MANAGEMENT AND UP KEEP OF AECL'S PROTOTYPE REACTORS BEING HELD FOR DEFERRED DECOMMISSIONING

S. Kenny and R. Parsonage
Atomic Energy of Canada Limited, Chalk River Laboratories
Chalk River, Ontario, Canada

AECL is responsible for three prototype power reactor sites located at Douglas Point on the Bruce Nuclear site, Ontario; Gentilly-1 (G-1) near Bécancour, Québec located on the Gentilly-2 Hydro Quebec site and Nuclear Power Demonstrator (NPD) located at Rolphton, Ontario. Each site has its own unique challenges in maintaining it in a static state. All three sites operate under separate Waste Management Facility Licenses approved by the Atomic Energy Board of Canada (now the Canadian Nuclear Safety Commission).

Decommissioning of a Nuclear Power Reactor Generating Station in Canada is carried out in various stages due to the safety and economic considerations associated with it. An immediate dismantling of plant and equipment following shutdown has not been desirable from the point of view of keeping worker radiation exposure as low as reasonably achievable (ALARA) and is scheduled taking this into consideration. The objectives of safe shutdown activities is to shutdown the reactors, systems and components along with the support buildings and place them in a safe and static state where only systems required for continued monitoring and surveillance activities over a predetermined period would remain operational. NPD, Douglas Point and G-1 sites were safely shutdown following this strategy. Maintaining the safe shutdown state of the active and non active facilities of each site varies as the only common approach used to bring each site to safe shutdown state was the removal of the secondary systems and equipment. From the time a facility is safely shutdown through to decommissioning and remediation of the site, maintenance and monitoring of the site must continue. Configuration management of the site must be maintained for estimating and maintenance purposes. Appropriate budget planning for upgrades, modifications and capital replacements even though the facility is shut down must be completed. Management and upkeep of AECL's prototype reactors being held for decommissioning presents various challenges. Knowledge transfer, aging facilities that have spent their projected life cycle and records management are underestimated tasks. Maintenance of the facilities, equipment, systems and site must be kept at an appropriate level to meet regulations and keep the facilities in a safe state until decommissioning is completed.

This paper details the ongoing activities required to identify and mitigate risks associated with extended periods of storage with surveillance (SWS). It will also outline how the ongoing long-term program for the sites is being developed to allow key decision points to be made on maintaining the period of SWS and the potential strategies reflecting on the transition into decommissioning, while being cognizant of international decommissioning initiatives.

1. INTRODUCTION

AECL owns three prototype power reactor sites located between Ontario and Quebec. Douglas Point (DP) is located in Bruce County in southern Ontario at the Bruce Power site. It went into operation in 1968 and shutdown in 1984. Gentilly-1 (G-1) was built near Bécancour, Québec and is located on the Gentilly-2 site operated by Hydro Quebec. The reactor went into operation in 1972 and was shut down in 1979. The Nuclear Power Demonstration (NPD) located at

Rolphton west of Chalk River was in operation from 1962 until shutdown in 1987. All three sites operate under separate Waste Management Facility Licenses approved by the Atomic Energy Board of Canada (Canadian Nuclear Safety Commission).

Decommissioning of a Nuclear Power Reactor Generating Station in Canada is carried out in stages due to the safety and economic considerations associated with it. Complete dismantling and management of wastes is currently planned to take place beginning over the next twenty to seventy years. In the case of G-1 and Douglas Point, the decommissioning of these facilities is currently planned to be completed in conjunction with the Hydro Quebec and Bruce Power site decommissioning. During this period, radioactive sources will decay significantly and the exposure to workers against radioactive hazards is greatly reduced. Dismantling, transportation and long term management of wastes can therefore be achieved in the safest and most cost effective manner.

AECL has taken the approach to prepare and retire the NPD, G-1 and DP facilities for an interim storage period called "Static State", rather than return it to "green field" condition immediately following shutdown. The Static State is a variant of long term "Storage with Surveillance" option defined as Stage I decommissioning as outlined by the International Atomic Energy Agency in Technical Report [1]. Safe Shutdown and Static state objectives

The safe shutdown and static state objectives follow general concepts and principles established for all three sites. The safe shutdown and static state activities were combined since a decision had already been made to remove the three reactors from operating to safe shutdown status. The safe shutdown plans for the three sites were driven by the static state objectives to safely shutdown the reactor and support systems and put the reactors, systems and components along with the support buildings in a static state where only systems required for continued monitoring and surveillance activities over the next twenty or more years would remain operational. The objective was achieved through the development of a static state plan that included; placing the facility into a safe shutdown, static state, protection of the environment and the public, and protection of the workers. More details on the safe shutdown of Douglas Point, Nuclear Power Demonstration and Gentilly-1 are discussed in section 2.4, 2.5 and 2.6 respectively.

2. PLACING A FACILITY INTO STATIC STATE

The Static State objective is to reduce the hazards associated with the site while safely maintaining the facilities until decommissioning is completed. Static state is achieved through the removal or containment of conventional and radiological hazards i.e. contamination clean-up that results to re-zoning of an area. Modifications may be required to reduce the number of services required to maintain the facility during surveillance activities. Modifications may also be required to control access, manage contamination zones, guard hazards and reconfigure the facility from its operational design into a surveillance phase. Modifications at the three sites included physical modifications or reconfiguration of the building heating, ventilation, air-conditioning, electrical and monitoring systems (fire, environmental and security systems) along with modifications to the core building structure to address revised entry and exit points, contamination zones and hazards that remain in the facility. This objective was completed to leave the site in a state where it could be maintained safely, at a minimum cost through a combination of monitoring and site inspections and meet regulatory requirements.

2.1 Protection of the Environment and the Public

The objective to protect the environment and the public is achieved by ensuing radioactive materials are contained within designated areas so that no uncontrolled activity release to the environment and the public takes place. AECL's approach involved a number of activities to achieve this objective. One of the steps taken included the development of a plan to maintain the integrity of the building shell and physical containment boundaries for radioactive materials during the static state period by way of inspection and maintenance programs. Another step included monitoring ground water ingress and removing accumulated water from sumps so that the internal structures are protected, and the uncontrolled spread of radioactive contamination inside and towards the outside environment is prevented. Water analysis is performed prior to pumping it out to ensure compliance with derived release limits set for each site. Another activity includes monitoring airborne radioactive contamination to ensure that any releases remain within specified limits during ventilation of the areas containing radiological hazards. Minimizing combustible materials and keeping fire detection and suppression systems functional so that probability of damage by fire to the containment structure is reduced is another essential component of the protection of the environment and public objective. One other element of this objective is that physical security measures were put in place along with access control to the areas containing radiological hazards to prevent entry of unauthorized persons.

2.2 Protection of Workers

To ensure that dose exposure to radiation workers during the surveillance in the static state period are as low as reasonably achievable (ALARA principle), and to provide safe working conditions, three main objectives were established. Objective one was to achieve stability of the remaining radiological inventory through implementation of a decontamination program and containment of the radioactive material within designated radiological zoning. Objective two involved the development or revision of health physics and industrial safety programs for personnel entering the facility. This was achieved through the extension of dosimetry and bioassay services, radiation protection and industrial safety protection programs, equipment and procedures centered at Chalk River Laboratories. The third objective was to maintain and modify building systems, structures and components required to maintain the building in a static state such as ventilation, lighting, fire detection/protection, security and structures to ensure adequate protection for workers during site visits and ensure site license conditions are met.

2.3 Douglas Point

Douglas Point is a 200 megawatt CANDU type reactor complete with generic support facilities located on a licensed site. Safe shutdown activities included a number of activities to prepare the site for long term storage and meet the static state objectives.

Following the shutdown of the facility in 1984, the primary heat transport and moderator medium was drained and shipped off site for re-use. Booster rods were removed and shipped to Chalk River. Non-radioactive hazardous materials e.g., asbestos, mercury flammables, etc. were catalogued and removed from the facility. Used fuel was transferred from wet to dry storage and the fuel bays emptied and dried. Decontamination of the facility was completed as required to meet the shutdown objectives. Radioactive material was consolidated on site, packaged and stored in the reactor building. The majority of systems and services remain in place as constructed and were only modified to meet static-state requirements.

Removal of all process systems, decontamination and final survey of the service buildings including the Administration, Turbine, Plate and Machine Shop buildings was completed. These buildings were then leased to Ontario Hydro for use and continue to be managed under a lease agreement. These buildings are included under the Douglas Point Waste Management License; therefore AECL provides oversight on the use, care and maintenance of the facilities to ensure compliance with the license. These areas are maintained as rentable space.

The remaining portions of the site, including the reactor and purification building and portions of the administration building, were not part of the lease agreement and are maintained, operated and occupied by AECL staff. The entire Douglas Point site is monitored by AECL staff including the leased areas.

2.4 Nuclear Power Demonstration

The NPD reactor was constructed to demonstrate the feasibility and cost effectiveness of the CANDU concept and to provide a test facility for the improvement and durability testing of CANDU technology.

Following the shutdown of the facility in 1987, a decision to place the NPD site in a cold, dark and quiet state was made. This involved the shutdown of all operating systems including heating, cooling, electrical and mechanical systems throughout the facility. A similar approach as Douglas Point was taken to safely shutdown the reactor and support buildings. The primary heat transport system, moderator, relief dousing, D_2O and other non-nuclear systems were isolated, flushed, drained and capped where possible. Non-radioactive hazardous materials e.g., asbestos, mercury flammables, etc. were catalogued and removed from the facility. Used fuel was transferred from wet to dry storage and the fuel bays emptied and dried. Decontamination of the facility was completed in areas where zoning of the facility needed to be downgraded to accommodate continuing storage with surveillance activities. Radioactive material was consolidated on site, packaged and stored within the facility or in some cases a small quantity was shipped to Chalk River Laboratories for storage at a Waste Management area. The majority of systems and services remain in place as constructed and were only modified where required to meet static state requirements. Key operating systems including security, lighting and ventilation were modified and upgraded to meet the requirements of the license. Reconfiguration of the facility into a nuclear and non-nuclear side was completed through sealing pathways between the two areas to allow ongoing control, and modifications were made to systems required for monitoring the facility. To this end, electrical, fire protection and ventilation systems were reconfigured or installed to address worker and site safety throughout the storage with surveillance phase.

Various parts of the site were dismantled including the training facility, administrative wing and pump house. The reactor building that incorporated the turbine is the only building remaining at the NPD site.

2.5 Gentilly-1

G-1 is a 250 megawatt Boiling Light Water reactor that only operated intermittently for one hundred and eighty-three effective days before a decision was made to shut the facility down. In 1984 a decision was made by AECL to decommission the G-1 reactor. Following an analysis of decommissioning options it was determined that decommissioning the plant to unrestricted site use was not justified since an adjacent operating plant G-2, was in operation next door with its full design life ahead. The G-1 Reactor and Turbine Building structures were constructed in a manner that they could be utilized for radioactive waste storage.

Unlike Douglas Point and NPD Heavy Water reactors, most of the activity at G-1 in the form of contaminants in the plant is due to Cobalt 60 which has a half life of 5.27 years. This activity will have decayed by a factor of 700 after 50 years. This will leave Cesium 137 as the predominant radionuclide contaminant and the activated components as the radiological hazards at that time.

The majority of the service building and portions of the turbine building were checked for contamination, stripped of process systems back to bare walls and decontaminated where required and turned over to Hydro Quebec for use. Waste from the safe shutdown activities was packaged and stored in the turbine hall and reactor building and routinely monitored by AECL.

3. MANAGEMENT OF AECL PROTOTYPE REACTORS

Storage with Surveillance (SWS) of the three prototype reactors in Canada comes with challenges. Once a facility is declared redundant it generally means that it has served its useful life cycle and it is not economically or technically feasible to continue to operating the facility. The current plan for decommissioning these reactors is linked with ALARA and the availability of a waste management facility in Canada to place waste generated during decommissioning activities. In the case of G-1 and Douglas Point, their decommissioning dates are also linked to the decommissioning of other reactors on their respective sites. NPD is the first of the three off-site reactors planned for decommissioning with an estimated start date of 2025-2030 subject to the availability of a waste management facility. The three prototype reactors are Class I nuclear facilities currently under a Waste Facility Operating License. Meeting program requirements e.g. radiation protection, environmental monitoring, fire, security, etc. continue to be a challenge in a shutdown facility as systems degrade or the equipment life cycle has been surpassed. Vigilance in ensuring compliance to the license conditions and program requirements requires ongoing effort throughout the SWS phase. Maintaining the safe shutdown state of the active and non-active facilities at each site have their own particular challenges as the facilities were constructed, configured and shutdown differently with the only common approach used to bring each site to SWS state was the removal of the secondary systems and equipment.

In adopting SWS, each site used different strategies in maintaining the atmospheric control of active areas including the reactor building. This resulted in varied success when maintaining the structures and systems during the period since adoption of SWS and consequentially, with changing requirements of modern standards, additional work is required. The structural integrity of various facilities is now starting to present new challenges that require attention due to structural damage such as degradation of concrete as a result of external weather conditions, degradation of structural steel and other metallic components due to humidity control or premature failure of electrical/mechanical or civil components as a result of improper maintenance techniques and ageing systems. In one instance, the concrete mix used during construction has led to challenges in maintaining the exterior of the reactor building as it is failing prematurely.

Management plans are in place to continue to maintain the Douglas Point, Gentilly-1 and Nuclear Power Demonstration reactor sites in static state and continue to maintain them through their respective life expectancies until final decommissioning can commence.

3.1 General Management and Up Keep of AECL's Prototype Reactors

From the time a decision is made to shutdown a nuclear facility through to decommissioning and remediation of the site, maintenance of the building, structure and components must continue. AECL has put in place a number of management systems to ensure compliance with the respective site licenses and maintain the facilities in a safe shutdown static state until decommissioning commences. Activities at the three off-site reactor sites fall within the programs, policies and procedures that are company wide. Programs include radiation and environmental protection, security, fire, dosimetry and occupational health and safety to mention a few. The off-site facilities storage with surveillance activities are monitored and audited against these programs to ensure compliance with policy and procedures and program requirements.

The site license issued for each facility outlines the regulatory and reporting requirements. The license describes the requirements for operating limits, reporting requirements, safeguards and general conditions for compliance to the Nuclear Safety and Control Act [2] and the General Nuclear Safety and Control Regulations [3]. An Annual Compliance Report is generated for each site which documents the conditions and data to which the facilities were operated to over the year and the current status of the site. Work performed, effluent treatment, releases and waste processing, modifications to the facilities, discoveries, waste inventories and training are a few of the topics documented in the Annual Compliance Report.

A Preliminary Decommissioning Plan (PDP) was developed for all three sites and submitted to the Canadian Nuclear Safety Commission. The PDP documents the facility location, describes the facility, current status of the buildings and operating systems, the proposed decommissioning strategy, hazards associated with the facility, health, safety and radiation protection requirements, waste management strategy, project management and quality assurance plans, environmental assessments, schedule, cost and funding requirements for decommissioning the site. These plans are reviewed every three years and updated as required.

Storage with Surveillance (SWS) plans were also developed for each site and filed with the Canadian Nuclear Safety Commission. The SWS plans outline the purpose and scope of the plan, administrative responsibilities, operational systems, security and access control, maintenance activities and frequency for them to be performed, radiation and environmental protection requirements and limits, usage limitations during SWS and reports and documentation required to be generated during this period.

Maintenance plans were also developed to support the activities defined in the SWS plans, and address the long term care requirements for the facility. Preventive maintenance plans are filed in the Maintenance Management System at the various sites. The preventive maintenance plans outline physical work including pre-defined job steps, checks and verification activities required to ensure ongoing operation of equipment identified in the plan. In addition to the maintenance plans, all corrective and breakdown maintenance activities are recorded in the Maintenance Management System for tracking purposes. Trends are developed from this information to determine the effectiveness of the preventive maintenance program and repairs of the non-routine activities. The development of a Master Equipment List (MEL) is currently underway. The MEL documents the essential operating equipment, systems and components including key interface points. This information is recorded on configuration records, documented in maintenance plans and uniquely identified in the field to ensure that these systems are maintained in compliance with the site license conditions.

On occasion, non-routine work must be performed that is outside the definition of SWS. This work is generally initiated by the need to address a safety or radiological issue that has been monitored but needs to be addressed prior to approval from the Canadian Nuclear Safety Commission to proceed with decommissioning. An example of non-routine work is asbestos removal. When a non-routine activity is identified, approval from the Canadian Nuclear Safety Commission is requested and a Detailed Work Plan (DWP) is developed. The DWP provides step-by-step instructions to the group performing the tasks including responsibilities of the team members, radiological and operating limits, tools required, hold points to control work and objectives and acceptance criteria of the DWP. Following the completion of the work, a lesson learned document is prepared and drawings updated to reflect what was completed, when, by who and what was learnt by performing the tasks.

When a facility is shutdown there will be ongoing requirements that need to be addressed to ensure that the facility remains in compliance. For example, a Fire Hazard Analysis (FHA) of the three shutdown reactors to meet current regulations was recently updated that identified a number of deficiencies. This work is currently in the planning stages with some priority work in progress. An asbestos survey of one facility was completed and the other two scheduled for this year to update the previous reports. Hazardous substances listings for the sites were also updated to add other hazardous substances not previously identified i.e. lead-based paint. The environmental aspect database is reviewed and updated annually to identify activities or events that could adversely impact the environment if not monitored. Action plans are developed to mitigate or eliminate the impact of upset conditions on the environment and the public.

Once a facility is shutdown and reconfigured to accommodate SWS activities, all drawings need to be confirmed accurate. Drawings are utilized to perform maintenance and repairs, planning for projects, development of waste volumes and cost estimates and eventual decommissioning. A Configuration Management Recovery Plan has been developed which outlines the steps over the next five years to maintain the configuration of the plant. The plan is a five year rolling plan which includes everything from field walk-downs to final drawings.

Document management is another focus area to ensure that records, data and information required, for the NLLP decommissioning and waste management projects and activities, are readily available, managed, protected and preserved. This is achieved through the use of international industry best practices, International Atomic Energy Agency guidance and other standards i.e. ISO microfilming standards [4], [5], [6], [7], [8].

Operational records, technical specifications, operational incident reports, drawings and design manuals are just of few of the documents that are being archived for long-term storage. The majority of records for the three off-sites are original documents therefore electronic copies are being made for a back-up and to ensure that they are available for future decommissioning. When gaps are identified in information, one of the techniques utilized is to conduct interviews with previous operating staff and document the discussion. The goal is to preserve these records and have them easily accessible for future generations.

Although the three facilities are shutdown, they provide an opportunity for other groups to learn from. For example, the NPD site is utilized for security training by various security groups.

This facility is used to simulate real time training opportunities which are difficult to perform at an operating facility. Another example is the study of effects of operations on components or the facility i.e. feeder tubes and how they worn after years of operation, through sampling, intrusive investigation and analysis of various components including configuration of the facility. This information is used to improve future reactor designs or address a problem that is encountered in an operating reactor.

3.2 Nuclear Power Demonstration

The Nuclear Power Demonstration reactor was shut down in 1987 and all fuel and non-nuclear equipment was removed from site by 2006 and the facility was placed into a cold, dark and quiet static state. With removal of all major non-nuclear systems and supporting infrastructure, the facility now relies on limited electrical power supplies for items such as lighting, fire alarms and active ventilation. Lighting and ventilation is only energized during periods of entry to the facility. This involved the reconfiguration of the facility so that all essential systems for the ongoing storage with SWS activities could be controlled from one room upon entry to the facility. The configuration of the NPD facility includes a single-story, above-ground structure with an approximately sixty foot deep basement broken out into various floor levels. The temperature varies from 5 to 20^0C throughout the facility during the summer months to -15 to -30^0C in the winter months in the upper two floor areas and 5 to -15^0 C in the lower floors. Due to the depth of the basement and the constant ground temperature, the bottom two floors remain at a fairly constant 5-15^0C throughout the year and humidity control is a problem with relative humidity in the basement areas remaining around 80-90%. An engineering analysis was performed to identify other deficiencies and challenges during a prolonged period in SWS and documented in a Life Management Plan. The findings of the life management plan are incorporated into annual plans.

3.3 Douglas Point

At Douglas Point where the weather is even more variable with extremes of heat, cold and humidity, the facilities are subject to humidity problems similar to NPD. The difference with Douglas Point is that the majority of buildings, with the exception of the reactor building, were emptied during safe shutdown and remains occupied or utilized for storage and warehousing by various Bruce Power groups. This has resulted in normal operating temperatures maintained throughout the facility and maintenance items addressed to meet tenant needs. For the active areas at Douglas Point including the reactor building and associated active facilities, problems similar to the other two sites are being encountered. Following removal of the secondary systems and equipment the ventilation systems were modified in the reactor building to allow ventilation to be turned on only when entry into the Reactor Building is required. An electric heating was introduced into the reactor building to minimize high humidity by keeping a constant temperature in the facility. High humidity leads to peeling paint, rusting surfaces, asbestos pipe insulation becoming saturated and falling off and introduces moisture in the facility that runs off surfaces and is collected in sumps. An investigation is currently in progress to determine the integrity of resin tanks and the underground concrete vaults that house them. At the time of shutdown an expected life span of these structures was calculated to be thirty years and must be confirmed.

In general, the Turbine Building, Shops and Administrative Buildings at Douglas Point are occupied. The buildings are not indicating any premature deterioration and continue to be operated as outlined in the static state documentation. The Reactor Building is also in relatively good shape with no detectible deterioration of the systems, components or structures. The facility is monitored on a weekly basis.

3.4 Gentilly-1

The shutdown of Gentilly-1 adopted the same process as Douglas Point. The secondary systems were removed and the non-reactor buildings were converted for alternative use. This site adopted an alternative approach to the atmosphere control of the reactor building because no exhaust ventilation was required during entry into the facility due to the absence of airborne tritium as a result of a different reactor design and thus the frequent introduction of outside air is not a factor. A dehumidifier was fitted in the reactor building to maintain the atmosphere in a suitably dry state that preserves the internal structures and systems. Other challenges being faced that are unique to Gentilly-1 include concrete degradation of the reactor building ring-beam and other support arrangements. This concrete degradation has resulted in defect repair of the ring beam which will require ongoing monitoring. The resins from operations are stored in underground concrete vaults and steel tanks. The life expectancy of these structures was estimated to be thirty years at the time of shutdown therefore inspection of the tanks and vaults are in progress to determine the integrity of these structures and possible removal of the resins. As with Douglas Point and NPD, a Life Management Plan has been prepared for the facility that identifies other areas of structural repairs that are required to preserve the structures until decommissioning commences.

4. CONCLUSION

Management and upkeep of AECL's prototype reactors being held for deferred decommissioning presents challenges and opportunities. Knowledge transfer between Operations to future decommissioning teams is difficult thus configuration management and confirmation that all documentation is accurate for future generations to perform decommissioning is one of the key elements to be managed. Maintenance of the facilities, equipment, systems and site must be kept at an appropriate level to keep the facilities in a safe state until decommissioning is completed. Maintaining a shutdown reactor site is very similar to maintaining operational reactors where the appropriate programs, procedures and compliance requirements are in effect until it is proven to the regulator that decommissioning was successful and the site can be returned for re-use.

Robust Storage with Surveillance plans and activities that ensure the facilities are monitored and maintained in a safe shutdown state, remain in compliance with the nuclear regulations and upgraded as required to meet these requirements are essential. Strategic planning must include the period of storage with surveillance and consider escalating costs associated with aging facilities, ability to retain knowledge transfer between generations and the availability of space to store waste generated during this period.

5. REFERENCES

[1] International Atomic Energy Agency in Technical Report Series No. 230, 1983.

[2] Nuclear Safety & Control Act, S.C., 1997, C. 9, 2009 May.

[3] General Nuclear Safety and Control Regulations, SOR/2000-202, 2009 May.

[4] Laraia, M., editor, "Information management for nuclear decommissioning projects", *Nuclear Decommissioning: planning, execution and international experience*, Woodhead Publishing Ltd, (forthcoming 2011).

[5] International Atomic Energy Agency," Long Term Preservation of Information for Decommissioning Projects", *Technical reports series no. 467*, Vienna, IAEA, 2002.

[6] International Atomic Energy Agency,"Record keeping for the decommissioning of nuclear facilities: guidelines and experience", *Technical reports series no. 467*, Vienna, IAEA, 2002.

[7] Taboas, A.L., Moghissi, A.A., LaGuardia, T.S., editors, "Decommissioning overview", *The decommissioning handbook*, New York, American Society of Mechanical Engineers, 2004, Chapter 1, p. 1-1 – 1-28.

[8] Draper DG, "Decommissioning of nuclear facilities, record keeping", *The* R^2D^2 *Project: Workshop 2, The Basics of Decommissioning of Research Reactors, Manila, Philippines, October 16-20, 2006*, Vienna, International Atomic Energy Agency, 2006.