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MANAGEMENT OF IRRADIATED FUEL AND RADWASTE AT A REFURBISHED GENTILLY-2 NPP

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ABSTRACT

Gentilly-2 nuclear power plant, in commercial operation since 1983, is located on the right bank of the St. Lawrence River about 15 km east of the city of Trois-Rivières. This paper focuses the irradiated fuel management system used for onsite interim storage. Average fuel consumption is approximately 4 500 bundles per year. After assessing the range of storage concepts, Hydro-Québec Production has selected the interim dry storage technology developed by Atomic Energy of Canada Limited (AECL) because of the advantages it offers in the areas of environmental protection, nuclear and radiological safety, technological control and economics. AECL technology deals with two types of storage unit: silo and CANSTOR module. Interim storage may end when a permanent storage site becomes available in Canada. It is assumed that a site of this nature would be in operation in 2040 to receive our irradiated fuel.

1. INTRODUCTION

The main objective of the energy policy the Québec government made public in 1996 [1] is to put energy at the service of Quebecers in a sustainable development perspective. Hydro-Québec is the lead actor in the implementation of that policy. The company is pursuing its objectives of profitability and creating value by developing its generating fleet and increasing its electricity sales on retail and wholesale markets. This is a fitting context for Hydro-Québec Production's proposed project to modify radioactive waste storage facilities and refurbish Gentilly-2 nuclear power plant [2]. If implemented, the refurbishment project will extend power plant operation until about 2035, allowing the producer not only to meet the rising demand for electricity but also to achieve the objective of long-term operability of its facilities [3]. A decision is expected in the first quarter of 2006. The project would be carried out in accordance with sustainable development objectives set out in the Hydro-Québec policy *Our Environment* [4].

2. SITE DESCRIPTION

Gentilly-2 is Québec's only nuclear generating station (see Figure 1). The 675-MW CANDU-PHW power plant supplies about 3 % of the total electricity generated by Hydro-Québec Production (HQP). Installed capacity such as that of Gentilly-2 is sufficient to meet the needs of about 74,000 clients. The plant was originally designed to operate until 2013. During the seventies, Hydro-Québec also operated Gentilly-1 generating station, a CANDU-BLW plant with a 266-megawatt capacity, belonging to AECL. The plant was shut down in 1979, when it became obvious that this type of reactor could not be operated for commercial purposes unless slightly enriched fuel was used. AECL then decided to abandon the CANDU-BLW option and to focus instead on the CANDU-PHW type of reactor like the one used at Gentilly-2. In 1980, AECL undertook to put Gentilly-1's equipment and systems into a static state.

Figure 1: Gentilly nuclear site

Operating a power plant produces solid radioactive wastes. Existing facilities in the radioactive waste storage area (RWSA) will be unable to meet the needs to 2013. Refurbishment would produce radioactive wastes, primarily from retubing the reactor. In addition, continued plant operation until about 2035 would produce more solid radioactive waste and irradiated fuel [5]. To meet all these needs, HQP is planning to build a new solid radioactive waste management facility (SRWMF) and add storage units to the existing irradiated fuel dry storage area (IFDSA). These storage facilities are subject to the Québec government's environmental assessment process under the *Environmental Quality Act* (EQA) [6-7] and to the federal process under the *Law List Regulations* of the *Canadian Environmental Assessment Act*. The plant can be refurbished under the operating licence for Gentilly-2 issued by the Canadian Nuclear Safety Commission (CNSC).

Work at the SRWMF would begin in 2006 (see Figure 2, Phase 1) with the construction of storage units for low- and medium-level solid radioactive waste to meet immediate operating needs. In 2008–2009 (Phase 2), storage units would be built for radioactive waste arising from refurbishment work planned for 2010–2011. In 2011–2012 (Phase 3), storage facilities would be built for spent resin from plant operations. Other storage units would be built as needed up to 2042. A distinct construction licence from the CNSC and a certificate of authorization from the Québec government are required to build the new storage units. Operating these units will require amendments to the current licence issued by the CNSC.

3. IRRADIATED FUEL STORAGE FACILITIES

When the plant is operating at full capacity, about 15 bundles are replaced daily, depending on the irradiation they have undergone. The heat is more intense near the core of the reactor than at its periphery.

Table 1: Irradiated fuel inventory as of December 31, 2004

Location	Irradiated fuel inventory (bundles)	Storage capacity (bundles)
In core	4,560	-
Primary bay	33,814	50,000
CANSTOR module	60,000	84,000
TOTAL	98,374	134,000

3.1 Wet storage

After approximately one year in the reactor, the highly radioactive fuel bundles are removed using a remote-controlled fuelling machine and then transferred to a storage bay designed for that purpose. The water in the bay serves to cool the bundles and provide protection against radiation. Demineralized water is used since it can better prevent metal corrosion. A cooling system helps keep the water at 26°C. Irradiated fuel must first be kept at least six years in the power plant primary bay before being transferred to dry storage facilities.

3.2 Dry storage options

Two dry storage units were authorized for irradiated fuel management in 1995. HQP prefers the CANSTOR modules, since they offer better performance with respect to heat evacuation, and they require approximately 40 % less space and smaller investments, while ensuring the same safety and protection of personnel, the public and the environment.

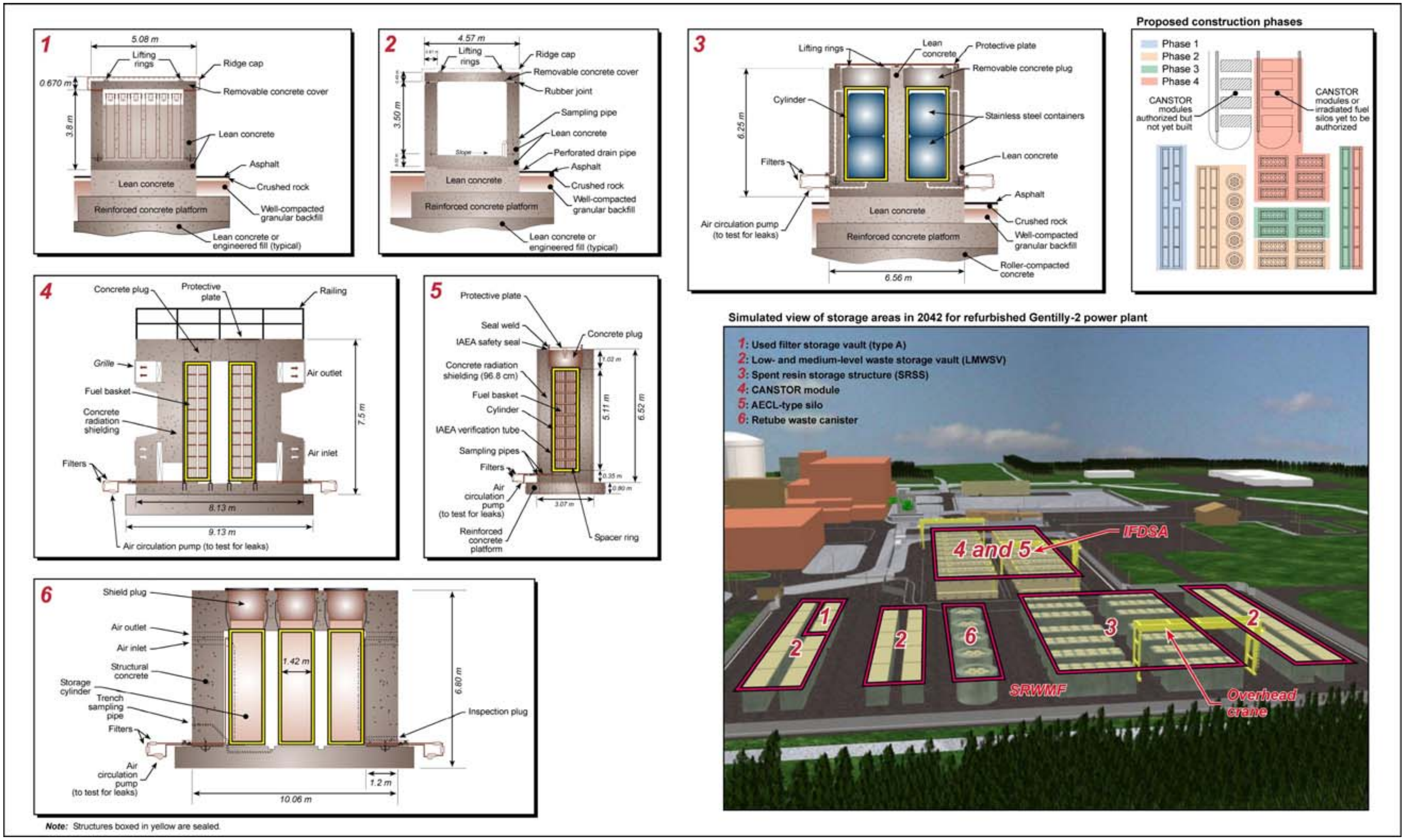

Figure 2: Typical layout of the SRWMF and the IFDSA in 2042, and sections of the storage units

3.2.1 CANSTOR module

HQP has built seven CANSTOR modules to date. The CANSTOR module is a reinforced concrete enclosure into which two rows of sealed galvanized carbon steel cylinders are placed in an upright position. The outer surface of the steel cylinders, galvanized as an anti-corrosion measure, is in contact with air circulating by natural convection within the enclosure. The CANSTOR module is designed to weather the elements throughout its 50 - year service life without any significant deterioration of its outer surface.

Figure 2 (view 4) shows a cross-section of the CANSTOR module. It also shows a simulated view of the SRWMF and IFDSA in 2042, seven years after the refurbished plant would be shut down. Twenty CANSTOR modules would be required to operate Gentilly-2 up to 2035. The implementation costs at the IFDSA are estimated at 48 M$ (2003) and are presented in Table 2 along with the schedule.

Table 2 : Cost and project implementation schedule at IFDSA

Activity [a]	Planned date	Estimated costs (M$ 2003)
Construction of module #8 and #9	2009	3.0
Construction of module #10 and #11	2016	3.0
Excavation and platform construction for module #12 to 16 (north-west corner)	2019	3.0
Construction of module #12	2019	1.5
Construction of module #13 and #14	2022	3.0
Construction of module #15 and #16	2025	3.0
Excavation and platform construction for module #17 to 20 (south-west corner)	2028	2.4
Construction of module #17 and #18	2028	3.0
Construction of module #19	2035	1.5
Construction of module #20	2038	1.5
Subtotal		24.9
260 cylinders for 13 modules	Subtotal	5.85
2 600 baskets for 13 modules	Subtotal	16.9
Total		47.65

[a] Construction of unit # 8 to 16 has been authorized in 1995. Authorization to build CANSTOR module #17 to 20 is still pending.

3.2.2 Irradiated fuel silo

The silos considered for Gentilly-2 are of the same design as those at the Point Lepreau nuclear power plant in New Brunswick (see Figure 2, view 5). This type of silo has been in use in Canada since 1977. Designed by AECL, the silo is a metal cylinder clad in reinforced concrete. The sealed steel cylinders are protected from the elements by a concrete outer cladding and coated with epoxy paint on the inside. Each silo can store 540 irradiated fuel bundles. Use of the silos will make it possible to optimize costs, especially at the end of the plant's useful life if a reduced number of bundles to be stored does not justify the construction of a CANSTOR module.

4. STORAGE FACILITY OPERATIONS

Irradiated fuel from plant operations is transferred from the service building to the IFDSA (see Figure 3). Operations at the storage facilities involve loading the basket in the basket, transferring the basket to the IFDSA, loading the fuel in the IFDSA storage units, and ensuring facility maintenance, monitoring and safety [8]. During these operations, confinement of the irradiated fuel is ensured by sealed baskets and transfer flask shielding protects workers from ionizing radiation.

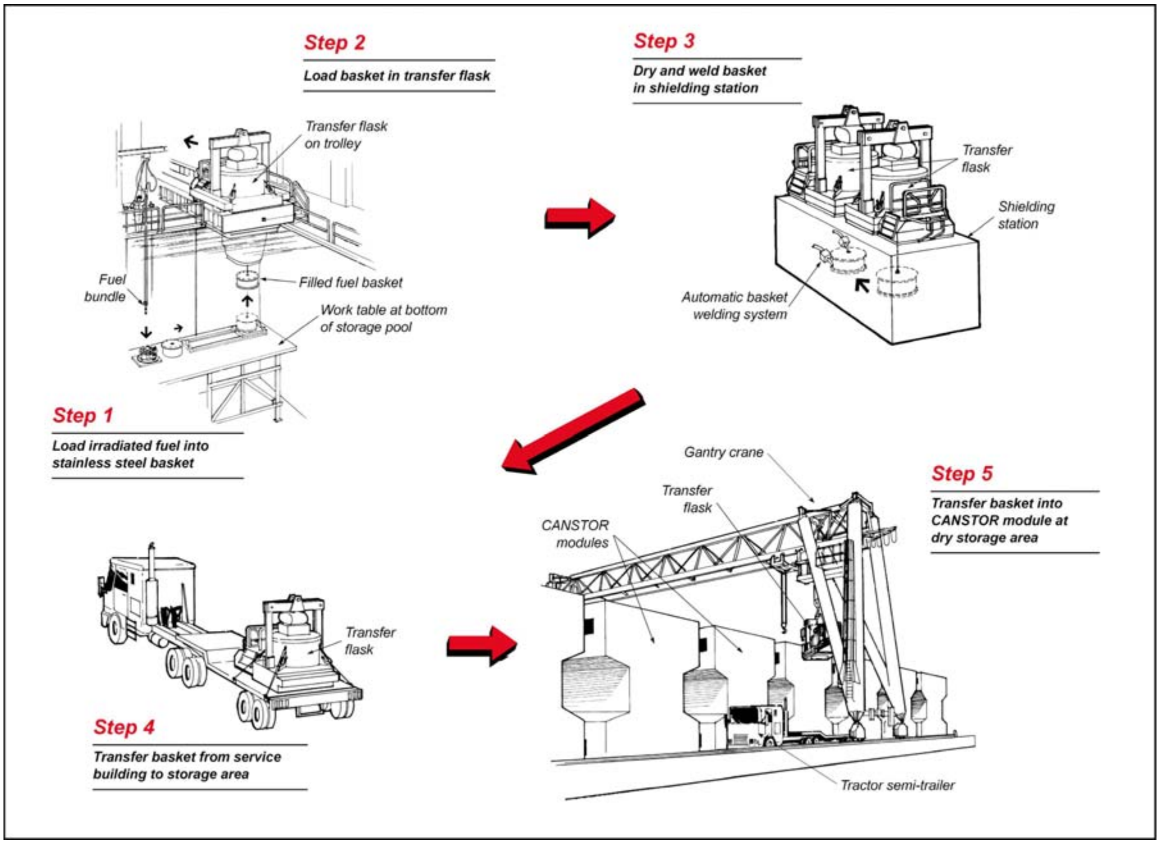

Figure 3: Irradiated fuel transfer from primary bay to CANSTOR module

4.1 Basket loading

Having been cleaned, the baskets and their cover are placed in the bay by a three-tonne hoist on a monorail. An empty basket is placed on the turntable of the work table. Then a tray filled with spent fuel bundles is placed on the tilting table located next to the turntable. Initially, this involves tilting a row of fuel bundles on the tray into the vertical position. Then, using the lifting tool, each bundle is moved individually and placed in the basket (see Figure 3, step 1). The operations outlined above are repeated until a basket is filled with 60 bundles. Then the cover is placed on the basket. The baskets filled with spent fuel can be deposited temporarily on the supports at the bottom of the bay or sent immediately to the shielded work station.

The fuel bundles can be inspected at any time during these operations who are conducted under at least three metres of water. Fuel bundle location onsite is monitored and kept in a database. It contains the number and position of each bundle in a basket along with the number and position of each basket, either in the primary bay or in a given sealed cylinder in a module or silo. This database also helps to manage the thermal load of each basket.

4.2 Transfer operations

Baskets are not always dried and welded immediately after they are filled. They can be stored temporarily in the bay. The basket is moved under the shielded chute (see Figure 3, step 2). The basket is then hoisted and placed into the transfer flask. These operations are performed using the transfer flask's pneumatic grapple and electric winch.

The basket is washed with water when it breaks the bay surface. It must then be allowed to drip dry for a few minutes prior to closing the sliding door below the transfer flask and lowering the basket onto the door. The transfer flask, which sits on a trolley set upon tracks, is brought near the shielded work station where it is then raised and placed on top of it (see Figure 3, step 3). The basket is then lowered into the shielded work station, onto the turntable/trolley and placed in the drying position. The cover is raised 5 cm using four pneumatic fingers. This will allow hot air to circulate over all basket and fuel bundle surfaces. After drying, the basket is moved to the welding position. The welding operation is automatic, with the table turning at a program - controlled speed. The operation is monitored with a video camera. The welding is inspected and repaired, if necessary. Qualified (and duly certified) operators and procedures are used to ensure the quality of the welding. Furthermore, quality control sample assays (test rings) are carried out on a regular basis.

When the welding is completed, the flask grapple is lowered and inserted into the hoist collar of the basket using the electric winch, then locked. The grapple and the basket are then hoisted into the second transfer flask, the door is closed and locked, and the basket is lowered onto the door. The transfer flask is examined for surface contamination, placed on the platform of the tractor semi-trailer with the 30-tonne crane and secured. During transfer to the dry storage area, traffic is disrupted along the route. Security personnel ensures that the road is free of any traffic. The transfer is done under the responsibility of the station shift supervisor, carried out strictly under favourable meteorological conditions and at a speed of less than 10 km/h.

4.3 Loading operations

The procedure for loading IFDSA storage units will remain unchanged (see Figure 3, step 5). The concrete plug of a cylinder is removed, the transfer flask placed over the opening and the basket lowered into the cylinder. The flask is then removed and a temporary plug is installed. These operations are repeated until ten baskets are piled into the cylinder of the CANSTOR module. The permanent concrete plug and its protective cover plate are welded shut and International Atomic Energy Agency (IAEA) safety seals affixed.

4.4 Facility maintenance, monitoring and safety

The ALARA principle of minimizing radiation risk is applied from the time the storage units are designed. The concrete walls reduce the radiation dose rate below 25 µSv/h. Leak detecting devices are used for monitoring purposes on silo and CANSTOR module. The ALARA principle is also an integral part of operating the waste storage areas. Exposure to workers and releases into the environment are thus minimized. Risks to the public are reduced by surrounding storage areas by fences placed at a distance where the dose rate is less than 2.5 µSv/h. Plant security personnel makes frequent rounds of the entire nuclear site.

5. MAIN ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

The storage facilities' various construction-related sources of impact (excavation, backfilling, hauling material, etc.) and operations-related ones (transfer and loading of radioactive wastes, maintenance, surveillance and control, etc.) were taken into consideration to assess the environmental impacts. Potential interactions were drawn between sources and environmental components, in particular valued ecosystem components (VECs) [5, 9]. The major issues boil down to protecting the quality of the environment (water, air, soil, sediment, wildlife and plants), human health, and the population's well-being (quality of life).

5.1 Impacts during normal operations

The IFDSA does not lead to any release into the environment since CANSTOR modules comprise multiple physical barriers. The same is true of irradiated fuel silos, should they be used. Small quantities of ^{3}H and ^{14}C will be released from the SRWMF. The exposures to Gentilly-2 nuclear energy workers (NEWs) that will result from operating the proposed storage facilities will be similar to those that have been measured to date at the RWSA and IFDSA. The latest measurements made at the IFDSA fence confirm that dose rates are, in fact, ten times lower than the 2.5 µSv/h design objective.

The various design criteria and administrative measures to protect human health (worker assignment and management of exposure time) ensure that exposure to all NEWs is always well below the CNSC regulatory limit.

5.2 Radiation risk from malfunctions, accidents or natural events

Risks in connection with several potential events were studied as part of the safety assessment [10-11]. A number of such events were not deemed credible since they have a probability lower than once in a million (1×10^{-6}) years of occurring at the storage areas. No credible accident scenario would expose the population, biota (flora and fauna) or the physical environment (water, air and soil) to an unacceptable risk. Only NEWs involved in the transfer of irradiated fuel could be subject to measurable exposures following an incident. In such instances, applying Gentilly-2 emergency response plan (ERP) would ensure safety and minimize the health impact of workers affected. The plant's ERP meets all existing federal, provincial and municipal standards and requirements.

6. MONITORING AND FOLLOW-UP PROGRAM

As is presently the case, an inspection and monitoring program during operations will ensure storage facilities are working properly. Such monitoring makes it possible to detect leaks and take the necessary corrective actions. Furthermore, the existing environmental monitoring program will be extended to the new radioactive waste storage facilities. This ensures that the action levels set in the radiation protection program are met at these facilities. HQP submits a quarterly report to regulatory bodies, notably the Québec Department of the Environment and the CNSC, concerning IFDSA and RWSA management. SRWMF management results will be included in this report. The revised monitoring program will specifically include additional monthly radiation measurements around the IFDSA and the SRWMF for groundwater quality, dose rate at the fence and air quality.

The physico-chemical quality of groundwater is being assessed at the storage areas by means of sampling campaigns, which have begun in 2003, still on-going and will possibly carry on thereafter if warranted. As part of the radiation protection program in effect at the plant, exposure of Gentilly-2 workers assigned to transferring radioactive waste and irradiated fuel is measured.

7. CONCLUSION

Dry storage facilities for irradiated fuel are designed to contain radioactive material and there are no release in normal operations. In common with nuclear reactors, waste management facilities are regulated under the Nuclear Safety and Control Act and regulations. Regulatory approval requires, amongst other things, submission of analyses and arguments showing that the requirements of the Radiation Protection Regulations are satisfied for nuclear energy workers, members of the public and biota in normal and abnormal operating conditions. The safety assessments are complemented by ongoing occupational and environmental monitoring, confirming that radiological impacts are within regulatory limits and are as low as reasonably achievable.

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