Joint Waste Owner Conceptual Designs

Overview Documentation

Basic Assumptions and Common Design Features

The conceptual designs and cost estimates for the three long-term management methods specified in the NFWA are based on proven technologies and on both Canadian and international experience. The principal design emphasis is on fuel receipt and placement of fuel packages into the used fuel management facilities. Consideration is also given to the operations phase, including performance monitoring. For the reactor site extended storage and centralized extended storage methods, the design approach also outlines requirements for facility refurbishment, repackaging and reconstruction activities that are expected to take place at regular intervals.

Used-Fuel Quantities and Emplacement Rate Assumptions - The total fuel inventory is assumed to be approximately 3.6 million fuel bundles. For centralized extended storage or a repository, this would be accumulated at the facility over a period of 30 years and the peak receipt would be approximately 120,000 fuel bundles per year.

Used-Fuel Characteristics - The reference fuel bundle developed for the Bruce Nuclear Generating Station is representative of typical CANDU fuel. It was used for the thermal analyses and the calculation of radionuclide inventories in the development of the conceptual designs. This fuel bundle consists of 37 fuel elements and is approximately 495 mm long and 102 mm in overall diameter. Its total mass is 23.7 kg and it contains 19.25 kg of elemental uranium (kgU) when initially loaded into the reactor. Fuel bundles for other CANDU nuclear generating stations would be similar in composition and geometry to the reference fuel and would be amenable to the same packaging and emplacement methods.

Fuel Handling - The design of used fuel handling systems and surface facilities considers that the fuel might be received at a used nuclear fuel management facility in packages of different types, originating from different organizations. Fuel that may be transferred from existing sites would be shipped in road-weight storage casks. Used fuel from Ontario reactors would be shipped in an Irradiated Fuel Transportation Cask (IFTC). Fuel stored in baskets (AECL, Hydro Québec and New Brunswick Power) would be transported in a cask designed to accommodate three baskets. All of the conceptual designs incorporate safe fuel handling methods, and where fuel bundle transfers are affected, employ shielded cells to minimize radioactive dose and maintain appropriate contamination control. Consideration was also given to the safe handling of fuel containers during transfer and placement in the storage facilities.

Transportation System Design - If continued storage at the current sites is chosen, then no transportation system would be required. For a centralised extended storage facility or repository, a used fuel transportation system (UFTS) would be required to move approximately 3.6 million bundles from the current storage facilities. The UFTS would need to be ready by approximately 2023 for a centralised extended storage facility or 2035 for a deep geological repository, consistent with the earliest potential in-service dates for emplacement of the used nuclear fuel. An underlying assumption for both of these options is that the facility would be located somewhere in Ontario. Three alternative transportation systems were considered in the development of the conceptual designs – all road, mostly rail and mostly water. Each of these systems would incorporate an existing cask, OPG's Dry Storage Container Transportation Package (DSCTP), and a new cask, the Irradiated Fuel Transportation Cask for Baskets or Modules (IFTC/BM). There is substantial international experience in the transport of used nuclear fuel casks and it is assumed that the Canadian system would be designed to operate in accordance with ISO 14001 environmental management system requirements.

Monitoring - It was assumed that all used nuclear fuel management facilities would be regularly monitored to ensure they remain suitable for housing used nuclear fuel. A program of preventive maintenance and repair would also be in effect. In the reactor site extended storage and centralized extended storage options, the storage buildings and structures would need to be regularly monitored. For the deep geological repository option, it was assumed that regular monitoring of operating facilities would continue at least until the final decommissioning of the repository.

Facility Refurbishment - For the reactor site extended storage and centralized extended storage options, it is assumed that the storage structures would ultimately deteriorate, due to normal wear and tear, and weathering processes, and would need to be replaced or refurbished. The steps necessary to perform a building refurbishment cycle would be:

- Construction of a new storage facility
- Provision of appropriate fuel package handling equipment
- Establishment of a fuel transfer route
- Transfer of fuel packages from the old storage facility
- Refurbishment or demolition of the empty old storage facility.

Used Fuel Repackaging - For the reactor site extended storage and centralized extended storage options, the used fuel bundles would be periodically removed from their existing casks and transferred to new ones. This transfer would take place within a shielded facility housed within a larger building. The shielded facility would permit opening of seal-welded casks and the withdrawal of the fuel bundles contained within. The fuel bundles would be inserted into new casks that would be seal-welded.

Radiation Protection - Used nuclear fuel is radioactive and hazardous if released during handling or storage. Radiological protection technologies and operational procedures using multiple barriers are needed to minimize exposure. CNSC Radiation Protection Regulations specify that the maximum occupational whole-body dose equivalent to a radiation worker shall not exceed 20 mSv/year, or 1 mSv/year to a member of the public. To account for the possibilities of process upset and accident conditions during non-routine operations (i.e., major maintenance, upgrades, and decommissioning), the radiation protection systems incorporated into the conceptual designs are based on not exceeding a routine dose of 2 mSv/year to an individual worker during normal operations. This limit corresponds to an individual worker being exposed to an average dose rate of 1 μSv/hour for 2000 hours (i.e. nominally a one year period, based on 50 weeks at 40 hours per week). All facilities requiring radiation protection were based on this criterion so that the surface dose rate at the operational face would be less than 1 μSv/hour. This is a conservative assumption, since not all operations require 100 percent occupancy at the operational face.

Description of Reactor Site Extended Storage (RES)

Used nuclear fuel is currently stored at seven sites in Canada, in both wet and dry storage facilities. Atomic Energy of Canada Limited (AECL) and Ontario Power Generation (OPG) began to investigate various options for dry storage in the 1970s. AECL has more than 25 years of experience with dry storage systems. Recent licensing of used nuclear fuel dry storage facilities at various reactor sites in Canada indicate general regulatory acceptance for the increasing use of dry storage at reactor sites as an interim method for managing used nuclear fuel.

Extended storage can be defined as permanent or indefinite storage with the necessary ongoing maintenance and facility refurbishment. The current design life of dry storage containers is 50 years; however, the expected life of dry storage containers is thought to be 100 years or more. In the event that centralized facilities for the management of used fuel are not available on a timely basis, extended storage could be used indefinitely.

Implementation of a reactor site extended storage (RES) alternative would involve the location of an extended dry storage facility at each reactor site. There are both surface and below-surface designs involving the use of casks, vaults and silos. Reactor site extended storage facilities would be designed to allow safe retrieval of used nuclear fuel from the storage complex at any point during the service life of the facility. After fuel receipt, all subsequent fuel movements would be under cover, minimizing effects of adverse weather and maximizing fuel container life. For all reactor site options, additional capacity would be provided by the construction of storage facilities on a rolling program (i.e., an ongoing, cyclical program of regular replacement and refurbishment activities).

Storage in Casks - A cask is a mobile, durable container for enclosing and handling nuclear fuel waste for storage or transport. The cask wall shields radiation and heat is transferred by conduction through the wall. In the context of reactor site extended storage, a cask is equivalent to the dry storage container (DSC) used by OPG, as well as a variation of this design similar to the DSC for storing fuel in baskets.

Storage in Vaults - The vault concept would involve the storage of fuel baskets confined in concrete vaults. The vaults would be constructed in the open on a concrete foundation slab. Fuel baskets would be transferred to the storage facility in a basket transfer flask. The basket transfer flask would deliver the basket to the dedicated vault on a powered transporter. Additional capacity would be provided by the construction of storage vaults on a rolling program. Cooling and ventilation to regulate the basket temperature inside the vault would be achieved by natural ventilation.

Storage in Silos - The storage of used nuclear fuel inside sealed steel baskets, with the baskets housed within a concrete silo (canister) is a dry fuel storage system used in Canada and other countries for used fuel dry storage. The silos are situated outdoors and are passively cooled. The concrete silos are a cylindrical reinforced concrete shell with an internal liner of epoxy coated carbon steel. The liner has an internal diameter of 84.5 cm. The external diameter of the silo is 2.59 m and the height is 6.2 m. A shield plug is inserted into the silo liner after completion of the loading operations (nine baskets). Provision is made for IAEA safeguard seals to go over the shield plug such that the plug cannot be removed without breaking the seals.

Description of Centralized Extended Storage (CES)

Centralized storage systems are storage facilities and associated systems to store used nuclear fuel in a central location. Producers of used fuel may build such facilities to provide effective management when they have many reactors producing used fuel. These can be developed within a regional or a national context by the implementing organizations responsible for the management of used fuel.

Centralized storage systems were initially developed as interim storage for periods of up to 50 years. These systems are already operational in twelve countries and used over a wide range of circumstances from providing common temporary storage for used fuel from a few reactors, to providing a fully centralized management system for used fuel at the national level. With increasing used fuel inventories, some countries are viewing centralized extended storage as a longer term management alternative which could encompass time periods of 50 to 300 years. As a result, more research and development is being undertaken on the durability of used fuel storage structures and the effectiveness of designs to ensure containment of radioactivity over extended timeframes.

As previously noted, following its removal from the nuclear reactor, used nuclear fuel is highly radioactive and is stored for about a decade in water pool storage facilities at the reactors. Following this period, it is easier to handle and transport the used fuel and store it away from the reactor sites. Centralized storage becomes attractive as a storage option at this stage. This could be done either in wet storage (i.e. in water-filled pools) or in dry storage facilities. The latter have advantages including modularity and less ongoing maintenance. Although several centralized water pools have been built, dry storage seems to be the preferred option. The concept that has been developed and that has been considered in this assessment includes variations of dry storage, both above- and below-ground.

Technologies for centralized dry storage of used fuel include metal casks, concrete casks, silos and vaults. Four alternatives for the Centralized Extended Storage Facility (CES) concept were selected by the Joint Waste Owners as representative of a range of possible centralized extended storage designs. The selected alternatives are:

- Casks and Vaults in Storage Buildings (CVSB)
- Surface Modular Vault (SMV)
- Casks and Vaults in Shallow Trenches (CVST)
- Casks in Rock Caverns (CRC).

Site conditions should not be a major constraint in the implementation of these alternatives. Of the alternatives considered, two would comprise surface facilities, in which fuel is stored in a series of storage buildings built above grade. The remaining two alternatives would be below-ground facilities, one near-surface and mounded over and one at about 50m below ground surface in bedrock. The near-surface alternative, the Casks and Vaults in Shallow Trenches (CVST) would be passively ventilated, with the deeper alternative, Casks in Rock Caverns (CRC), ventilated using a forced system. Three of the alternatives (CVSB, CVST, CRC) would minimize repackaging of fuel upon receipt at the CES facility, which would allow higher fuel throughput and minimize cost.

Centralized storage could be built at nuclear plant sites, adjacent to a geological repository or at a fully independent site. For the assessment, it is assumed that the CES facility would be located on a greenfield site. The CES facility would not rely on the services or provisions to other nuclear facilities, and would be considered as a standalone facility. It is assumed the facility would be constructed in the province of Ontario at a location with low earthquake risk and that the site would be relatively flat, be free draining, have stable soil structures, and have competent rock structures. Irrespective of the alternative under consideration, a CES facility would comprise a Processing Building and a Storage Complex. Each of the CES alternatives would provide sufficient storage for the full fuel bundle inventory. Each site layout would provide sufficient space to allow for the construction of used fuel storage and repackaging facilities. For all of the alternatives, additional capacity would be provided by the construction of storage facilities on a rolling program.

Description of the Deep Geological Repository (DGR) Concept

A deep geological repository is an engineered facility located within a naturally-occurring geological formation. Such facilities are widely, but not universally, regarded as having characteristics suitable for providing safe and secure the storage and/or disposal of used nuclear fuel well into the future. While uncertainties exist about the very long-term performance of repositories, many countries support the concept of deep geological disposal including, among others, Sweden, Italy, Spain, Japan, China and the United States.

The design concept used in the assessment has been developed over a significant period of time and with considerable effort. A deep geologic repository for used CANDU fuel was developed by Atomic Energy of Canada Limited (AECL) during the period 1978-1996, under the Canadian Nuclear Fuel Waste Management Program. The results of that review are documented in the final report of the Environmental Assessment Panel, published in March of 1998. The Panel report summarized the concept review and recommended changes to address comments from a broad range of stakeholders, including the public. Since 1996, Ontario Hydro, and subsequently OPG and the other members of the Joint Waste Owners, have continued the development of the original AECL repository concept. Using the design parameters and specifications established through this work, together with information from existing repository design experience in Canada and internationally, a preliminary DGR design was produced to meet the following goals:

- receive used nuclear fuel shipped from interim storage and/or from extended storage facilities;
- encapsulate the used nuclear fuel in long-lived used fuel containers (UFCs) and place them in the DGR; and

- retrieve the used fuel containers from the repository during the pre-closure phase, if required.

The modified DGR concept developed by the Joint Waste Owners is a further development of the in-room emplacement configuration. The design would involve the encapsulation of the used nuclear fuel in copper/steel double-shell containers with a capacity of 324 bundles, and emplacement of these containers inside emplacement rooms, in a horizontal position. The containers would be arranged in two rows parallel to the longitudinal axis of the emplacement rooms and would be surrounded and supported by an assembly of pre-compacted blocks of buffer and dense backfill material. A system of monitoring the performance of the engineered barriers during the pre-closure phase would also be incorporated.

It is assumed that the repository would be located in the Canadian Shield at a depth of 1000 meters. In developing the concept, different excavation techniques (including the drill and blast method and the use of tunnel boring machines) were assessed based on cost, design flexibility, proven capability and the effect on long term performance with respect to blast damage. The repository would be self-contained, except for the supply of materials, used fuel containers and their components. The facility design is based on the receipt, packaging and placement of CANDU used-fuel bundles at a rate of 120,000 per annum. The design assumes that these used-fuel bundles have been discharged from reactors and stored for 30 years prior to receipt at the DGR facility.

Overall, the conceptual design developed by the Joint Waste Owners provides sufficient detail to confirm the engineering feasibility of a DGR and to allow the preparation of a conceptual cost estimate for its implementation, including its siting, construction, operation, decommissioning, closure and post-closure management. The concept is sufficiently well-developed to be considered in this assessment. Until the repository is operational, interim measures would be needed to effectively manage the used nuclear fuel and to ensure safety and security.