protection purposes. There will be enough instruments to be able to survey two locations simultaneously. All of these instruments will be obtained through IAEA technical assistance.

2.2.2.3.2 Laboratory Equipment

Work will be done by the specialists in laboratory analysis in the task force to obtain, assemble, test and calibrate the following instruments to perform laboratory radionuclide analysis:

a. HPGe gamma spectrometer. This instrument will be used to identify and quantify gamma-emitting radionuclides. The entire equipment, except for the host computer and shielding, will be obtained through IAEA technical assistance. The host computer will be obtained through DOST-GIA assistance; the shielding is already available at the PNRI. This spectrometer will be set up in a clean air-conditioned room controlled by the reactor staff.

b. Liquid scintillation counter. This instrument will be used to identify and quantify beta and alpha-emitting radionuclides. One or more of the liquid scintillation counters already existing in the PNRI will be used.

c. Alpha/beta/gamma sample counter. This instrument will be used for the gross radiation counting of samples (typically smears and swipes) taken from the facility. The radiation protection unit of the PNRI will provide the counter.

Work will be done by the reactor staff to prepare a suitable counting room to house the HPGe gamma spectrometer (the other instruments will be used where they are already installed). Work will also be done by the reactor staff to prepare a sample preparation room and a sample storage room.

2.2.2.3.3 Calibration Sources

Work will be done to obtain and prepare the following certified standard sources for calibrating instruments:

a. Planar calibration standards for gamma, beta and alpha radiation. These sources will be used to calibrate the portable instruments that will be used to measure contamination on surfaces.

b. Eu-152 standard reference source (in liquid form). Secondary standards in various matrices similar to the material samples that will be taken from the facility will be created from this primary standard. The secondary standards will be used to calibrate the laboratory HPGe gamma spectrometer.

All of these standard sources will be obtained through IAEA technical assistance. The work will be done by the specialist who will use the particular source.

2.2.2.3.4 Sample-Taking Equipment

Work will be done by the reactor staff to obtain and test a diamond coring system. This equipment will primarily be used to obtain core samples from biological shield concrete, but can also be used to obtain cores from other hard materials. The equipment will be obtained through IAEA technical assistance.

2.2.2.4 Personnel Training

The specialists in the task force will do the work of training the other people in their teams to perform the day-to-day work using the procedures that the specialist have created (see Creation of Procedures).

2.2.2.5 Regulatory Approval

The Task Force Leader will do the work of preparing an Application for Authorization to perform the hazards characterization survey and submitting the same to the Radiation Safety and Security Board for review and to the Nuclear Regulations, Licensing and Safeguards Division for regulatory review and approval. The Task Force Leader will be the contact person with the RSSB and the NRLSD.

2.2.3 Determination of Natural Radioactivity References

The Task Force Leader will manage the finding of non-contaminated analogues of the locations and items in the facility. The selection of analogues will be done in consensus with the regulatory body. Once the analogues have been identified, the various *in-situ* survey, sample-taking and laboratory analysis procedures will be applied to obtain results that will be used as natural radioactivity references.

2.2.4 Implementation and Work Scheduling

The Task Force Leader, in consultation with the leaders of the various work teams, will prepare monthly, weekly and daily work schedules and review and revise them as necessary as the survey progresses. The schedules will implement in detail items f and g described in the section on General Work Flow.

2.2.5 Writing of the Report

The Task Force Leader will be responsible for writing the Hazards Characterization Report. The report will present the results of the survey. The report will describe the location, extent, physical and chemical form, and radionuclide components of the all of the radioactivity found above clearance level in the facility. The report will describe the location and nature of nonradiological hazards as well.

2.3 THE HAZARDS CHARACTERIZATION REPORT

The actual hazards characterization report will be placed in this section after it is written.

Chapter 3

DECOMMISSIONING PLAN

Table of Contents

3.1 INTRODUCTION

This chapter contains the decommissioning plan of the Philippine Research Reactor (PRR-1), owned by the Philippine Nuclear Research Institute (PNRI). The preparation of this chapter was started before the commencement of the hazards characterization survey of the PRR-1, and some sections do not yet contain much detail. The project's management structure is also not yet fully worked out.

The format and content of the decommissioning plan follows IAEA Safety Reports Series No. 45, *Standard Format and Content for Safety Related Decommissioning Documents*, July 2005, STI/PUB/1214.

3.2 FACILITY DESCRIPTION

The physical description and the operating history of the PRR-1 are given in Chapter 1, *Reactor Description*.

The radiological status of the PRR-1 is described in Chapter 2, *Hazards Characterization*.

3.3 DECOMMISSIONING STRATEGY

3.3.1 Alternatives considered

The alternative decommissioning strategies that are normally considered in decommissioning a nuclear research reactor are described in IAEA Safety Reports Series No. 50, *Decommissioning Strategies for Facilities Using Radioactive Material*, March 2007, STI/PUB/1281. The alternatives are immediate dismantling, deferred dismantling, and entombment.

Ideally the strategy is selected well in advance, perhaps while the facility is not yet shut down. However, no decommissioning plan nor strategy was prepared for the PRR-1 up to the time the decision to decommission the facility was taken in 2005, although the facility was shut down for repair (ultimately unsuccessful) in 1988.

3.3.2 Rationale for chosen strategy

Deferred dismantling has become the decommissioning strategy not by deliberate choice but by default. Immediate dismantling is no longer an option because of the time that has passed since 1988; in any case funding will not be available for at least a few years more. The other alternative of entombment is not considered acceptable because the site is inside a university campus in a highly urbanized part of Metropolitan Manila.

The PNRI has decided that the end state of decommissioning is to be unrestricted release from regulatory control, because the site will eventually be returned for re-use to its owner, the University of the Philippines. However, the facility will not be dismantled down to a “green field”. The reactor building is considered to be architecturally significant, and its shell is to be preserved. The building can be refurbished to serve a non-nuclear purpose after its release from regulatory control.

3.4 PROJECT MANAGEMENT

3.4.1 Legal and regulatory requirements

This section explains and summarizes the rules and regulations that will be observed during PRR-1 decommissioning.

3.4.1.1 PNRI internal regulatory system

The PNRI is both an operator of nuclear facilities and the national nuclear regulator in the Philippines. Current Philippine laws are interpreted to mean that the PNRI nuclear facilities (such as the PRR-1) are exempted from nuclear licensing. A new national nuclear law has been drafted that will create a separate nuclear regulatory agency that will have the power of regulating the PNRI facilities. To serve the purpose of effectively-independent regulation of the PNRI facilities until that law is passed, the PNRI has created an interim internal regulatory system.

Internal nuclear regulation has been made the direct responsibility of the PNRI's Nuclear Regulations, Licensing and Safeguards Division (NRLSD), which is separate from the PNRI's Nuclear Services and Training Division (NSTD) that runs nuclear service facilities (including the PRR-1) and the PNRI's Atomic Research Division (ARD) that runs nuclear research laboratories. Until the new nuclear law is passed, which could take several years, the decommissioning of the PRR-1 will be regulated by the NRLSD.

Under the internal regulatory system, the same regulations that the PNRI imposes on facilities not owned by the PNRI (a power given by existing law) are also imposed by the NRLSD on the PNRI facilities. The PNRI has a published set of nuclear regulations called the Code of PNRI Regulations (CPR) based on, among others, the IAEA Safety Standards. The decommissioning of the PRR-1 will comply with the CPR.

The parts of the CPR that will notably be applied (among others) to PRR-1 decommissioning are:

a. CPR Part 2, *Licensing of Radioactive Material.* 16 July 1990.

b. CPR Part 3, *Standards for Protection Against Radiation*. 6 September 2004.

c. CPR Part 4, *Regulations for the Safe Transport of Radioactive Materials in the Philippines*. 25 October 2004.

3.4.1.2 Administrative limits

The PRR-1 has adopted administrative limits on the radiation exposure of its workers that are lower than the regulatory limits, in the spirit of the ALARA principle. This commitment is documented in Appendix D, *Administrative Limits*, of the application for authorization of the PRR-1 for its current shutdown state, which has been approved by the NRLSD. This commitment will be extended to the decommissioning of the PRR-1.

3.4.1.3 IAEA safety standards

The decommissioning of the PRR-1 will also have to directly comply with the IAEA safety standards. The project receives technical assistance from the IAEA, and the IAEA requires such compliance as a condition for assistance. This requirement has been published in IAEA Information Circular 127, *The Revised Guiding Principles and General Operating Rules to Govern the Provision of Technical Assistance by the Agency*, March 1979.

The IAEA Safety Requirements that will notably be applied (among others) to PRR-1 decommissioning are:

a. Safety Series No. 115, *International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources*. February 1996. STI/PUB/996.

b. Safety Standards Series No. WS-R-2, *Predisposal Management of Radioactive Waste, Including Decommissioning*. July 2000. STI/PUB/1089.

c. Safety Standards Series No. WS-R-5, *Decommissioning of Facilities Using Radioactive Material*. October 2006. STI/PUB/1274.

The following IAEA Safety Guides, Safety Reports, and Technical Reports are notably being used (among many others) to guide compliance with the IAEA Safety Requirements:

a. Safety Standards Series No. RS-G-1.7, *Application of the Concepts of Exclusion, Exemption and Clearance*. August 2004. STI/PUB/1202.

b. Safety Standards Series No. WS-G-2.1, *Decommissioning of Nuclear Power Plants and Research Reactors*. October 1999. STI/PUB/1079.

c. Safety Standards Series No. WS-G-5.1, *Release of Sites from Regulatory Control on Termination of Practices*. November 2006. STI/PUB/1244.

d. Safety Standards Series No. WS-G-6.1, *Storage of Radioactive Waste*. November 2006. STI/PUB/1254.

e. Safety Reports Series No. 45, *Standard Format and Content for Safety Related Decommissioning Documents*. July 2005. STI/PUB/1214.

f. Safety Reports Series No. 50, *Decommissioning Strategies for Facilities Using Radioactive Material*. March 2007. STI/PUB/1281.

g. Technical Reports Series No. 389, *Radiological Characterization of Shut Down Nuclear Reactors for Decommissioning Purposes*. October 1998. STI/DOC/010/389.

3.4.2 Project management approach

The discussion of project management in this and in the following sections does not include management of decommissioning regulation. Although the PNRI will remain the regulatory body until the new nuclear law is passed, the regulatory function will be independent and separately managed, and is outside the scope of this document.

The project management approach has to solve the following problems:

a. The PNRI will be responsible for the entire decommissioning process, including hazards characterization, development of the decommissioning plan, performing dismantling and decontamination, and waste disposal. Unlike in some other countries, the Philippines does not have specialized organizations (government or private) that can be commissioned to undertake any of those jobs.

b. The PNRI has a limited amount of resources, both in manpower and funding. Using its present resources (including some local and foreign assistance that it normally receives), the PNRI can probably only undertake the decommissioning process up to the development of the decommissioning plan and some minor dismantling and decontamination. Going further into major dismantling and decontamination (such as of the bioshield) and providing for waste disposal or storage will need the infusion of resources much beyond what the PNRI usually has.

   The problem that the project management approach has to solve is not the getting of those resources (that is a large and separate problem, out of the scope of this section) but the problem of managing the resources when they become available.

c. The PNRI has no experience in the decommissioning of a large nuclear facility, and its present management structure is that of a small government bureaucracy that does scientific research and provides some technical services, which may not be well suited to the management of a large project.

During the early stages of decommissioning, up to the preparation of the decommissioning plan and a little beyond to light decontamination and dismantling, the PNRI will be using only the resources it already has and will be doing work that is still within a simple extension of its present competence. During those early stages, the project management approach that the PNRI already uses to set up new projects will work: Create a small temporary task force, assigning personnel to work part-time but with high priority on the project until it is done. This small task force needs only a simple structure, with most of the direction directly provided by the task force leader.

When decommissioning proceeds to major decontamination and dismantling, the simple task force approach will no longer work. The project will be dealing with large resources, complex work items being done simultaneously, a fixed schedule, and contractors. Project management will have to be more sophisticated and formally organized. The project as a minimum should have a Project Manager with real responsibility and authority and a staff with people assigned full-time to planning, quality assurance, administration, and engineering.

3.4.3 Project management organization and responsibilities

As could be expected, the PRR-1 decommissioning project was started with the creation of a task force to perform the hazards characterization survey and prepare the decommissioning plan. A small work group was created, based on what remained of the reactor operations staff augmented with a few specialists on radiation protection and laboratory analysis. Management of this small task force (a dozen people or so) has been simple and uncomplicated.

The PNRI has started to prepare for the full implementation of PRR-1 decommissioning by appointing a Project Manager, who will guide the completion of the decommissioning plan and will then move on to organize and lead its implementation. To provide oversight from PNRI upper management, and also to obtain the external funding and resources that will be necessary, the PNRI has created a Decommissioning Management Committee chaired by the PNRI's Deputy Director. The Project Manager reports to this committee.

3.4.4 Task management organization and responsibilities

The main tasks that will be performed to implement the PRR-1 decommissioning plan are classified into groups and summarized in this section. The details of the tasks are in the section of this document on Decommissioning Activities.

The tasks will be performed by the PNRI or by contractors as indicated. Generally, the PNRI will perform tasks that require radiological expertise and contractors will perform tasks that require equipment and manpower that is impractical for the PNRI to acquire just for this project.

3.4.4.1 Engineering design

a. Design of the fuel storage vault - PNRI.

b. Design of the new waste enclosures (trenches) - PNRI.

c. Design of custom waste containers - PNRI.

d. Design of the tent for reactor pool dismantling - PNRI.

e. Preparation of specifications for work to be performed by contractors - PNRI.

3.4.4.2 Fabrication and construction

a. Construction of the fuel storage vault - contractor.

b. Construction of the new waste enclosures (trenches) - contractor.

c. Fabrication of custom waste containers - contractor.

d. Fabrication of the tent for reactor pool dismantling - contractor.

3.4.4.3 Dismantling

a. Removal of movable radiation sources and nuclear fuel - PNRI.

b. Removal of light uncontaminated equipment and material - PNRI.
c. Dismantling and removal of heavy uncontaminated equipment and material (such as heat exchanger, pumps, some tanks) - contractor.
d. Dismantling of uncontaminated upper stages of reactor pool - contractor.
e. Dismantling of contaminated first stage of reactor pool - PNRI and contractor.

3.4.4.4 Decontamination

a. Decontamination of West Wing (if necessary) - PNRI.
b. Decontamination of East Wing - PNRI.
c. Decontamination of recyclable equipment and material - PNRI.
d. Concrete scabbling - PNRI if small area, contractor if large.
e. Removal of contaminated soil (if any) - PNRI if small amount, contractor if large.

3.4.4.5 Waste management

a. Waste packaging and transport to RWMF- PNRI or contractor closely supervised by PNRI.
b. Package acceptance and management at RWMF - PNRI.

3.4.4.6 Radiation protection

a. Provide and maintain personal protective equipment – PNRI.
b. Do radiological workplace monitoring – PNRI.
c. Do radiological environmental monitoring – PNRI.
d. Secure workplace and control access – PNRI.

3.4.4.7 Administration

a. Project management – PNRI.
b. Quality assurance management – PNRI.
c. Contracts management – PNRI.
d. Records-keeping – PNRI.
e. Training – PNRI.

3.4.5 Safety culture

Safety culture is a set of attitudes, and is not something can be practiced mechanically or imposed willfully. The PRR-1 decommissioning project will foster (not impose) a safety culture by ensuring that the following are done:

a. All personnel (including those of contractors) have a good understanding of the nature of radiation, the harm it may cause, and how it is present in the work environment (Training);
b. Work procedures are written to consider radiation safety, to have any safety-related provisions clearly explained, and are implemented (Quality Assurance);
c. Necessary equipment, materials, and manpower are provided for radiation protection (Resources);
d. Radiation exposure limits are clearly defined and known to all personnel (Clear Safety Goals);

e. Personal radiation exposure is measured and the workplace is surveyed (Monitoring);
f. Safety concerns are reported and acted upon among workers and between workers and supervisors (Communications).

As required by current PNRI regulations, the PRR-1 Decommissioning Project will have a Radiological Health and Safety Officer (RHSO). Fostering the above characteristics will be one of his responsibilities, though not his alone. The project manager, planners, and supervisors share the responsibility.

3.4.6 Safety training

The PNRI shall provide safety training in formal classes to all personnel involved in PRR-1 decommissioning, including those of contractors.

3.4.7 Contractor support

The tasks that contractors will perform are listed in a previous section.

The Philippine government has comprehensive and very detailed rules on contracted services that its agencies like the PNRI must observe. The PNRI has a well-established administrative process for soliciting, evaluating, awarding, and monitoring contracts, which the PRR-1 decommissioning project will use.

3.4.8 Schedules

Detailed schedules will not be available until the decommissioning tasks are better refined.

3.5 DECOMMISSIONING ACTIVITIES

The details of the decommissioning activities described in this section depend on the extent of contamination above clearance levels that is reported by the hazards characterization survey (Chapter 2). However, at the time of this writing, the hazards characterization survey has not yet produced much data. The activities in the following descriptions are based on contamination that would be reasonably expected based on the reactor's operating history (Chapter 1) and on experiences of similar reactors that have been decommissioned. The following sections may be rewritten as the hazards characterization survey produces data.

3.5.1 Uncontaminated areas and items

The entire West Wing of the reactor building is believed to be uncontaminated, which will be confirmed by the hazards characterization survey. Much of the reactor equipment is not contaminated above clearance levels. Also, the reactor bay and other places in the reactor building have been used to store extraneous equipment and materials that are not likely to be contaminated. Cross-contamination during dismantling and decontamination will be reduced in advance by removing the uncontaminated items and disconnecting the uncontaminated areas from the workplace:

a. Seal the connections of the West Wing to the rest of the reactor building. There are only two open passages: the door in location code W1-6 and the steel grille between location codes W1-1 and W1-2. (See Chapter 1.) Those passages will be completely closed with masonry before any major dismantling is done in the rest of the reactor building.
b. Remove movable non-contaminated equipment and materials from the areas in the Reactor Bay and East Wing where dismantling and decontamination will be performed.

3.5.2 Preparation for waste storage

There is no national waste disposal facility in the Philippines yet. The waste that will be generated by PRR-1 decommissioning will be placed in the Radioactive Waste Management Facility (RWMF), located in a fenced-off and secured part of the PNRI compound adjacent to the PRR-1. The RWMF presently has two below-ground covered concrete enclosures for the temporary storage of packaged radioactive waste. PRR-1 decommissioning will produce only low-level waste, all of which can probably be accommodated in the RWMF by building at least four more similar concrete enclosures.

The RWMF will also house the slightly-irradiated and fresh fuel that is presently stored in the reactor building, for the sake of simplifying the enforcement of perimeter security. There is enough ground space in the RWMF to build a small fuel storage vault in addition to the new low-level-waste enclosures.

The decommissioning activities related to waste storage are:

a. Design and build additional low-level waste enclosures.

b. Develop waste packaging requirements and acceptance procedures for the PRR-1 decommissioning waste. The requirements will probably be similar to packaging requirements and procedures that already exist for other low-level waste. Most packages will probably be standard 200-liter drums, although some custom containers will be used.

c. Obtain authorization from the NRLSD for the additional enclosures and procedures.

The activities for nuclear fuel are described in a separate section.

3.5.3 Slightly-irradiated and fresh fuel

All of the reactor's spent fuel were shipped out in 1999. However, some nuclear fuel remains in the facility in the form of 115 slightly-irradiated TRIGA rods, 15 fresh TRIGA rods, and 2 slightly-irradiated plate assemblies. These fuel will be removed from the facility as soon as possible.

The fuel is much more similar to fresh fuel than spent fuel. The fuel requires only minimal radiation shielding but consequently needs an effective physical security system even more because it is not self-protecting. Like spent fuel, it also needs effective precautions against criticality.

The decommissioning activities associated with the slightly-irradiated and fresh fuel are:

a. Design and build a dry-storage vault within the fenced grounds of the RWMF, following well-known requirements on physical security and criticality .

b. Obtain authorization from the NRLSD to move the fuel elements to the fuel storage vault. The application for authorization will be supported with the design, procedures and safety analysis of the vault and the transport of the fuel.

c. Move the fuel elements in small batches to the fuel storage vault using a small shielded cask that can be transported by the reactor's forklift.

3.5.4 Movable radiation sources

Some movable radiation sources are stored in the reactor building. These sources will be moved to the RWMF before dismantling and decontamination of the building is begun, after obtaining authorization from the NRLSD.

3.5.4.1 Co-60 sealed sources

Co-60 sealed sources that were used for gamma irradiation are stored in the Reactor Bay in two casks. The Co-60 casks will be moved the RWMF using a rented forklift or flatbed truck as the casks are too heavy for existing PNRI equipment.

3.5.4.2 Neutron sources

The PRR-1 has three neutron sources that were used for reactor start-up. These are: a) two small-diameter sealed rods containing Cf-252; b) a small capsule containing Pu-Be; and c) a sealed can containing Sb-Be.

The Cf-252 and Sb-Be sources have short half-lives, and by this time are no longer producing significant neutron radiation, although they still have residual radioactivity from neutron activation of their body and cladding material. The Pu-Be source is log-lived enough to be still producing significant neutron radiation.

The following activities are associated with the neutron sources:

a. Package the Cf-252 and the Sb-Be sources as low-level waste in a standard 200-liter waste drum and move the drum to the RWMF.

b. Design a modification of a 200-liter waste drum to hold the Pu-Be source. A container for the source should be suspended by metal spiderwork in the center of the drum and the drum filled with melted paraffin (wax). Place the Pu-be source in the modified drum and move the drum to the RWMF.

3.5.4.3 Various loose neutron-activated items

Various loose neutron-activated items stored in the reactor building, such as discarded irradiation rigs and sample holders. Those materials will be packaged in standard 200-liter waste drums and taken to the RWMF.

3.5.5 Lightly-contaminated areas

The hazards characterization survey will probably reveal only light surface contamination (or none) in most rooms of the East Wing of the reactor building. The rooms that were used for small-scale radioisotope production up to the 1980s were decontaminated in the 1990s, and it is believed that the other former laboratories in the East Wing will need only minor cleaning to put them below clearance levels.

The decommissioning activities associated with the lightly-contaminated or uncontaminated parts of the East Wing are:

a. Obtain authorization from the NRLSD to decontaminate these areas.

b. Decontaminate the areas.

c. Seal the areas to prevent cross-contamination.

3.5.6 Contaminated structures

It is believed that only the reactor structures that were directly irradiated with neutrons have bulk contamination above clearance level. Those structures are the reactor core box, the thermal column, the beam ports, and the bioshield (the reactor pool).

3.5.6.1 Reactor core box

The reactor core box is the structure containing the core grid and the core's coolant flow channels. The core box is suspended from the reactor's bridge and suspension frame (see Chapter 1). Only the core box is radioactive, and not very much so. The remaining radioactivity is mainly from a few small stainless-steel bolts that hold the core box together; the core box itself is made from high-purity aluminum that has low residual radioactivity.

Most of the contents of the core box, including the fuel, the graphite reflector elements, and the irradiation rigs were removed in the 1990s. Only the control elements, their shrouds, and the instrumentation neutron detectors remain in the core box.

The decommissioning activities associated with the core box are:

a. Design and build a custom waste container that will be large enough to hold the core box. It is believed that the radioactivity of the core box is large enough that very little shielding (or none) will be necessary to bring the radiation level at the exterior of the container within the authorized acceptance limit of the RWMF. It is also believed that the weight of the filled container will be low enough to be lifted by the building crane and transported with the reactor's forklift (less than 2 tons).

b. Remove the remaining contents of the core box and temporarily set aside.

c. Place the empty waste container inside the pool. Cut the four support tubes of the core box at a point where all the material above clearance level will go with the core box. Lower the core box to the pool floor. Move the bridge and suspension frame away from the core box. Place the core box inside the waste container. Place the removed contents of the core box inside the waste container.

   The radiation level of the core box is low enough that all of this work can be manually done without remotely-operated equipment.

d. Move the waste container into the RWMF, using the reactor's forklift.

e. Dismantle and remove the bridge and the suspension frame. With all of the contamination gone with the core box, this will be an ordinary demolition job not needing radiation protection.

The core box, bridge and suspension frame must be removed before work proceeds to the dismantling of the reactor pool (described in one of the next sections).

3.5.6.2 Thermal column

The thermal column is a graphite-filled irradiation facility that fills a penetration in the bioshield (see Chapter 1). The structure is made of a thick aluminum casing embedded in the pool concrete that is completely filled with tightly-packed blocks of graphite. The thermal column casing facing the reactor core has a lead layer incorporated within it. The thermal column has a wheeled shield door at the rear made of concrete with a face layer of boral.

The decommissioning activities associated with the thermal column are:

a. Design and fabricate custom waste boxes for the graphite. Most of the blocks are too long to fit into standard 200-liter waste drums, but all will fit in a few custom rectangular boxes about 2.5 meters long.

b. Place the graphite blocks into the waste boxes.

c. Move the boxes to the RWMF.

The remaining thermal column casing and door will be dismantled together with the reactor pool.

3.5.6.3 Beam ports

The beam ports are horizontal penetrations of the bioshield made of 6-inch and 8-inch aluminum pipes embedded in the concrete. There is neutron-activated contamination of the pipes and probably some of the concrete beyond the pipe walls. The beam ports have detachable shutters and plugs at both ends, that also have some neutron activation.

The smaller shutters and plugs will be placed in standard 200-liter waste drums. The air space in the drums can be packed with contaminated concrete rubble later to help reduce waste volume.

The larger concrete outer plugs that are too large to fit in 200-liter drums will be set aside and broken up later at the same time as the bioshield.

The aluminum pipes making up the rest of the beam ports will be demolished together with the reactor pool.

3.5.6.4 Reactor pool

The dismantling of the reactor pool is the most complex and expensive part of PRR-1 decommissioning and will generate most of the waste.

Neutron irradiation of the bioshield occurred around the two places where the reactor core was operated: at location code RP-1 (high power) and at location code RP-3 (low power.) It is expected that contamination will exceed clearance level only within a meter from the concrete's inner face (probably much less, the actual depth to be measured during the hazards characterization survey), and some smaller distance into the concrete from the casings of the thermal column and beam tubes. However, removal of this much concrete from the bottom part of the bioshield will destabilize the upper parts. All of the pool should therefore be removed, but most of the waste will be non-radioactive and will not need to be placed in the RWMF.

In particular, it is believed that the second to fourth stages of the reactor pool (see Chapter 1) are not contaminated. Only the first (and lowermost) stage, which is at the vertical level of the core itself, is believed to contain radioactivity above clearance level.

The decommissioning activities associated with the reactor pool are:

a. Obtain authorization from the NRLSD to dismantle the reactor pool. The application for authorization will be supported with procedures and a safety analysis of the work.

b. Disconnect all electrical power, instrumentation, and water connections to the pool.

c. Install scaffolding for personnel access inside and around the pool. The pool is already dewatered.

   There is no significant radiation exposure except at the first pool stage inside the pool, and even there the radiation level is not high. Access to the first pool stage should be blocked off until dismantling work is to be done there.

d. Dismantle the walkway platform around the top of the pool. This structure is primarily made of steel, and could be broken up with cutting wheels or torches. Precautions should be taken against starting a fire.

   Special care should be taken to support the heavy steel pieces while the platform is being cut up.

e. Dismantle the pool starting from the top (fourth stage) down to and including the second stage. Parts of the first stage that are below clearance level (as proved by the hazards characterization survey) may be removed if there is no danger of cutting through contaminated material.

   The dismantling technique could be one or a combination of the following, based on a study of the cost, waste handling, and personnel safety:

   1. Using diamond-wire equipment, cut the concrete into rectangular blocks that could be safely lifted by the building crane (1 to 2 tons per block), or
   2. Break the concrete into manageable pieces using expanding grout, or
   3. Break the concrete into manageable pieces using manually-operated demolition equipment, or

4. Use the same Brokk machine that will be used later on the contaminated part of the pool.

Dismantling will also deal with embedded piping (up to 8-inch size). The aluminum pool liner may be fully stripped before the concrete is broken up, or could be cut up and removed with the concrete.

f. Move the waste into a part of the PNRI compound that has been designated as the landfill area for non-radioactive waste.

Pool dismantling up to this point will not involve contaminated material, and could be done without any significant radiation protection measures. The next activities will deal with contaminated material.

g. Clear and clean a work area around the pool, and apply a durable coating to the floor. Seal any floor drains. This will prevent liquids used during dismantling from diffusing contamination below the floor.

h. Completely enclose what remains of the first stage of the pool and the cleared work area around it with a custom-designed and built dust-proof tent.

The tent should have an internal air circulation system that will remove suspended dust and air conditioning (cooling), to make conditions inside the tent bearable when humans have to work inside it. There should also be a filtered air exhaust system (separate from the internal circulation system) will maintain a slight negative pressure inside the tent.

Electrical power and lighting should be provided inside the tent.

The tent should be wide enough to enclose the area above the underfloor runs of the primary coolant piping going to the equipment rooms under the East Wing.

The tent opening serving as the entrance and exit should face the door to the Truck Entrance Ramp (location code RB-3).

i. Prepare the tunnel portion of the Truck Entrance Ramp as the waste staging area. Apply a durable coating similar to the one applied around the pool to the floor and walls of the area. The staging area will be used for any repackaging, assay, and temporary storage of filled waste packages before their transport to the RWMF. Empty waste containers will also be prepared and temporarily stored in the staging area before being filled inside the tent.

j. Dismantle the remaining first stage of the pool. A Brokk remotely-controlled demolition machine will be used to break concrete and cut metal into pieces that will fit inside waste containers. The Brokk machine will also be used to load the waste containers.

An enclosed and air-conditioned control room for the Brokk operator will be set up outside the tent.

The beam port outer plugs will be broken with the Brokk machine and mixed with the other radioactive concrete debris.

Dismantling will include excavation of the pool floor until the concrete meets clearance levels.

k. Break and segregate from the concrete the aluminum pool liner, embedded primary coolant piping, the thermal column casing and door, and the beam ports with the Brokk machine as they are encountered while dismantling the pool concrete.

Exception: Cut out the lead shield at the front face of the thermal column casing as a single piece. Place the lead shield in a custom waste container before transport to the RWMF.

l. Excavate and remove the underfloor primary coolant piping.

m. After the dismantling of the reactor pool is completed, clean and decontaminate the Brokk machine

n. Clean and decontaminate the tent and its interior. Disassemble and remove the tent.

o. Remove a few centimeters of the floor of the work area (including the coating applied earlier) with a scabbler machine to assure the removal of all contamination.

3.5.7 Contaminated reactor systems and equipment

3.5.7.1 Water purification system

The PRR-1 had two original water purification systems: a) the make-up system, which purified water from the city supply for introduction into the pool, and b) a clean-up system, which maintained the purity of the pool water (which is also the reactor core's primary coolant). The make-up system never handled irradiated water and is not contaminated. The clean-up system is contaminated with neutron-activated material, and possibly by fission products from any leaking fuel cladding.

When the fuel elements were moved to a separate storage tank constructed beside the pool, the tank was provided with a third water purification system. This purification system has potential for contamination, although small: it did not exist when the reactor was operational and would have collected only whatever activated material escaped the original clean-up system or fission products from failed cladding of spent fuel (otherwise undetected).

It is expected that the contamination of the water purification systems will nearly all be in the ion-exchange resin, with some possibly in internal deposits of the systems' piping and valves. The hazards characterization survey will reveal the actual amount and distribution of the contamination.

The decommissioning activities associated with the water purification systems are:

a. Cut and seal all piping connections to the vessel housing the ion-exchange column of the clean-up system (in location code E0-8). With the ion-exchange resin still inside, move the entire column to the RWMF. Do the same with the water purification system of the fuel storage tank (in location code RB-4).

   The removal of the ion-exchange resin from their vessels, the repackaging of the resin in waste storage containers, and the decontamination of the vessels are better done in the future at a prepared set-up at the RWMF than on-site.

b. Cut the systems' piping that have deposits above clearance level into short lengths. Put the cut pipe and valves into waste containers and move the drums to the RWMF.

c. Decontaminate the storage tanks of the clean-up system (in location codes E0-4 and E0-5).

d. Decontaminate the pumps of the clean-up system (in location codes E0-3b and E0-4b).

3.5.7.2 Reactor cooling system

The reactor cooling system had two water loops separated by a heat exchanger. The primary loop used pool water to cool the reactor and carried the heated water through the heat exchanger. The heat exchanger transferred the heat to the secondary loop, which carried to heat to an evaporative cooling tower outside the building. Unless the heat exchanger had a leak, only the primary loop components could be contaminated.

Nearly all of the reactor cooling system was dismantled and removed in the 1980s during the reactor's TRIGA conversion, and the replacement was never used significantly. The only remaining original components are the N-16 delay tank and the piping embedded in the reactor pool and under the floor of the reactor bay. It is believed that the hazards characterization survey will confirm that the cooling system is not contaminated, except possibly for the N-16 delay tank and the embedded piping.

The embedded piping will be dismantled and removed together with the reactor pool.

The N-16 delay tank will be decontaminated, if necessary. If contamination exists, it will be as deposits in the wetted interior of the tank. The interior of the tank is accessible by opening a flanged manhole, and the interior is large enough to work within.

3.5.7.3 Storage tanks

The PRR-1 has three steel storage tanks, two in the original design and a tank built after shutdown for the temporary wet storage of fuel.

One of the original tanks (the Drain Storage Tank) was dismantled and replaced in the 1990s during the reactor shutdown; the replacement was never used for reactor operations and could not be contaminated.

The Retention Tank (location code E0-3a) is full of demineralized water originally from the reactor pool. The water has been sampled and analyzed in the past and is not believed to be contaminated above clearance level.

The Fuel Storage Tank (location code RB-4) contains demineralized water, the slightly-irradiated TRIGA fuel elements, the reactor's neutron sources, a few small neutron-activated metal parts removed from the core box, and a cask containing sealed Co-60 pencils. The removal of the fuel elements, the neutron sources, the small neutron-activated parts, and the Co060 cask are dealt with in other sections.

The following activities are associated with the last two storage tanks:

a. If the hazards characterization survey reports contamination of the water in the Fuel Storage Tank above clearance level, run the tank's water purification system until the contamination drops below the clearance level.

b. Do the same for the Retention Tank, moving the portable water purification system from the Fuel Storage Tank to the Retention Tank if necessary.

c. Obtain authorization to do so, and then discharge the water in the tanks into the storm drain outside the reactor building.

d. Verify that the tanks do not have residual surface contamination that exceeds the clearance level. Decontaminate the tanks if found otherwise. The tanks are very large and could be easily entered for internal work.

3.5.7.4 Sump pit and floor drains

All the floor drains in the reactor discharge into the concrete sump pit (location code E0-7). If there is contamination that exceeds clearance level in the sump pit and in the floor drains, the following activities will be performed:

a. Excavate and remove the floor drains and the piping into the sump pit.

b. Excavate and remove the concrete from the sump pit until the remaining concrete is below clearance level.

The Brokk machine used to demolish the reactor pool can be used.

3.5.7.5 Process equipment room and tank rooms

The components described above are all housed in the process equipment room and tank rooms (location codes E0-1 to E0-6)in the basement of the reactor building. The hazards characterization survey will identify contamination on the floors, walls and ceiling of the rooms that may have been produced by spills. A concrete scabbler will be used to remove a few centimeters of concrete from the contaminated room surfaces.

3.5.7.6 Reactor building ventilation system

Nearly all of the reactor building ventilation system was dismantled, redesigned and replaced during the 1990s while the reactor was still under repair. The only remaining original ventilation components are some of the ducts and a small blower that were re-integrated into the new ventilation system. The new ventilation system was never used and the new components could not be contaminated.

If the hazards characterization survey shows that there is contamination above clearance level in the old ducts, the material will be decontaminated if it is practical to do so. If decontamination is not practical, the contaminated ducts will be cut into into short sections and folded flat, packed in waste containers and taken to the RWMF.

b. Disassemble and decontaminate the old blower.

3.5.7.7 Reactor bay

The reactor bay is the basement area around the reactor pool.

Contamination is possible on the concrete floor and walls of the reactor bay from the use of the beam ports, which open into that area. If contamination is found, a scabbler will be used to remove sufficient concrete from the floor and walls to meet clearance level requirements.

The neutron spectrometers that were installed in the reactor bay were removed in the 1990s, but some shielding and metal parts remain. These will be packed into waste containers and moved to the RWMF.

Contamination is also possible on the niches on the walls of the reactor bay which were used during reactor operation to store the beam port plugs and irradiated material. The Brokk machine that will be used to demolish the reactor pool could be used to break off the contaminated concrete. Caution should be taken not to damage load-bearing elements of the wall.

The reactor bay also has floor drains, but their treatment is described in the section dealing with the sump pit.

3.5.7.8 SNIF

The Seed Neutron Irradiation Facility (SNIF) is a rig that was built to enhance fast-neutron flux and reduce gamma and thermal-neutron flux for the irradiation of a small amount of target material, usually plant seeds. The SNIF is basically a barrel made of depleted uranium with a metal cladding, with an inner cavity to hold the seeds. The SNIF has a funnel-like structure on top to guide the underwater insertion of a sample into the cavity. The SNIF was floor-mounted on a pedestal outside the core box.

The SNIF was removed when the reactor pool was dewatered, and is now in the reactor bay (location code RB-12).

The following activity is associated with the SNIF:

a. Remove the SNIF's funnel and pedestal. If these parts do not have contamination above the clearance level, dispose of them as metal scrap. Otherwise, cut them up and package with the rest of the SNIF.

b. Design and build a custom waste container for the main body of the SNIF. Place the SNIF main body in the custom container and move to the RWMF.

3.5.8 Reactor grounds

3.5.8.1 Soil

It is not expected that there will be much soil contamination in the PRR-1, possibly none above clearance level. If any is found by the hazards characterization survey, it would likely be on the surface, or around the septic tanks of the toilets ,or around the underground waste water discharge pipe of the reactor sump, or beneath the sump pit under the reactor building basement floor.

The following activities will be undertaken if the hazards characterization survey finds soil contamination above clearance level:

a. For soil accessible by simple excavation from the surface, remove the contaminated soil and place in standard-200-liter waste drums. Take the drums to the RWMF. It is assumed that there will not be enough contaminated soil for their total volume to be a problem.

b. For soil under the basement floor, use the Brokk machine to remove the overlying concrete and remove as much of the soil as necessary. It is assumed that contamination will be confined to the small area under the sump pit and that destabilization of the reactor building foundation will not be a problem.

3.5.8.2 Surface and groundwater

It is believed that there is no water contamination above clearance level around the PRR-1. The environmental radioactivity in and around the PNRI compound has been measured many times. The PRR-1 hazards characterization survey will provide confirmation.

3.5.8.3 Auxiliary external structures

It is believed that none of the auxiliary structures in the grounds outside the reactor building (see Chapter 1) is contaminated. The PRR-1 hazards characterization survey will provide confirmation.

3.5.9 Decommissioning schedule

The decommissioning activities should be performed in a prescribed order to ensure that resources are available, dependencies are met and the possibility of re-contamination of cleaned areas and items is minimized.

The following should be the general order of activities:

a. Start working immediately on building the additional storage facilities in the RWMF (waste enclosures and the fuel storage vault). Building physical infrastructure like these has a long lead time.

b. Release the West Wing as soon as possible, ahead of the work in the rest of the reactor. This will immediately reduce the size of the workplace and make available the West Wing to other use.

c. Remove uncontaminated items from the reactor building as soon as a place to transfer them is available. It is desired that clutter be removed from the workplace as soon as possible, but much of the material has some scrap value which will be lost if they are just dumped out of the building into the weather. A cleared West Wing may be able to serve as storage for uncontaminated materials.

d. Remove the C0-60 sources and all the other movable radiation sources from inside the reactor building. There is space for these in the RWMF without waiting for additional storage enclosures.

e. Move the fuel to the new storage vault in the RWMF. This will have to wait until the vault is ready, but some of the next items can be done with the fuel still inside the building, provided only PNRI personnel do the work. For security reasons, the reactor building should not be opened to contractors while nuclear fuel is still inside it.
f. Decontaminate the East Wing.
g. Decontaminate the process equipment room and tank rooms.
h. Remove the fuel storage tank.
i. Package and remove the core box.
j. Remove the bridge and suspension frame.
k. Remove the walkway platform around the top of the pool.
l. Remove the upper stages of the reactor pool (not contaminated).
m. Remove the first stage of the reactor pool (contaminated).
n. Decontaminate the reactor bay and truck entrance ramp.
o. Decontaminate the grounds (if necessary).

3.6 SURVEILLANCE AND MAINTENANCE

With a deferred dismantling strategy, surveillance and maintenance of the facility is necessary during the extended period between shutdown and dismantling to prevent unsafe deterioration of the facility and to ensure that equipment that will be needed during dismantling is preserved.

Many of the activities that would have been done during the transition phase of the deferred dismantling strategy were actually performed in the context of reactor repair from 1988 to 2005:

a. The reactor pool and coolant systems were drained, and most movable radiation sources were removed from them.
b. All spent fuel were shipped out of the facility in 1999, although some slightly irradiated fuel remained.
c. Auxiliary reactor systems were kept in working condition, coincidentally including components such as the building crane that will be needed during dismantling.
d. Many of the reactor's operational staff remained in the facility.
e. Essential reactor records were preserved.
f. Monitoring of the facility for the purpose of radiation protection continued.

3.6.1 Equipment and systems requiring surveillance and maintenance

The following equipment and systems in the reactor building will need to be in good working condition during dismantling and decontamination, and should be checked and maintained until that work begins:

a. The polar crane;
b. The electric forklift and its charger;
c. The electrical power system (including the diesel emergency genset);
d. The lighting system;
e. The water supply system;
f. The storm drainage system (to prevent rainwater from flooding the reactor bay);
g. Old records and drawings;

h. Field and laboratory electronic instruments, obtained for hazards characterization but will be re-used during dismantling and decontamination.

3.6.2 Schedule for surveillance and maintenance

Surveillance and maintenance will have to be continued until funding is obtained to do the dismantling and decontamination work. The wait time is likely to be at least two years.

3.7 WASTE MANAGEMENT

This section identifies and describes the radioactive waste that the PRR-1 decommissioning will produce, and how that waste will be managed.

All the radioactive waste will remain the PNRI's responsibility and will be stored in the RWMF pending the creation of a national repository for low-level waste.

3.7.1 Identification of waste streams

Only a small part (by volume and by weight) of the waste that will be generated by PRR-1 decommissioning will contain radioactivity above clearance level. It is believed that all of the non-radioactive waste will also be non-hazardous in a non-radiological sense, and could be disposed of by recycling as scrap, or by landfill inside the PNRI compound.

The non-radioactive waste will be mainly broken concrete, structural steel, and aluminum. There will also be some surplus equipment from the reactor's mechanical systems.

3.7.2 Solid radioactive waste

The solid radioactive waste will be mainly:

a. The reactor core box (aluminum with some stainless steel), to be stored as-is in a custom container.

b. The SNIF (aluminum and depleted uranium), partially disassembled and stored in a custom container.

c. The lead shield of the thermal column (with an aluminum cladding), in a custom container.

d. The sealed clean-up demineralizer vessel (aluminum with a rubber internal lining), with the ion-exchange resin still inside. The resin will be removed, dried and repackaged in the RWMF at some future time.

e. Standard 200-liter drums containing the following:

   1. Broken-up neutron-activated concrete from the first stage of the reactor pool; mixed in with the concrete during demolition are fragments of iron rebars and aluminum from embedded piping, the thermal column casing, the beam ports and the pool liner.
   2. The shutters and plugs (steel, aluminum and concrete) of the beam ports, packed with radioactive waste concrete.
   3. Various neutron-activated irradiation rigs and other small metal parts (aluminum and stainless-steel) from inside the core box, also packed with radioactive waste concrete.
   4. Contaminated piping (aluminum and steel), cut into short segments and packed with radioactive waste concrete.
   5. Contaminated protective clothing and discarded tools, also packed with radioactive waste concrete.
   6. Contaminated soil, if not excessive in amount.

f. The reactor's Pu-Be neutron source, packed with paraffin in a modified 200-liter waste drum. The reactor's other neutron sources are no longer significant neutron emitters and will be packaged with the other loose metal parts from the reactor core.

3.7.3 Liquid radioactive waste

PRR-1 decommissioning will generate very little liquid radioactive waste. The liquid radioactive waste will be:

a. Water that will be sprayed for dust control during demolition of the reactor pool. Most of the liquid will evaporate away, although some will be retained by the concrete packed in the waste containers.

b. Sludge produced by water-cooled diamond core drilling of neutron-activated concrete. The sludge will be collected and the water will be allowed to evaporate, leaving only solid waste.

c. Water condensed from the atmosphere when the air conditioning inside the tent enclosing the first stage of the reactor pool is turned on. The water will be collected and allowed to evaporate and the solid contaminants left behind will be considered solid waste.

c. Liquids, mainly water, that will be used during manual decontamination. Free liquid will be collected and allowed to evaporate.

d. Scintillant from the operation of liquid scintillation counters in the laboratories doing waste assay. This used scintillant will be collected and treated by the RWMF in the same way that scintillant from the PNRI's research laboratories is handled.

3.7.4 Waste containing both radionuclides and other hazardous material

The PRR-1 does not contain non-radioactive hazardous material except for lead in radiation shields and possibly a small amount in paint. The only lead mixed with radionuclides is in the shield of the thermal column, and that will be packaged and stored in one piece in its original cladding (see the section on solid radioactive waste).

3.8 COST ESTIMATE AND FUNDING MANAGEMENT

3.8.1 Cost estimate

Based on the known experience in other countries, the expected cost of decommissioning a facility like the PRR-1 is around 100 million pesos (about US$ 2 million), with a large variability. A much better estimate will be made as the decommissioning plan is refined.

3.8.2 Funding mechanisms

The major source of funding will probably be the Philippine government; the PNRI itself is a government agency. There are several government funding mechanisms that are possible: an increase in the PNRI's annual budget, a special trust fund, grants-in-aid from the Department of Science and Technology (of which the PNRI is a unit) and other government agencies.

Some non-monetary assistance could probably be obtained from foreign organizations that are already providing assistance to the PNRI, such as the International Atomic Energy Agency (IAEA) and the U.S. Department of Energy (USDOE). This assistance is likely to be small and highly specific, and will support but not sustain the project.

3.9 SAFETY ASSESSMENT

The detailed safety assessment of PRR-1 decommissioning will be developed as the details of the activities are being worked out. This section contains mostly general information at this time.

3.9.1 Identification of relevant safety criteria

The following regulations and safety standards will apply:

a. PNRI CPR Part 3, *Standards for Protection Against Radiation*. 6 September 2004.

b. IAEA Safety Series No. 115, *International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources*. February 1996. STI/PUB/996.

If there are any differences in the criteria imposed by these documents, the more restrictive criteria will be used.

The PRR-1 has adopted administrative limits on radiation exposure dose that are generally 1/10 of the regulatory limits specified by the above documents. The administrative limits will be used as the safety design basis for the work procedures that will be developed for PRR-decommissioning.

3.9.2 Operational limits and conditions

The original operational limits and conditions of the PRR-1, as expressed in its safety analyses (for the original 1960s configuration and for the 1980s TRIGA conversion), referred only to the operation of the reactor core and have no relevance to the work that will be done on PRR-1 decommissioning.

The PRR-1 defined operational limits and conditions in its application to be formally authorized to continue in its shutdown state. The authorization was issued in 2007. The limits and conditions were intended to prohibit movement of the nuclear fuel out of its storage racks except for inspection, preserve the quality of the wet storage of the fuel, and prevent any radioactive material from being removed from the reactor building. These limits and conditions obviously cannot be used during decommissioning.

Operational limits and conditions will have to be defined and attached to the applications for authorization to perform decommissioning work, specially those for moving the nuclear fuel and large radiation sources out of the building, and for performing dismantling and decontamination work. The operational limits and conditions will be defined in the course of preparing the procedures for the decommissioning activities.

3.9.3 Hazard analysis of normal decommissioning activities

The hazard analysis of normal decommissioning activities is actually part of the process of the development of work procedures. Development is iterative; hazards analysis provides some of the feedback that leads to the modification of tentative procedures, until both practical and safety goals are met. The hazard analyses that went into the end products of the procedure development process will be placed in this section.

3.9.4 Hazard analysis of abnormal events and incidents

The identification of scenarios of abnormal events and incidents is also part of the process of work procedure development. Those scenarios will also undergo hazard analyses which will provide feedback to procedure development. The final hazard analyses of the abnormal scenarios will be placed in this section.

3.9.5 Assessment of potential consequences

The potential consequences of PRR-1 decommissioning will be predicted and placed in this section. As a minimum the following will be presented, calculated for both the normal decommissioning activities and the abnormal events:

a. The predicted radiation exposure doses to the workers and to the public,.

b. The predicted radioactivity released to the environment.

This section will also contain an explanation of the methodology used to perform the calculations.

3.9.6 Preventive and mitigating measures

The processes of creating the hazard analyses and the assessment of potential consequences would have revealed what radiological hazards and potential consequences were most significant and what measures were taken to reduce the hazards and mitigate the consequences. This section will present those measures, and also the parts of the quality assurance program that will ensure that those measures are properly taken.

3.9.7 Risk assessment

This section will present estimates of the probabilities that the events producing the potential consequences described above will actually occur. It should be demonstrated that the probabilities combined with the corresponding consequences together define risks that are acceptable.

The decommissioning plan is not acceptable unless the risks are acceptable.

3.9.8 Comparison of analysis results with relevant safety criteria

This section will compare the results of the hazard analysis and the assessment of consequences with the identified safety criteria, and prove that the safety criteria are met.

The decommissioning plan is not acceptable unless the safety criteria are met.

3.9.9 Conclusions

This section will summarize the safety assessment and state that the decommissioning plan is acceptable from the point of view of safety.

3.10 ENVIRONMENTAL ASSESSMENT

3.10.1 Background data

The objective of PRR-1 decommissioning is to release the reactor from nuclear regulation. The PRR-1 will be decommissioned by removing all radioactive material from the reactor building and grounds down to clearance levels set by regulations. It is believed that PRR-1 decommissioning will have negligible environmental impact.

3.10.2 Description of project

The reactor pool will be demolished, but the reactor building will be left intact. All radioactive sources and contamination will be removed from the reactor building and grounds. The reactor building and grounds will be suitable for unrestricted use after decommissioning.

Decommissioning will produce a few hundred cubic meters of low-level radioactive waste. None of these will leave the PNRI compound; all radioactive waste will be properly packaged and placed in the PNRI's Radioactive Waste Management Facility.

A few hundred cubic meters of non-radioactive and non-hazardous concrete rubble will also be produced. This material will probably be used as landfill, possibly to level some low spots in the PNRI grounds.

Decommissioning will produce a few tons of non-radioactive scrap material, mostly recyclable metal. This material will be recycled commercially.

Decommissioning will have no significant solid effluent; some dust will be produced by concrete demolition, but all of those will be confined within the reactor building. There will be no liquid effluent except for about 120 cubic meters of demineralized water. There will be no gaseous effluent except possibly for diesel engine exhaust if the reactor's 500 kW emergency genset is run during an interruption of electrical power supply.

3.10.3 Environmental protection program

Environmental monitoring in and around the PNRI compound is done by the PNRI as a regular program. This monitoring is primarily for protection against the radioactive material used by the research laboratories and facilities inside the compound, but will be extended to detect any radioactivity released by PRR-1 decommissioning.

3.10.4 Effluent monitoring program

A full effluent monitoring program is not needed because there will be effluent only when some stored demineralized water is released, which will probably be only in one or two occasions. The water will be tested for radioactivity before release.

3.10.5 Effluent control program

A full effluent control program is not needed because decommissioning will not produce any effluent except for the demineralized water mentioned above.

3.11 HEALTH AND SAFETY

This section is to be developed.

3.11.1 Radiation protection plan

3.11.2 Nuclear criticality safety

3.11.3 Industrial health and safety plan

3.11.4 Audits and inspections

3.11.5 Record keeping program

3.11.6 Optimization analyses and program

3.11.7 Dose estimation and optimization for major tasks

3.11.8 Clearance criteria

3.11.9 Final release criteria

3.12 QUALITY ASSURANCE

This section is to be developed.

3.12.1 Organization

3.12.2 Quality assurance program

3.12.3 Document control

3.12.4 Control of measuring and test equipment

3.12.5 Corrective actions

3.12.6 Quality assurance records

3.12.7 Audits and surveillance

3.12.8 Lessons learned program

3.13 EMERGENCY PLANNING

This section is to be developed.

3.13.1 Organization and responsibilities

3.13.2 Emergency situations

3.13.3 Records

3.13.4 Physical Security and Safeguards

3.13.5 Organization and responsibilities

3.13.6 Physical security program and measures

3.13.7 Safeguards program and measures