SAFE DRY STORAGE OF INTERMEDIATE-LEVEL WASTE AT CRL

A. Chiu, T. Sanderson, J. Lian
Atomic Energy of Canada Limited
Chalk River, Ontario, Canada

ABSTRACT

Ongoing operations at Atomic Energy of Canada Limited's (AECL) Chalk River Laboratories (CRL) generate High-, Intermediate- and Low-Level Waste (HLW, ILW and LLW) that will require safe storage for several decades until a long-term management facility is available. This waste is stored in below grade concrete structures (i.e. tile holes or bunkers) or the above-ground Shielded Modular Above Ground Storage (SMAGS) facility depending on the thermal and shielding requirements of the particular waste package. Existing facilities are reaching their capacity and alternate storage is required for the future storage of this radioactive material. To this end, work has been undertaken at CRL to design, license, construct and commission the next generation of waste management facilities.

This paper provides a brief overview of the existing radioactive-waste management facilities used at CRL and focuses on the essential requirements and issues to be considered in designing a new waste storage facility. Fundamentally, there are four general requirements for a new storage facility to dry store dry non-fissile ILW. They are the need to provide: (1) containment, (2) shielding, (3) decay heat removal, and (4) ability to retrieve the waste for eventual placement in an appropriate long-term management facility. Additionally, consideration must be given to interfacing existing waste generating facilities with the new storage facility. The new facilities will be designed to accept waste for 40 years followed by 60 years of passive storage for a facility lifespan of 100 years. The design should be modular and constructed in phases, each designed to accept ten years of waste. This strategy will allow for modifications to subsequent modules to account for changes in waste characteristics and generation rates. Two design concepts currently under consideration are discussed.

1. INTRODUCTION

The Chalk River Laboratories (CRL) has been in operation since 1942 for the development of nuclear technology in Canada. A wide variety of activities are performed at this site including research and development, constructing and operating nuclear reactors and medical isotope production. These activities have been supported by several nuclear research reactors and other nuclear facilities including several hot cells and a waste treatment center. These activities have generated a significant amount of radioactive waste with a wide variety of characteristics. Many will continue to operate and generate radioactive waste into the future. It is regulatory policy to ensure this waste is stored safely to protect the environment for future generations [1].

High-Level Waste (HLW), Intermediate-Level Waste (ILW) and Low-Level Waste (LLW) at AECL's Chalk River Laboratories (CRL) is currently stored in the above-ground Shielded Modular Above Ground Storage (SMAGS) or in below-grade concrete structures (tile holes or bunkers), depending on the thermal and shielding requirements of the particular waste package. Tile holes and bunkers were originally placed in service around 1953 and represent AECL's first generation of "dry" storage technology. The tile holes house the more radioactive material (radiation fields exceeding 0.045 Gy/h on-contact) while the larger structures, referred to as bunkers, house less radioactive waste (less than 0.045 Gy/h).

Since 2008, the SMAGS facility has been accepting the majority of radioactive waste material that would have otherwise been transferred to the bunkers. An additional SMAGS facility was completed in 2011 and four more are planned for the next 20 years. These facilities have over 50 times the capacity compared to the 6 m diameter, 4 m deep, concrete bunkers while offering similar radiological protection. Nevertheless, they cannot meet all the needs of the CRL. With storage capacity of the tile holes and bunkers nearing their limits, a new generation of waste management facilities are required to meet the continued storage needs at CRL. The project identified as the New Dry Storage System (NDSS) has been initiated to undertake this work. This project was mandated to provide safe interim storage for CRL's HLW and ILW until a facility for permanent long term management is available.

The NDSS is currently in the concept stage. The waste considered for the NDSS design is classified into two broad groups: (1) fissile waste which includes irradiated fuel from the National Research Universal (NRU) reactor, irradiated CANadian Deuterium Uranium[1] (CANDU®) reactor fuel which has undergone Post-Irradiation Examination (PIE), fuel fabrication waste, and fissile isotope production waste; or (2) non-fissile ILW which includes irradiated components and reactor parts, hot cell waste, non-fissile isotope production waste, resins, and filters. This paper focuses on the essential requirements and issues being considered in designing safe dry storage for CRL's non-fissile ILW. The storage of irradiated fuel at CRL is addressed in [2].

Non-fissile ILW slated for storage at CRL's waste management areas include a variety of waste from on- and off-site waste generators. The waste is shipped in a variety of package shapes and sizes using a wide range of shielded flasks. This variety challenges both the handling and storing of the waste packages. Unlike many existing dry-storage facilities which are built to store a specific and "standard" waste package, the non-fissile ILW at CRL are currently stored in 23 L and 68 L pails, 205 L drums, and miscellaneous odd-shaped boxes and packages. Some packages are loaded in the reactor bay and are not actively dried before they are shipped for storage. Other packages contain freshly cemented liquid waste while others contain de-watered resins. Many of the waste generators are constrained in their operations and modifications to their existing facilities and processes are difficult. These constraints must be considered while working toward the goal of improving storage and handling for the waste with a strong focus on protection of workers, the public and the environment.

2. EXISTING WASTE STORAGE FACILITIES

The three existing radioactive waste storage facilities at CRL are bunkers, SMAGS and tile holes. Concrete bunkers are constructed below grade to utilize the natural shielding properties of the ground. They are used to store solid waste packages which do not require a significant amount of shielding. These facilities are reaching their capacity. This has led to the recent introduction of the SMAGS facilities, which have replaced bunkers except for the storage of low-level waste and non-irradiated fissile material that are not eligible for storage in SMAGS due to nuclear criticality concerns or packaging requirements. Each SMAGS unit is capable of

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[1] CANadian Deuterium Uranium (CANDU) is a registered trademark of AECL.

storing 3500 m^3 of solid processed waste with an on-contact dose rate of no greater than 0.045 Gy/h.

Tile holes have been in use at CRL for over 50 years. Tile holes are below grade concrete structures with typical internal diameters between 0.15 m and 0.9 m and a depth of 4.8 m. These facilities are used for the storage of radioactive waste packages that emit greater than 0.045 Gy/h on contact.

The tile holes are not designed to provide complete containment, with early designs more prone to water ingress than later designs. The accumulation of moisture inside some of the earlier tile holes have led to some corrosion and deterioration of the waste packaging. Improvements to the tile hole design have been implemented over the years including improved shield plugs, water interrogation tubes. The facilities have also increased routine inspections and maintenance, and in some cases employed weather shields.

3. DESIGN CONSIDERATIONS

3.1 Interfacing with Existing Facilities

Original design efforts for the new facilities focused on the use of proven AECL dry-storage concepts developed for the storage of spent CANDU® fuel bundles. This decision was made with the intention of reducing design and licensing costs and project schedule. The nature and manner of waste generated at CRL, however, is significantly different from those of irradiated CANDU® fuel.

The variety of waste generated at CANDU® plants is limited relative to that generated at CRL. Unlike spent-fuel storage where the majority of the waste packages are identical in terms of geometry, thermal load, and shielding requirements, the non-fissile ILW at CRL covers a wide range of characteristics. Intermediate-level waste are generated from NRU reactor operations, research and development activities, activities from within the hot cells, isotope production (both on-site and off), and decommissioning. Waste packages are shipped in different sizes and while some packages are contact handleable, others must be transported in heavily shielded flasks. Similarly, the amount of residual heat to be dissipated varies from package to package. In addition, some waste packages contain moisture because waste generating facilities do not possess drying systems that can dry the packages. Furthermore, the wide range of facilities serviced (e.g. NRU, Universal Cells, Molybdenum Production Facility, etc.) have resulted in a proportionate variety of flasks and waste package configurations placing additional demand for flexibility on receiving and handling components of the new dry-storage facility.

The design of the new dry-storage facilities need to accommodate existing waste generators to the extent that will ensure current practices at CRL operating facilities can continue.

3.2 Additional Design Requirements

Unlike the current tile holes, a new dry-storage facility is expected to store the waste packages in a controlled system that would prevent the potential release of all gases (both radiological and non-radiological) to the environment [3]. This has created challenges due to the lack of adequate removal of residual water from a variety of the waste prior to packaging and the potential for some packages to contain organic material. Water and organics convert to volatile gases through radiolysis in high radiation fields and chemically through corrosion of the waste material and packaging. The amount of gas generation from either off-gassing through corrosion or radiolysis must be well understood in order to safely store waste in sealed containers. Off-gasses do not present any immediate hazards to the storage facility because gases are generated and released at a slow rate within the waste storage package. The use of a normally closed containment equipped with an active ventilation filtration system can be utilized to reduce pressure build up and minimize any potential environmental impact.

The characteristics of many historic CRL waste streams are based on simple theoretical bounding cases and are not well substantiated due to the limited amount of physical data available. The wide variation of the waste stream characteristics is proving to be particularly challenging to accommodate. Some waste streams radioactively decay quickly. Upon initial receipt at storage, they require up to 1.6 m of concrete to provide adequate protection to facility staff. After 60 days of storage, the shielding requirement decreases to less than 1.0 m of concrete. Other waste packages do not possess these characteristics, and instead contain longer-lived radionuclides that require less than 1.2 m of concrete shielding for essentially the entire period the packages are expected to be stored in the facility.

The theoretical bounding characteristics of the waste packages affect the design equally in terms of the heat dissipation necessary. The waste streams that require the greatest amount of shielding when transferred to storage also represents a high thermal density (up to 2000 W/m^3). Due to the high thermal density of these waste packages, the design must incorporate features that can dissipate the heat generated and ensure the integrity of the waste package and the storage structure.

Retrievability of the stored waste is a requirement to conform to modern standards [4]. Implementing a grappling system between the waste packages and the transfer flask is an improvement to existing CRL practices and will facilitate both emplacement and retrieval of the waste packages. Retrievability prior to implementing a long-term management plan should be made possible on both an individual package and (where feasible) on a multi-payload package basis. Ideally, waste packages would be placed into storage in packaging that is also acceptable under a long-term management plan. This would eliminate the need to repackage or over-pack when the waste is transferred from storage to a long-term management facility.

A final project challenge is the uncertainty in the future waste volume. The project was given the mandate to provide storage capacity for the next 40 years of waste generation at CRL. However, the anticipated volume and the characteristics of the waste expected to be received at the new dry-storage facility have evolved with the changing business needs of AECL in recent years.

4. CONSIDERED CONCEPTS

Several concepts have been explored for the new storage facility, but two concepts have been selected for further consideration. One concept consists of a self-contained, enclosed facility where the waste packages are received, transferred from the waste generator flask to a facility transfer flask and then emplaced in a storage location in the storage vault. The facility includes a reception area, flask transfer stations, dedicated crane, and the storage vault all enclosed inside a weather-resistant structure. The second concept consists of an enclosed waste reception and transfer area where the waste packages are placed in larger, multi-payload baskets. The filled baskets are stored in shielded storage pits until clement weather conditions when the baskets can be emplaced in a detached outdoor storage module.

These concepts were selected over other options based on their ability to meet the technical requirements of the project while accommodating the constraints of existing operations at the waste generator facilities. Both concepts are based on AECL's Modular Air-Cooled Storage[2] (MACSTOR®) design [5], modified and adapted to meet the project requirements. Each design is capable of accepting a wide range of solid radioactive waste and the modular design allows for a staged construction over the 40-year waste receipt period. Accommodation will be made for the delivery of waste in a variety of packages using numerous unique flasks.

Both concepts include a security component provided by site-access facilities using a controlled access approach. These site-access facilities will include space for administrative activities related to receiving and storing the waste, access control for staff and vehicles, and change facilities. The conceptual design has drawn upon the experience gained in the design, construction and operation of other Canadian waste storage facilities. The open-plenum natural convection air-cooling feature of the MACSTOR® has been adapted for the storage of radioactive non-fissile waste. The storage facilities for the non-fissile waste are required to provide significant shielding, but are not required to include criticality control.

A grappling mechanism will be used on the dry-storage facility transfer flasks. The grapple design is a proven system that has been used at the Gentilly-2 nuclear power plant for the transfer of waste packages containing highly radioactive fuel [5] and facilitates both emplacement and retrieval of the waste packages. Modifications are required to adapt the larger grapple, designed for the transfer of packages weighing approximately 2 tonnes, for CRL waste packages that weigh between 15 kg and 250 kg.

A 100-year storage period is estimated to be sufficient to allow for a long-term management facility to become available. To ensure safe storage for 100 years, detail design activities will assess and select materials to resist corrosion and ensure structural integrity. An assessment of the wastes will be undertaken to determine if drying is necessary. Should drying be required, a portable drying system will be considered.

In general, the concept design of this facility has considered:

- providing shielding to meet dose criteria;
- maintaining stable storage of the radioactive waste packages;
- providing decay heat dissipation;
- maintaining structural integrity of the storage structure;
- providing and maintaining containment; and
- facilitating safe retrieval of the waste throughout the selected 100 year lifetime.

The applicability of specific engineering and environmental codes will be determined during the detail design based on the risk for over-pressurization and other potential hazards under normal, abnormal and credible accident conditions [6, 7]. The frequency of routine inspection and monitoring will be based on physical data gathered during operation. The decision to reduce the amount of monitoring or to stop and to permanently seal the storage locations will also be confirmed as operational data becomes available.

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[2] Modular Air-Cooled Storage (MACSTOR) is a registered trademark of AECL.

To ensure that the waste packages and concrete structure are kept below their respective temperature limits during storage, the design will incorporate an air-cooled, open-air plenum storage structure. This type of cooling system allows outside air to flow pass the storage tubes, absorb some of the heat generated, and exit the storage structure without increasing the radiation dose to the worker or increasing the risk of release to the environment. Due to the complexity of the air-cooling circuit, monitoring of the storage block temperature may be required during the operating life of the facility.

4.1 Indoor Waste Transfer, Indoor Storage

This concept includes an over building which houses an air-cooled vault with an open-plenum that contains many storage locations and a reception bay. The components of the dry-storage facility are covered with an over-building structure that provides protection from sun, rain, snow, and wind (see Figure 4- 1). The building will also contain a crane that can traverse the length of the facility.

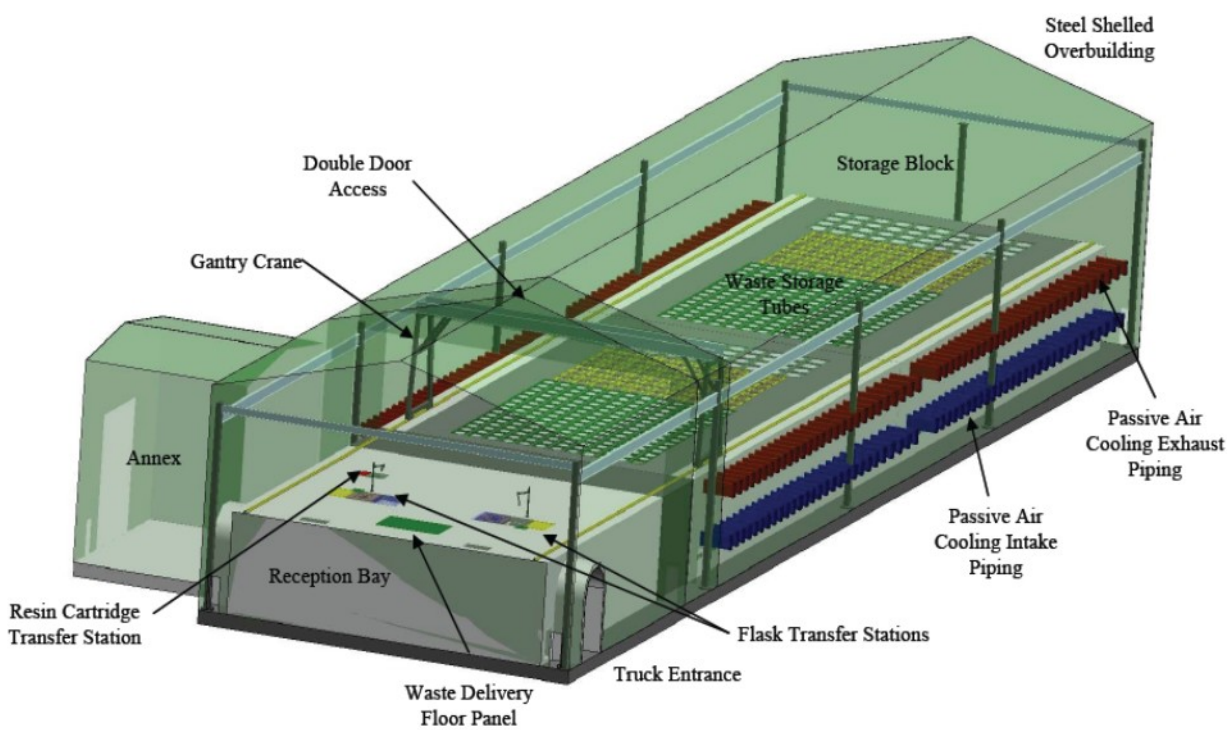

Figure 4- 1: Layout for the Indoor waste transfer, Indoor storage conceptual design.

The vault will contain multiple storage locations that will each accommodate multiple packages emplaced as single-payload waste storage containers. The proposed strategy is to phase in additional storage facilities every ten years to adjust for changing waste characteristics and volumes. Thus, the expected day-to-day operational period of the new dry-storage facilities will be for 40 years followed by a passive operational period of up to 60 years. The longer design life will decrease the risk that another interim facility would be needed.

For the initial 10-year facility, two air-cooled storage structures are envisaged to have the following characteristics:

- Cast-in-place rectangular storage structure made with regular density concrete built to prevent water from accumulating on the top surface during any abnormal events;
- The concrete walls surrounding the storage locations have sufficient thickness to limit the surface dose rate in compliance with CRL radiation protection standards;
- Each storage block will be approximately 35 m long × 19 m wide and would have an estimated height of 7 m;
- Approximately 300 storage tubes are required based on waste volume estimates for each storage block. Each storage location in the block will be comprised of a pre-positioned storage tube, approximately 1.0 m center-to-center pitch laid out in a 12 × 15 array (width × length) for 23 L (5 gallon) containers, 1.4 m center-to-center pitch laid out in a 10 × 8 array for 68 L (15 gallon) containers and 1.6 m center-to-center pitch laid out in a 10 × 4 array for 205 L (45 gallon) drums;
- The packages with volumes of 23 L, 68 L and 205 L will be stacked nine, six or four high, respectively, in a storage location. As well, there will be resin cartridge over packs that will be stacked five high in a storage location;
- The top of the storage tube will feature a closure to prevent the release of any gases generated during storage. Any gases produced will be vented from within the storage tube by vent lines, located at the top and bottom of each storage tube, through an active ventilation filtration system before being exhausted to the environment.
- Each storage tube will feature a shield plug to maintain the necessary level of shielding. These plugs will be raised and lowered by a secondary hoist on the gantry crane and be designed to move in tandem with the flasks to reduce any reflective shine within the storage area and to maximize shielding during operations.

In order to transfer a waste package to a storage location in the storage vault, the facility must be capable of retrieving the package from the waste generator transfer flask. A truck bay will allow access of a flask transfer vehicle and any waste generator transfer flask into the facility. A gantry crane designed to transverse the entire length of the storage facility will perform all the lifting required. Two flask transfer stations will provide the shielded work environment for the waste package so that it can be removed safely from the waste generator transfer flask and emplaced in storage.

4.2 Indoor Waste Transfer and Overpacking, Outdoor Storage

The second concept under consideration consists of a system that accumulates a number of short waste containers in a large diameter basket in a single plane. This is similar to existing practices at most AECL dry-storage facilities and at eleven other CANDU® 6 reactors [5]. Waste will be received at the reception area and will be placed in baskets which are temporarily stored in shielded storage pits. During clement weather, loading campaigns will be used to transfer the loaded baskets to the outdoor storage MACSTOR®-type module.

While the MACSTOR® features sealed transfer baskets, the baskets in the new dry-storage concept will only be designed to provide structural support to allow for stacking inside each storage location. The new baskets will not be sealed.

Each basket will be filled in a waste reception area similar to the indoor reception of the indoor storage concept discussed in section 4.1. The use of baskets would require an additional transfer in the process compared to the first concept, requiring the use of transfer stations to retrieve the waste packages from the waste generator flasks (identical to the first concept) before placing the waste packages into the baskets. The baskets will be properly shielded in storage pits in the reception area. The storage pits are essentially larger diameter transfer stations designed to accommodate the basket geometry instead of a waste generator flask. The storage pits will provide waste storage until clement weather conditions permit a loading campaign to transfer the baskets to the detached, outdoor, dry-storage facility. The final transfer will be completed using a much larger transfer flask that can encompass the entire basket and a vehicle to transport the flask to the storage facility.

In addition to the technical considerations required for the first concept design, this concept must also consider the weight of the basket transfer flask due to stress limitations on the module's upper deck from accidental drop conditions and to accommodate the modularity/construction sequence requirements.

5. PROGRESS TO DATE

A location, suitable for both concepts, has been chosen on the CRL site. The site features several preferable characteristics including: size, proximity to other waste management areas, accessibility to a road, yet isolated from the heavily accessed areas, depth to water table and terrain conditions. A limited geologic and hydrogeology investigation of the selected site was conducted in 2007 and a subsequent sub-surface geotechnical survey using ground penetrating radar was conducted in 2009. A preliminary archaeological assessment suggests that there are no significant Cultural Heritage resources on the site.

6. SUMMARY

AECL is in the process of designing a modern dry storage facility for a large variety of waste streams generated from multiple waste generating facilities at the CRL site. The adaptation of proven AECL dry-storage technology has been helpful in providing a solution to some of the technical issues faced by the project. The new dry-storage design considers:

- the use of a modular, replicable design that allows the new dry-storage facility to adapt to changes in waste streams over time, thus reducing capital costs;
- the use of a common, reliable grappling mechanism to allow packages to be transferred to and from storage in a simple fashion;
- the use of storage tubes to ensure that waste packages are properly cooled and any gases generated during storage are dealt with appropriately; and
- the cooperative use of shielded transfer stations, facility transfer flasks and the shielded storage facilities to minimize radiation exposure to the facility staff.

Two concepts have been identified which meet the performance requirements. The final design will be selected with due consideration of the overall technical merits, cost, and schedule for implementing the facilities at AECL's Chalk River Laboratories.

7. REFERENCES

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[6] CSA Standard N285.0-08, "General requirements for pressure-retaining systems and components in CANDU nuclear power plants/Material Standards for reactor components for CANDU nuclear power plants", 2008.

[7] ASME Boiler and Pressure Vessel Code, Section VIII, Division 3, "Alternative Rules for Construction of High Pressure Vessels", 2010.