NUCLEAR WASTE MANAGEMENT ORGANIZATION

SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

October 2003

NWMO BACKGROUND PAPERS
6. TECHNICAL METHODS

6-1 STATUS OF REACTOR SITE STORAGE SYSTEMS FOR USED NUCLEAR FUEL

SENES Consultants Limited

NWMO Background Papers

NWMO has commissioned a series of background papers which present concepts and contextual information about the state of our knowledge on important topics related to the management of radioactive waste. The intent of these background papers is to provide input to defining possible approaches for the long-term management of used nuclear fuel and to contribute to an informed dialogue with the public and other stakeholders. The papers currently available are posted on NWMO's web site. Additional papers may be commissioned.

The topics of the background papers can be classified under the following broad headings:

1. **Guiding Concepts –** describe key concepts which can help guide an informed dialogue with the public and other stakeholders on the topic of radioactive waste management. They include perspectives on risk, security, the precautionary approach, adaptive management, traditional knowledge and sustainable development.
2. **Social and Ethical Dimensions** - provide perspectives on the social and ethical dimensions of radioactive waste management. They include background papers prepared for roundtable discussions.
3. **Health and Safety –** provide information on the status of relevant research, technologies, standards and procedures to reduce radiation and security risk associated with radioactive waste management.
4. **Science and Environment –** provide information on the current status of relevant research on ecosystem processes and environmental management issues. They include descriptions of the current efforts, as well as the status of research into our understanding of the biosphere and geosphere.
5. **Economic Factors** - provide insight into the economic factors and financial requirements for the long-term management of used nuclear fuel.
6. **Technical Methods** - provide general descriptions of the three methods for the long-term management of used nuclear fuel as defined in the NFWA, as well as other possible methods and related system requirements.
7. **Institutions and Governance** - outline the current relevant legal, administrative and institutional requirements that may be applicable to the long-term management of spent nuclear fuel in Canada, including legislation, regulations, guidelines, protocols, directives, policies and procedures of various jurisdictions.

STATUS OF REACTOR SITE STORAGE SYSTEMS FOR USED NUCLEAR FUEL

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SUMMARY

As mandated by the federal government, the Nuclear Waste Management Organization (NWMO) was established by the utilities that produce used nuclear fuel in November 2002. This organization is in the process of creating a series of background papers, which will provide information to decision makers and the public regarding the management of used nuclear fuel. This background report on reactor site storage of used nuclear fuel in Canada is one of the series of reports being prepared for the NWMO, which will be posted on the NWMO website (http://www.nwmo.ca/).

Current practice in Canada is to allow used fuel (i.e., fuel which has been irradiated in a reactor) to cool in used fuel bays (essentially water-filled pools) for ten years or more, and then to transfer the fuel to above-ground dry storage. Recent Environmental Impact Statements to assess used fuel dry storage at Ontario Power Generation's Darlington and Pickering (Phase II) sites demonstrate the increasing use of dry storage at reactor sites in Canada.

Atomic Energy of Canada Limited (AECL) and Ontario Power Generation (OPG) began to investigate dry storage alternatives in the 1970's. AECL has more than 25 years of experience with dry storage systems. The current design life of dry storage containers is 50 years; however, the actual 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 use of dry storage would provide a reliable method of managing used fuel in the longer term. In such an event, regulatory and environmental issues would need to be revisited.

While Ontario Power Generation is the largest producer of used fuel, the other nuclear utilities Hydro Quebec and New Brunswick Power also produce significant quantities of used fuel. Additional, but much smaller, quantities of used fuel have been produced from research activities by Atomic Energy of Canada and various research and prototype reactors in Canada.

This report provides brief descriptions of used fuel storage systems at commercial reactor power sites in Canada. In addition, selected comments are provided on a variety of environmental and regulatory issues relevant to reactor site used fuel management systems.

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COMMONLY USED ABBREVIATIONS

AECL	Atomic Energy of Canada Limited
ALARA	As Low As Reasonable Achievable
BNPD	Bruce Nuclear Power Development
CANDU	Canadian Deuterium Uranium (trademark of AECL)
CANSTOR	Canister Storage (same as MACSTOR – Gentilly 2)
CNSC	Canadian Nuclear Safety Commission
CRL	Chalk River Nuclear Laboratories
DNGS	Darlington Nuclear Generating Station
DOE	U.S. Department of Energy
DSC	Dry Storage Container
DSM	Dry Storage Module
HQ	Hydro Quebec
IAEA	International Atomic Energy Agency
IFB	Irradiated Fuel Bay
MACSTOR	Modular Air Cooled Storage System
NBP	New Brunswick Power
NWMD	Nuclear Waste Management Division of Ontario Power Generation
NWMO	Nuclear Waste Management Organization
OPG	Ontario Power Generation
PLGS	Point Lepreau Generating Station
PNGS	Pickering Nuclear Generating Station
TC	Transfer Cask
USNRC	United States Nuclear Regulatory Commission
WL	Whiteshell Laboratories

GLOSSARY

Term	Definition
Basket	A sealed container that holds the used nuclear fuel bundles in a geometrical symmetry inside a cask, silo or vault.
CANDU	A nuclear power reactor system designed by Atomic Energy of Canada Limited known as **Can**ada **D**euterium **U**ranium.
Canister	Same as cask
Cask	Reinforced concrete container for the storage as well as transport of used nuclear fuel. Fuel is stored in the fuel baskets, and then placed into these casks.
Coolant	Fluid substance used especially for the removal of heat from the core of the nuclear reactor.
Exclusion Zone	Zone at the site prohibited for public entry.
Extended Storage	Storage for an interval time of more than 50 years after the facility is operational.
Irradiated Fuel Bay	Site location to store the used fuel under water to allow for the fuel to cool down (heat and radioactivity reduction).
Moderator	A substance, such as water or graphite, that is used in a nuclear reactor to decrease the speed of fast neutrons and increase the likelihood of fission.
Module	Rack System for holding fuel bundles, and storing in fuel bays and Casks.
Processing Building	Building for receiving fuel, offloading transportation Casks, unloading fuel, transferring to storage containers, and loading containers onto the on-site transfer system.
Reactor Extended Storage (RES) Facility	Facility for the extended storage of used nuclear fuel
Silo	Large reinforced concrete container for storage of used nuclear fuel
Spent/ Used Fuel	Fuel from the Nuclear Reactors which can no longer be used in the reactor, and hence, is a waste product. Fuel is stored in the form of used fuel bundles.
Storage	Placement of used nuclear fuel in a nuclear facility where used fuel is contained and shielded, and loses its heat.
Storage Building	Building for the long-term storage of the used fuel.
Storage Chamber	Chamber for the long-term storage of the fuel where each chamber has two storage bays.
Used fuel bundles	Bundles that store the used nuclear fuel from the nuclear reactors in the form of small rod-like pellets
Vault	Strong and large reinforced concrete structure providing shielding from the radioactivity of Used Fuel stored within baskets.

1.0 INTRODUCTION

1.1 BACKGROUND

Among its various activities, the Nuclear Waste Management Organization (NWMO) has commissioned several background papers to provide them with factual information on a number of topics important to the development of a socially acceptable, technically sound, environmentally responsible and economically feasible management plan for used nuclear fuel. This report discusses the status of reactor site storage systems for used nuclear fuel. It is one of a series of background papers prepared for the NWMO. All of the background papers will be posted on the NWMO web site (http://www.nwmo.ca/).

1.2 CONCEPT OF REACTOR SITE STORAGE OF USED NUCLEAR FUEL IN CANADA

Steam which energizes the turbines to generate electricity at nuclear power stations is produced by heat from nuclear fission in fuel bundles in each reactor. In CANDU, each bundle contains a total of approximately 20 kg of uranium in small pellets seal-welded in 28 zircalloy tubes (elements) and mounted in concentric rings. In addition to heat, uranium fission also produces fission products – radioactive isotopes of lighter elements (e.g., Cs-137, I-131, Kr-85) and transuranics (radioisotopes heavier than uranium) that remain trapped within the fuel elements. The inventory of fission products and transuranics increases with increasing residence time of the fuel in the reactor.

Upon removal of the used fuel from the reactor, the production of fission products ceases, but the used fuel continues to produce intense gamma radiation and decay heat. To protect workers from the radiation levels and to remove the decay heat, used fuel bundles are stored in water-filled fuel bays at each reactor site. The fission product inventory, gamma radiation levels and decay heat decrease with increasing time after removal of the used fuel from the reactor. After approximately 10 years of cooling in wet storage, the used fuel can be economically and safely transferred into dry storage containers for extended interim storage at each reactor site.

According to [1], experience with used fuel storage in water (commonly referred to as storage in irradiated fuel bays or IFBs), has shown that bundles of irradiated fuel can be stored for long periods of time without deterioration. Hence, storage in IFBs would appear potentially suitable for extended storage. Nevertheless, while pool storage is safe, and auxiliary fuel bays such as those at the Pickering and Bruce sites can be built to extend IFB storage time, alternatives to pool storage for long term management of used fuel have been under consideration for many years.

Dry storage of used fuel as an alternative to wet storage was initiated by Atomic Energy of Canada Limited (AECL) and Ontario Power Generation (OPG) in the mid 1970's. [1] Initially, AECL evaluated engineered concrete canister designs using electrical heating as a power source. The next phase of evaluation studied the impact of used fuel storage on the canister design by loading two canisters, one with WR-1 reactor fuel and one with Douglas Point reactor fuel.

The AECL program also included a materials test component to evaluate the effects of storing fuel materials that defect during service or which were otherwise removed from protective fuel cladding.

AECL's demonstration project continued for approximately 25 years even though data collected early in the program had confirmed the viability of dry storage in concrete canisters as a safe alternative for the interim storage of used fuel.

Based on the results of the demonstration program [2, 3, 4, 5] commencing in 1977, canisters were routinely used for the storage of WR-1 used fuel at Whiteshell. Following the shutdown and defueling of the WR-1 reactor in 1985 to 1989, all remaining WR-1 fuel was transferred to canister storage [6]. Therefore, routine use of the dry interim storage option at Whiteshell represents over 25 years of experience. Routine surveillance monitoring has indicated no problems to date and that the planned canister lifetime of up to 100 years appears viable.

Above-ground dry storage of used fuel is considered an interim measure at a number of reactor sites in Canada until an approach for the long-term management of used fuel is implemented. The future time at which such a transfer will begin is unknown at present; however, assumptions of when such a facility might become available have been made by some operators for planning purposes. For example, the Ontario Power Generation plan for used fuel management currently assumes that shipping of used fuel to such a long-term management facility will begin in 2035. While the design life of the dry storage canisters is 50 years, it is thought that the used fuel could be safely left in dry storage canisters for 100 years or more. Thus, in the event a centralized management facility was not available on a timely basis, by 2035 for example, extended management of used fuel in dry storage at reactor sites provides a viable alternative. In such an event, there is likely to be a need for re-licencing or other regulatory action and additional public communication.

1.3 OBJECTIVE AND SCOPE

The purpose of this background paper is to provide an overview description of the current status of the reactor site storage systems for used nuclear fuel. Although the main focus of this paper is to describe reactor site storage systems at nuclear power generating stations in Canada, there are other sources of used nuclear fuel in Canada, including, for example, used fuel at Atomic Energy of Canada's (AECLs) Chalk River and Whiteshell Laboratories and from research reactors such as the McMaster University facility.

Much of the information in this background paper was extracted from recent Environmental Impact Statements for dry fuel storage at Ontario Power Generation sites at Bruce, Pickering and Darlington [7, 8, 9]. This was augmented by the information from the open literature, from several websites and through personal contact with representatives of various utilities.

1.4 REPORT CONTENTS

In Canada, used fuel is stored in fuel bays at nuclear reactor facilities for a nominal period of ten or more years, to allow for cooling and radioactive decay. After cooling, the used fuel is transferred to above ground canisters or concrete modules at reactor sites. As a consequence of the potential radiological hazard and the need to safeguard the inventory of fissile material in the spent fuel, the reactor site storage systems must satisfy stringent safety, security, engineering and environmental requirements while at the same time being both economically viable and acceptable to the public. This background paper is structured in the following manner.

Chapter 2, **Existing Reactor Site Storage for Used Nuclear Fuel in Canada**, describes the current and currently planned methods for used nuclear fuel storage at different reactor sites in Canada.

Chapter 3, **Additional Considerations** provides an overview of selected regulatory, occupational, environmental and public perception issues associated with reactor site storage of used nuclear fuel.

Appendix A provides a brief summary of each web site consulted in the development of this report.

Appendix B provides supplementary background information on the development of dry storage systems for used nuclear fuel in Canada. Selected information on dry storage systems in the United States and elsewhere is also provided.

2.0 EXISTING REACTOR SITE STORAGE FOR USED NUCLEAR FUEL IN CANADA

In Canada, it is the practice to store the used nuclear fuel in irradiated fuel bays (IFBs) for a number of years to allow for cooling and radioactive decay. After cooling, it is now common practice to transfer the used fuel to above ground dry storage at the reactor sites. The recent environmental impact statements (EISs) for used fuel dry storage at Darlington, Bruce and additional used fuel dry storage at Pickering reflect the increasing need for dry storage systems. Table 2.1 provides a summary of the current (2001) and ultimate inventory of used fuel bundles in dry storage[1].

TABLE 2.1
INVENTORY OF USED NUCLEAR FUEL BUNDLES IN DRY STORAGE AT REACTOR SITES IN CANADA[1]

	Current Inventory (2001)		Ultimate Inventory	
Reactor Site	**Bundles**	**DSCs[2]**	**Bundles**	**DSCs**
Ontario (DSCs)				
- Pickering	79,266	202	929,624	2,421
- Bruce	-	-	1,490,967	3,929
- Darlington	-	-	876,096	2,282
- Douglas Point	22,256	46	22,256	46
- Chalk River	4853	14	4850	14
Quebec				
- Gentilly-1	3,213	11	3,213	-
- Gentilly-2	48,000	5 (vaults)	132,838	12 (vaults)[3]
New Brunswick				
- Pt. Lepreau	48,600	140 (silos)	119,500	221 (silos)[4]
Manitoba				
- Whiteshell	2300[5]	16	2300	16
Total Bundles	**208,488**	**434**	**3,581,634**	**8,941**

1 Adapted from [10, 11, 12,13, 32]
2 DSCs (dry storage containers are used) to store used nuclear fuel after it is removed from the IFBs.
3 Including used fuel from Gentilly-1.
4 Estimated number of surface silos.
5 Includes 360 CANDU fuel bundles plus used fuel from WR1.

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1 The numbers of bundles in current inventory (i.e. 2001) vary slightly among various references. For consistency and ease of reference, all values in Table 2.1 were taken from reports prepared in 2003 [10, 11, 12, 13, 32] except for AECL's inventory for Whiteshell which was provided in a personal communication [31].

2.1 ONTARIO

Ontario Power Generation (OPG) reviews their system planning assumptions for used fuel management on an annual basis. In general terms, the key assumptions factored into OPG's plan are:

- estimates of used fuel potentially generated from OPG's 20 reactors at Pickering, Bruce (operated under lease by Bruce Power) and Darlington;
- all reactors are assumed to provide 40 years of service;
- used fuel is stored in dry storage facilities at Pickering, Bruce and Darlington following removal from water-filled station bays;
- the design life of dry storage containers (DSCs) is 50 years, although the actual engineered life of the DSCs is thought to be 100 years or more; and
- transfer of used fuel to a long-term management facility will start in 2035.

Figure 2.1: Pool Storage at Pickering

In addition to information from recent EAs, the following descriptions of used fuel management at nuclear generating stations in Ontario are developed from personal communications with OPG personnel and from information provided in a February 2003 report on reactor site extended storage options [10]. Other materials reviewed in developing this section included [7, 8, 9, 10, 14].

2.1.1 Pickering Nuclear Generating Station (NGS)

The Pickering Nuclear Generating Station is located on the north shore of Lake Ontario in the City of Pickering just to the east of Toronto.

Located at the southeast corner of the Pickering Waste Management Facility (PWMF) are two sub-facilities for the storage of nuclear waste from the generating station; namely the Pickering Used Fuel Dry Storage Facility and the Retube Components Storage Facility.

Used fuel is initially stored in IFBs such as that shown in Figure 2.1 for a minimum of 10 years to allow the fuel to cool before transfer to above ground dry storage (Figure 2.2).

OPG uses a standard canister referred to as a DSC (Dry Storage Container). The DSC holds 4 standard modules of fuel of 96 fuel bundles each containing 384 bundles in total cooled at least 10 years in the IFB after discharge from the reactor. The DSC is wet loaded in the station bay, then moved to a processing building where the lid is welded on. The DSC is also licenced by the CNSC as a transportation package for used fuel (when used with purpose built impact limiters).

The Processing Building includes an area for receiving and preparing new DSCs, an area for painting, and a workshop area that houses the following dedicated systems for processing loaded DSCs:

- Closure Welding and welding-related systems;
- X-ray radiography system; and
- Leak Testing system.

Figure 2.2: DSCs in a Storage Facility

Figure 2.3: Transfer of Dry Storage Canister at Bruce B Ancillary Services Building

After a loaded DSC is transferred to the Processing Building (See Figure 2.3), vent and drain port transfer plugs are removed. Next, the transfer clamp is removed, the weld preheater is attached, and the DSC lid is attached to the base with a continuous thick DSC closure weld. On completion, the weld is cooled and inspected by X-ray radiography. After the welding has met specifications, the interior of the container is vacuum dried, and the DSC is backfilled with helium. The DSC is then tested to verify leak tightness, and the exterior surfaces are checked for contamination and decontaminated if required. Weld affected areas are cleaned, and touch up paint is applied as necessary on the container surface.

The planning for storage has two phases. Phase I currently provides this facility with a storage capacity of 469 DSCs in the Stage II storage area which is additional to the 185 DSCs that were already present at the end of 2001 in the Stage I storage area which will reach its maximum capacity by 2008.

OPG is proposing to expand the storage to construct and operate PWMF Phase II (see Figure 2.4). The PWMF II consists of two additional storage buildings of used fuel dry storage;

transfer of loaded welded DSCs from PWMF I to the Storage Buildings in PWMF II; and operation and maintenance of the PWMF II Storage Buildings.

Subject to the approval of the recent Environmental Impact Statement, OPG currently plans to start the construction of PWMF II in the fall of 2004. Phase II, will provide sufficient capacity to store the used fuel from the fall of 2007 until the currently projected end of Pickering NGS service life.

Figure 2.4: PWMF I and Proposed PWMF II Area.

2.1.2 Bruce NGS

The Bruce Nuclear Power Development (BNPD), located on the shore of lake Huron near Kircardine in Bruce county, has been on lease to Bruce Power since May 2001. The site has two nuclear generating stations: Bruce A and Bruce B. These two stations (see Figure 2.5) have a total IFBs (Irradiated Fuel Bay) storage capacity of 725,000 fuel bundles located in each station. Additional storage of 705,000 fuel bundles will be needed over the expected 40 year life of these stations.

Figure 2.5: Bruce Nuclear Generating Station

Figure 2.6: Western Used Fuel Dry Storage Facility

Once fuel is removed from in-station bays, OPG assumes responsibility for its management in the Western Used Fuel Dry Storage Facility (WUFDSF) (see Figure 2.6). This facility was formerly named the Bruce Used Fuel Dry Storage Facility. It was renamed when Bruce Power entered a lease agreement with OPG in May 2001. This facility provides additional storage space, beyond that provided by the IFBs, for used fuel obtained from the eight CANDU reactors on the Bruce Nuclear Power Development (BNPD) site. The WUFDSF is designed to provide storage space for approximately 1,940 Dry Storage Containers (DSCs). The WUFDSF currently includes a processing building and four DSC storage buildings, each having a potential storage capacity for about 500 DSCs. The used fuel is stored in IFBs for 10 years and then transferred from the IFB to dry storage. Therefore, the expected average age for used fuel bundles in dry storage in this facility is more than ten years. The design life for the system and components in this facility is at least 50 years. This implies that the WUFDSF will be operational for at least 10 years after the currently anticipated shutdown of the last Bruce reactor unit.

OPG is preparing the sites for the construction of three additional buildings and is planning to bring these buildings into service in 2007. OPG also plans to build two additional buildings (a total of 5 new buildings) for future storage of used fuel; however, approval from CNSC is needed for their construction.

2.1.3 Darlington NGS

Darlington NGS is located about 70 km east of Toronto on the north shore of Lake Ontario in the Municipality of Clarington.

Figure 2.7: Darlington Nuclear Generating Station

Currently, the Darlington NGS has two water-filled pools to store the irradiated fuel removed from the reactors. OPG is proposing construction of a used fuel dry storage facility on this site following the approval of the facility by the Canadian Nuclear Safety Commission (CNSC). The facility will only store used fuel from Darlington. The CNSC review is expected to take several years to complete. This facility will have the same design as the Western Waste Management Facility, and is targeted to be in operation by October 2007.

2.1.4 Douglas Point Reactor Facility

The Douglas Point Reactor, owned by Atomic Energy of Canada Limited is located within the BNPD site. In 1986, the Douglas Point NGS was shut down. The used fuel from this reactor included 22,256 used fuel bundles, which were stored in 46 canisters. This storage facility is located adjacent to the Douglas Point Reactor Building about 1.5 km west of the WUFDSF. Currently, it consists of canisters arranged in three rows of 12 and one row of 11 resting on a 0.6 m thick concrete foundation covering 660 m^2 area. Each silo can store nine fuel baskets with each basket having a capacity of 54 fuel bundles. AECL is planning to decommission the

Douglas Point Dry Storage facility in period 2040 to 2045 [13] at which time, it is planned to transfer the used nuclear fuel to a new central facility.[2]

2.2 QUEBEC

2.2.1 Gentilly-1

This reactor is owned by Atomic Energy of Canada Limited (AECL), and is located on the banks of the Saint Lawrence River, about 15 km each of Trois-Rivieres. The fuel has been removed from Gentilly-1 to on-site dry storage, and the reactor currently awaits decommissioning [13].

The used fuel remains the responsibility of AECL. Gentilly-1 holds a total of 3,213 bundles of used fuel within 85 baskets in its dry storage area (approximately 37 bundles per basket). An array of Concrete Canisters, or silos, holds these baskets inside a turbine building. Each canister can hold 9 stacks of baskets, and is of the same design as the Nuclear Power Demonstration Reactor at dry storage canisters located at Chalk River. Gentilly-1 currently has a total of 11 canisters.

2.2.2 Gentilly-2

The Gentilly-2 reactor, owned by Hydro Quebec, is located on the same site as Gentilly-1 on the south shore of the St. Lawrence River, 15 kilometres east of Trois-Rivieres.

Gentilly-2 is the only nuclear generating station operated by Hydro-Quebec. At this time, the Gentilly-2 station is expected to be operational until October 2013. Fuel is transferred to dry storage after a minimum of seven years.

Figure 2.8: Gentilly-2 Area

The used dry storage facility is approximately 150 meters to the south west of the NGS (see Figure 2.8). At this time, it consists of five reinforced concrete storage modules (see Figure 2.9); each consisting of 20-steel lined vertical cylinders for storing used fuel bundles. A description of the dry fuel storage facility, including an evaluation of potential accident scenarios and risks is provided in the report submitted to the CNSC for licensing of the facility [17].

[2] As noted earlier, the used fuel could be safely managed in its current configuration in the event that such a central facility was not available at that time.

At Gentilly-2 dry storage facility, the used fuel is stored in baskets within concrete vaults. Each Vault can hold 200 baskets in 20 liners (10 baskets per liner). Gentilly-2 has 5 concrete vaults, but future demands indicate that a total of 12 vaults are required. The current projected final fuel inventory at Gentilly-2 reactor is 132,838 used fuel bundles. [11]

Figure 2.9: A MACSTOR at Gentilly-2

As noted earlier, in the event that a new central storage facility was not available at that time, it is thought based on AECL's experience, that the used fuel would continues to be safely stored in its current configuration.

2.3 NEW BRUNSWICK

2.3.1 Lepreau

Point Lepreau is located on the Bay of Fundy, about 80 km southwest of Saint John. Point Lepreau Generating Station (PLGS) generates 680 MW of electricity and is a CANDU pressurized heavy water reactor (PHWR) like Gentilly-2. It is expected that this reactor will be operational to March 2008. New Brunswick Power is currently evaluating the possibility of extending the operating life.

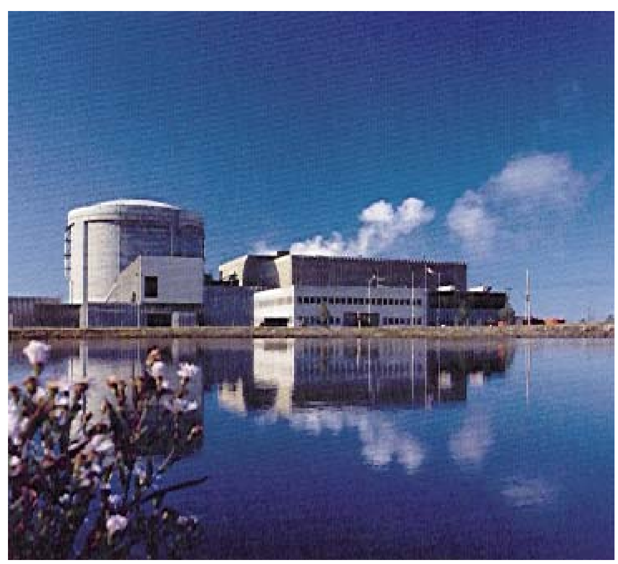

Figure 2.10: Point Lepreau Nuclear Generating Station

Key references considered in developing this section include [12, 18, 19, 20, 21].

The Solid Radioactive Waste Management Facility is within the exclusion zone for the Point Lepreau Generating Station. This facility is licensed by the CNSC. The facility was designed and sized to accommodate all the material from the operation of two nuclear units at PLGS, including the decommissioning waste (only one unit has been constructed). In 1988, approval was granted by the CNSC for dry canister storage of used fuel.

After being removed from the reactor, the fuel is stored underwater in a spent fuel bay for seven years to allow for cooling and to reduce the radioactivity level. Once the radioactivity and heat of this fuel is at acceptable levels, irradiated fuel is transferred to dry storage in above ground concrete canisters. Each canister can accommodate nine baskets with each basket able to hold 60 used fuel bundles. The design of the canister is similar in height to the NPD and Douglas Point canisters; however, this design has a greater diameter to store larger diameter fuel baskets. For the currently projected life of this reactor, a total of 119,500 used fuel bundles will need to be stored in the facility. [12]

New Brunswick Power is currently planning to modify the existing solid radioactive waste management facility. Planned modifications include the construction of a series of new structures for storing radioactive material in two stages: construction of new storage structures for storage of radioactive wastes and construction of new facilities for storage of used nuclear fuel. The facility can then be operational for an additional 25-30 years after 2008.

2.4 CANADIAN RESEARCH REACTORS

2.4.1 Chalk River Nuclear Laboratories and Nuclear Power Demonstration Reactor (Rolphton)

The Chalk River Laboratories (CRL) cover a 37 square kilometre area site on the Ottawa River (see Figure 2.11). The Chalk River site stores used nuclear fuel from the National Power Demonstration reactor at Rolphton, Ontario which was shutdown in 1987. Used nuclear fuel was stored in fuel bays at the Rolphton site, and then transferred to dry storage canisters following reactor shutdown and start of decommissioning operations.

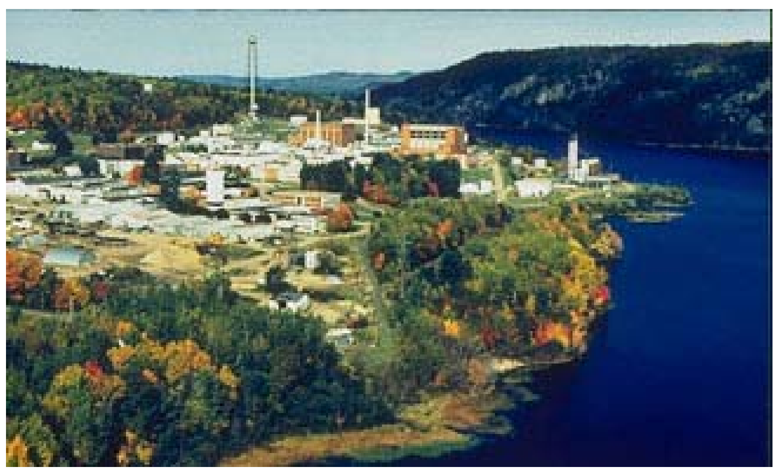

Figure 2.11: Chalk River Laboratories Site

Chalk River currently has 14 concrete silos, and it is assumed that no additional silos will be constructed at this site for research purposes [13]; however, additional silos may be built to store future fuel waste from generators elsewhere. In addition, as noted below, AECL will, under contract, take delivery of spent fuel from its Slowpoke reactors for storage at CRNL.

2.4.1.1 NRU Research Reactor – Chalk River Laboratory

The NRU reactor is also located at AECL's Chalk River Laboratories. This reactor operates at 125 MW (thermal), and is unique because ordinary water is used in this reactor as coolant and heavy water as a moderator. The NRU uses 20% enriched fuel. The large core of NRU is within a vessel 12 ft (3.66 m) in diameter and 10 ft (3.05 m) high. NRU does not operate on a fixed fuelling cycle. Used fuel from this facility is stored in tileholes in the ground, at the CRL Waste Management Facility.

2.4.2 Whiteshell Laboratories – WR-1

The Concrete Canister Fuel Storage system was developed at Whiteshell Laboratories to demonstrate that dry storage is a feasible alternative to water pool storage for irradiated reactor fuel [13, 22] (see also Appendix B). Because of the success of the demonstration program, concrete canisters have been used to store all remaining WR-1 used fuel. The Concrete Canister Storage Facility is composed of two storage areas: the main canister site adjacent to the waste management area (shown in the lower left of Figure 2.12); and the demonstration canister site within the site laboratory area.

The main canister site is located on a prepared site about 1000 m to the northeast of the plant site. The centre-to-centre canister spacing is 7.5 m within a row and the canister rows are 9 m centre-to-centre apart. Each canister is located on a pad of reinforced concrete 3.66 m square and 0.2 m thick.

The demonstration canister site is located within the present Whiteshell Laboratories site active area approximately 85 m southeast of the central powerhouse. There are two canisters, located in a north-south row immediately adjacent to an existing access road running along the east boundary of the plant active area. The canisters are placed on 3.048 m square. These pads rest on 46 cm of compacted granular fill (replacing the excavated topsoil) over undisturbed native soil. Fuel from these canisters has already been transferred into the main canister facility and both demonstration canisters are now empty.

Figure 2.12: Whiteshell Waste Management Area (Dry Storage Cannisters are in the lower left of the Figure)

2.4.2 McMaster University

McMaster Nuclear Reactor (MNR) has a power output of 2 MW (thermal). Throughout the history of the operation of the reactor, McMaster University has been storing the used nuclear fuel in the reactor pool. The fuel is stored for approximately 10 years. The used nuclear fuel is then transferred into specialized containers and shipped to the United States for reprocessing.

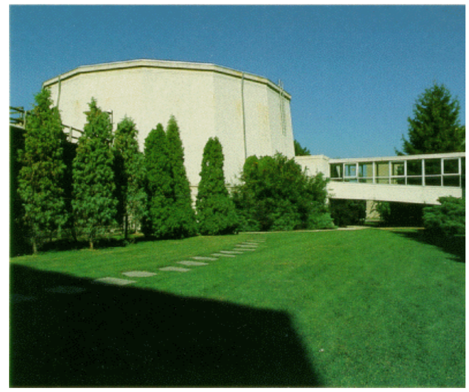

Figure 2.13: Nuclear Reactor at McMaster University

2.4.3 Slowpoke Reactors

Slowpoke is an acronym for Safe Low Power Critical Experiment. Figure 2.14 shows a 20-kWt Slowpoke reactor located at Chalk River. The original purpose of this reactor was to perform neutron activation analysis, trace radioisotope production and to aid in teaching nuclear science and engineering. A total of eight SLOWPOKE reactors are located across Canada and in Jamaica, out of which only six are now operating. AECL will, under contract, take possession of used fuel from its Slowpoke reactors.

Figure 2.14: Slowpoke Reactor at Chalk River

3.0 ADDITIONAL CONSIDERATIONS

The purpose of this chapter is to provide an overview of a number of regulatory, occupational and environmental issues relevant to reactor site storage of used nuclear fuel. A few general comments on public perception of reactor site storage of used nuclear fuel are also provided.

The recent EISs in support of dry storage of used nuclear fuel and associated discussions form much of the basis for this chapter. [7, 8, 9, 23, 24]

3.1 FEDERAL REGULATOR

The Canadian Nuclear Safety Commission (CNSC) is responsible for the regulation of all nuclear facilities in Canada and hence for the regulation of used nuclear fuel.

3.2 SAFEGUARDS

The Safeguarding of used nuclear fuel is the responsibility of the International Atomic Energy Agency (IAEA), and is represented in Canada by the CNSC. Continuous Containment/ Surveillance (C/S) will be required by the IAEA to demonstrate the continuous custodial control of the used fuel. Canada is required to report in fulfillment of its obligations pursuant to article 32 of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management coordinated by the IAEA, its national inventories of spent fuel and radioactive waste. A public document following the outline as prescribed under article 29 of the Joint Convention was produced by the CNSC in fulfillment of this obligation in May 2003. [32]

3.3 SECURITY

Security systems for the storage of used nuclear fuel must satisfy the requirements of the CNSC. Security programs fall under the category of prescribed information. Prescribed information is defined in the Canadian Nuclear and Safety Regulations as information that concerns *security arrangements, security systems and security procedures established by a licensee in accordance with the Nuclear Safety and Control Act. Disclosure of such information is restricted.*

In general terms, however, security is maintained by trained and equipped security staff including security guards responsible for day-to-day operations, maintenance staff who ensure the condition and upkeep of the security infrastructure, and engineering staff who are responsible for system surveillance and condition. Local police assist the security staff in their duties, when requested. Security procedures are designed to ensure that only staff, contractors and visitors who have been authorized gain access to the used fuel storage facility. The procedures include information, verification of documentation, physical searches, visitor escort, and security clearance.

3.4 OCCUPATIONAL HEALTH AND SAFETY PROGRAMS

The following section briefly outlines various occupational health and safety programs applicable to all OPG sites. In general terms, similar practices would apply to other reactor sites.

3.4.1 Occupational Radiological Safety Management Program

This program is currently in place at all OPG sites and will be present for all new OPG facilities. The program identifies the operations and materials that potentially contribute to the occupational dose and provides guidelines to monitor and minimize occupational dose and reduce the potential for contamination in the facility.

3.4.2 Contamination Control

After a DSC is prepared for transfer; a Transfer Vehicle picks up the DSC for on-site transfer to the Processing Workshop. Before exiting the fuel bays, both the vehicle and DSC are monitored for contamination and decontamination of the DSC is done if required. In the processing building, the DSC is prepared for storage. Then the exterior DSC surfaces are again checked for surface contamination and decontaminated if required.

During storage, DSCs are monitored for loose contamination. Any occurrence of loose contamination is removed by manually wiping with a cloth, or by wet methods if necessary, taking appropriate measures for containment of contamination at the source and for personnel protection. All facilities are equipped with contamination monitoring tools.

3.4.3 Radiological Hazard Monitoring

In addition to careful monitoring of potential radiological doses to workers, monitoring of area gamma radiation levels and contamination levels is also done along with routine radiological surveys. This helps to detect any changes in radiological hazard levels on a timely basis in order to take the proper remedial actions and avoid unnecessary radiation exposures.

3.4.4 ALARA

An ALARA (as low as reasonably achievable) assessment is carried out during the detailed design phase of all facilities. The purpose of this pre-operational assessment is to identify potential radiological and non-radiological hazards associated with facility operations, and to provide a baseline for radiological safety performance. These analyses help to ensure that doses to workers are low.

3.4.5 Doses to Workers

OPG assesses all occupational doses of ionizing radiation received by workers and visitors to their facilities. CNSC also requires OPG to provide dosimetry data to the National Dose Registry (NDR), which is maintained by the Radiation Protection Bureau of Health Canada. The annual dose limit for Nuclear Energy Workers (NEWs) is 50 mSv in any single year and 100 mSv over 5 years (i.e., the average dose to individual workers must be below 20 mSv per year).

The recent Environmental Assessment in support of Phase II used fuel dry storage at Pickering indicates that the incremental dose to individual workers at Pickering Nuclear from Normal operation of the existing used fuel dry storage facility would be less than about 0.64 mSv/y and that the average individual dose to nuclear worker at Pickering Nuclear would be less than about 1.7 mSv/y, which includes any contribution from used fuel management.

3.5 ENVIRONMENTAL PROGRAMS

This section outlines some of the environmental, safety and monitoring programs at Pickering sites. Programs are similar at all sites within OPG.

3.5.1 Environment, Safety and Health Management Systems

The Nuclear Waste Management Division (NWMD) has established this system in order to provide an effective method of managing risks. Workers and the public are ensured safety, and the environment is ensured protection since this program sets controls on operations in nuclear facilities. The International Safety Rating System (ISRS) and International Environmental Rating System (IERS) require the NWMD to follow these controlled activities. OPG's ISO 14001 Environmental Management System (EMS) covers the environmental aspect of the program.

International Environmental Rating System/ International Safety Rating System

These systems consist of 20 elements, which are implemented by OPG to help manage potential losses arising from an undesirable event. Administrative and technical procedures, employee training, and scheduling activities in the work control system are all part of these loss control measures.

Environmental Management System

The requirements of the ISO 14001 EMS Standard are followed by the Nuclear Waste Management Division's managed environmental program. These requirements include:

- committing to continual improvements of its environmental performance,
- complying with all relevant legislation,
- committing to the prevention of pollution, and
- ensuring that the adverse environmental impacts of its activities, products and services are as low as reasonably possible.

Annual reviews and evaluations maintain the performance of the EMS by the Environmental Management Review Team which determines the progress of objectives and targets for the Significant Environmental Aspects and establishes new targets and objectives as needed.

3.5.2 Doses to Public

The recent Environmental Assessment in support of Phase II of Used Fuel dry storage at Pickering reports that the annual dose to a hypothetical maximally exposed individual living near and on the east property boundary would be less than 10 μSv/y which is less than 1% of CNSC's regulatory limit at a very small fraction of the dose from the natural background (OPG 2003).

3.6 PUBLIC ACCEPTABILITY ISSUES

This summary was created based on a review of readily available reports and participation in the Dry Storage Facility Environmental Assessment for Pickering and Darlington Nuclear.

In the late 1980's, the Siting Task Force on Low-Level Radioactive Waste Disposal recognized that there was a lack of public trust and hostility towards nuclear waste producers and regulatory agencies. They suggested that this lack of trust was the product of the lack of sound solutions for managing the waste, general distrust in government, and higher public concern about the consequences of ionizing radiation than about the probability of an event occurring. The Seaborn Panel in 1998 in carrying out their assessment of AECL's concept for the management of used nuclear wastes came to a similar conclusion. "The public tends to be concerned less about the probability of extreme events than about their potentially negative consequences and the magnitude, the reversibility and the extent over time of these consequences." The Seaborn Panel identified the same lack of trust of the federal government, regulatory agencies and the nuclear industry as the Siting Task Force identified.

The Nuclear Waste Management Organization (NWMO) has recently completed an investigation of relevant public attitudes [25]. This investigation consisted of workshops with fourteen discussion groups drawn from the general public within a variety of communities.

Generally, the Canadian public has an extremely low awareness and knowledge of nuclear waste and its source, nuclear power. [26-p.2] Participants in the discussions were emotionally subdued. However, concern tended to rise as participants sought information about nuclear waste. Furthermore, facts only went so far and thinking about the issues created more worry. "*Of this, however, participants were certain: any solution to this 10,000 year challenge will be threatened by changing weather patterns, earthquakes or ground shifts, human neglect, mischief or abuse (such as terrorism), simple mechanical failure, perhaps even by the effects of the radiated material on the containers and vaults themselves."* [26-p.12]

Most participants could not see being involved in the issue unless they felt that "their backyard" was threatened. Those that did not live near a nuclear facility felt they were safe from any decision making, while those participants who lived near a nuclear facility felt that the costs of nuclear waste should be spread more broadly to those who experienced the benefits of nuclear power. Trust is a major issue with respect to nuclear waste. Participants were willing to trust the NWMO as long as it was independent of government and the nuclear industry, benchmarked against the world's best, directed by science, led by an active and known CEO, counseled by an expert Advisory Council, and competently managed. *"The role of the federal government in reviewing and deciding the fate of a long-term approach recommended by the NWMO was the single most contentious item."* [26] The involvement of the federal government and/or nuclear industry was seen as a detriment to the establishment of trust. *"Several people in most groups rejected the notion that only three options for long-term nuclear waste management be examined over a three-year period. Their view was that it ought to be an ongoing concern until the means are found to rid society of the danger altogether. Re-use of spent fuel waste, re-processing of it into harmless substances and its complete neutralization were additional options perceived to be worthy of study."* [26-p.13]

Recent proposals for the storage of used nuclear fuel in dry storage containers at Pickering and Darlington Nuclear have raised some comment from the general public. Most comments, particularly in the wake of September 11, reflected concerns about the security of fuel currently stored at the reactor sites. Other concerns related to the safety of the dry storage technology, the visibility of the buildings that will house the storage containers, and concern that this form of storage will become long-term. Examples of questions and (general) responses to questions from the public that arose during the recent EA process for Phase II of the Pickering Waste Management Facility [8] are given below:

How safe is Dry Storage?

The used nuclear fuel stored in DSC is made of solid pellets of uranium dioxide. Uranium dioxide contains over 99 per cent of the radioactive material. The pellets are a solid ceramic-like material. Pellets, or used nuclear fuel, are therefore encased in sealed metal tubes that act as an initial barrier to radiation.

Each DSC has walls of high density, 20 inches thick, reinforced concrete, that is lined outside with half-inch thick steel. Before storing the DSC in the facility, the lid is welded to the base of the container. In addition, the thickness of the concrete and steel provides an effective barrier against the radiation from the used fuel.

Would radiation escape from the storage building?

The radiation field outside the DSC is due to the gamma rays emitted by used fuel. The radiation field outside the storage building would be much smaller than the radiation field on contact with the container because of the distance from the DSCs and the shielding effect of the building walls.

What happens if there is an accident while loading or transporting a DSC?

Based on the rigorous design, testing and operating procedures at OPG, the risk is small. OPG concludes that, even in the worst-case accident postulated to be cladding rupture of 100% of the fuel elements of 384 bundles and a DSC seal rupture resulting in the instant release of the entire free inventory of tritium and krypton-84 gases, the doses received by workers and the public would be only a fraction of the dose limits established by Canadian regulations.

4.0 SUMMARY

The Nuclear Waste Management Organization (NWMO) was established under the Nuclear Fuel Waste Act to investigate approaches for managing Canada's used nuclear fuel.

In order to help develop their approach for long-term waste management, the NWMO decided to commission the development of a number of background papers on specific topics. This paper on the "Status of Reactor Site Storage Systems for Used Nuclear Fuel" is one of these background papers and like the other background papers, will be posted on the NWMO website (http://www.nwmo.ca/).

Steam which energizes the turbines to generate electricity at nuclear power stations is produced by heat from nuclear fission in fuel bundles in each reactor. In addition to heat, uranium fission also produces fission products – radioactive isotopes of lighter elements (e.g., Cs-137, I-131, Kr-85) and transuranics (radioisotopes heavier than uranium) that remain trapped within the fuel elements. The inventory of fission products and transuranics increases with increasing residence time of the fuel in the reactor.

Upon removal of the used fuel from the reactor, the production of fission products ceases, but the used fuel continues to produce intense gamma radiation and decay heat. To protect workers from the radiation levels and to remove the decay heat, used fuel bundles are stored in water-filled fuel bays at each reactor site. The fission product inventory, gamma radiation levels and decay heat decrease with increasing time after removal of the used fuel from the reactor. After cooling in wet storage, referred to as irradiated fuel bays (IFBs), the used fuel can be economically and safely transferred into dry storage containers for extended interim storage at each reactor site.

In general terms, the key observations from this review of reactor site storage systems for used nuclear fuel include:

1. All spent reactor fuel produced in Canada is strictly regulated by the Canadian Nuclear Safety Commission (CNSC) and inventoried and reported on to the Joint Convention administered by the International Atomic Energy Agency (IAEA).
2. In Canada, both wet and dry storage technologies have been proven safe with over 25 years of proven operation.
3. Dry storage management systems currently in use in Canada have a design life in excess of 50 years and an expected life of at least 100 years.
4. On site wet and dry spent fuel storage is presently practiced at all commercial reactor sites in Canada. As of December 31, 2001, there were about 1,400,000 spent fuel

bundles in wet storage, and 200,000 bundles in dry storage at Canadian Nuclear reactor sites.

5. Additional dry and wet storage facilities are presently being planned or under construction sufficient to hold all of the fuel bundles that will be produced by Canadian power reactors to the end of their design service life.
6. In 1998, the Seaborn Panel in assessing AECL's concept for managing used nuclear fuel, observed, as did the Port Hope Study Task Force some 10 years earlier, that the public lacks trust in the federal government, its regulatory agencies and the nuclear industry. Establishing public trust will be key to the success of the NWMO's program.

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APPENDIX A

ANNOTATED BIBLIOGRAPHY OF USED NUCLEAR FUEL STORAGE WEBSITES

Preface

There is a considerable information on a nuclear power, radioactive waste storage site, nuclear waste management and other "nuclear related" topics on the web. A number of these web sites were reviewed for this background paper for information relevant to this background paper as reactor site storage of used fuel. The appendix provides a brief commentary on the various web sites examined during the preparation of this background paper. In same current area, the realm is directed to the web site home page and in other cases; the realm is directed to the specific pages.

TABLE OF CONTENTS

1 World Nuclear Association

Web address:
http://www.world -nuclear.org/
***Summary*:** The World Nuclear Association website discusses worldwide advances in Radioactive waste management. Only particular sections on this web site were visited relating to used fuel dry storage methods. Information on the following website is given for different countries:

- General policies, plans& funding
- Low & intermediate waste treatment
- Low & intermediate waste disposal
- Transuranic waste disposal
- Spent fuel & high level waste interim storage
- Research
- Transportation
- Clean up
- Treatment and conditioning of industries
- Site Rehabilitation & decommissioning

2 Yucca Mountain – Eureka County Nuclear waste

Web address: http://www.yuccamountain.org/time.htm
Summary: This web site discusses the timeline for the nuclear waste policy dilemma. It shows the historical view, current developments and future action plans for the Yucca Mountain project.

3 Nuclear Waste: Storage and Disposal Methods

Web address: http://www.etu.edu/writing/3120f99/nuclear2.htm
Summary: This website mainly discusses nuclear waste storage and disposal methods by the United States. It gives an introduction discussing the dilemma of nuclear waste, and then explains the ways used and considered for removing such hazardous waste. Proper disposal of plutonium has now become important to prevent terrorism.

4 Nuclear Waste Forms and Disposal Methods

Web address: http://www.platts.com/features/nukewastedisposal/waste.shtml
Summary: The website categorizes the waste nuclear waste with different levels according to the type of waste. For each type of waste, it discusses the disposal and storage methods currently used.

5 US Department of Energy, Office of Environmental Management

Web address: http://www.em.doe.gov/em30/waststor.html
Summary: The above web site explains the potential hazards of nuclear waste, types of waste, and the way this nuclear waste is currently stored in United States.

6 Connecticut Yankee: Fuel Storage

Web address: http://www.connyankee.com/html/usedfuel_storage.html
Summary: The web site describes the dry fuel storage method, and the reasons for ConnecticutYankee site in United States to switch from Wet to Dry Fuel Storage method. Paper is described as "Spent fuel White Paper by the CY, YAEC, and New England Council"

7 Radioactive Waste Storage Sites and Methods

Web address: http://www.aber.ac.uk/iges/cti-g/hazards99/nuclear
Summary: The website gives classification of radioactive waste by type and level of radioactivity. For each type of waste, it discusses the disposal and storage methods currently used in England.

8 The Swedish System- High Level Waste

Web address: http://193.235.25.3/English/avenka_systemet/hogakivt/clab.html
Summary: This website describes the Swedish Central Interim Storage Facility for spent nuclear fuel known as CLAB. It explains the importance of this facility, the need, and how is this waste stored at the facility.

9 Standort-Zwischenlager: On-site Interim Storage Facilities

Web address: http://www.infokreis-kernenergie.org/e/aufbauundfunktion.cfm
Summary: This website discusses on-site interim storage facilities in Russia, and their current method of storage. It also explains completely the different components in Castor Casks, and its functionality.

10 The Bane of Nuclear Energy: Nuclear Waste Storage

Web address: http://library.thinkquest.org/17940/text.waste_storage.html
Summary: This website has a general description on the options used to store nuclear waste especially in United States. It discusses both temporary and permanent storage/disposal methods particularly for fuel rods. Also, it gives a brief overview of Yucca mountain nuclear waste disposal site.

11 "Prolonging Nuclear Waste Storage"

Web address: http://www.howstuffworks.com/news-item141.htm
Summary: This website has a brief article, posted on August 8, 2000, which explains the discovery by international team of scientist. Scientists claimed that they have discovered a material, ceramic in structure called complex oxides, which can hold nuclear waste safely for thousand of years, that is, even after irradiation.

12 Nuclear Waste in Sweden: 3. "Solving the high-level waste problem"

Web address: http://www.folkkampanjen.se/nwchap3.htm
Summary: This website discusses the high level waste problem in Sweden, and how it has been resolved over the past years. It describes the stipulation act, the KBS affair, and the history and functionality of CLAB (Central Storage facility for Spent Nuclear Fuel).

13 Nuclear Waste Disposal Fund

Web address: http://www.etde.org/html/budget/nwdf.html
Summary: This website is unique because it contains information about the mission of the Office of Civilian Radioactive Waste Management, overview of the FY program, highlights of changes in program, and finally, the budget required for disposing the nuclear waste.

14 Frontiers: Article on Argonne's Spent-Fuel

Web address: http://www.anl.gov/OPA/frontiers/d5ee.html
Summary: The website is an article on Argonne National Laboratory's spent fuel. It discusses the possibility of reducing the nuclear waste storage shortage by recycling through an Advanced Recycling Facility (ARF).

15 Nuclear Waste Storage in Andreeva Bay

Web address:
http://www.bellona.no/en/international/russia/navy/northern_fleet/spent_fuel/andreeva_bay/
Summary: This website explains the nuclear waste storage methods in Andreeva bay, the largest storage site in Russia. A detailed map is given for all storage locations. Other information regarding the history of Andreeva Bay, and recommendations for nuclear waste disposal are also provided.

16 International Nuclear Waste Disposal

Web address: http://www.uic.com.au/nip49.htm
Summary: This website outlines the international nuclear waste disposal concepts contained in a Nuclear issues briefing paper published in October 2002. Main sections explained on this website include responsibility for wastes, international repositories, the Pangea proposal, and other proposed projects.

17 Rising Needs: Management of Spent Fuel at Nuclear Power Plants

Web address: http://www.iaea.or.at/worldatom/Periodicals/Bulletin/Bull401/article6.html
Summary: The article explains the management of nuclear spent fuel at nuclear power plants in different countries. It outlines the different approaches used by different countries, changing practices, and the developments in some of these countries in resolving the problem of nuclear fuel storage and disposal.

18 Different Strategies for Different Waste

Web address:
http://www.greenpeace.org.au/nuclear/whatawaste/solutions_differentstrategies.html
Summary: This website, by Green Peace Australia, briefly explains the strategies currently in use in Australia for different kinds of nuclear waste. It emphasizes stopping the production of the waste on the basis of being environmentally unacceptable.

19 Nuclear Power in Quebec

Web address: http://www.ccnr.org/Nuke_Quebec.html
Summary: This website prepared for *Public Debate on Energy* by Gordon Edwards, President of CCNR, discusses the historical perspective, escalating costs, changing perceptions, nuclear hazards, radiation exposure and health concerns associated with Nuclear power in Quebec.

20 The Canadian Nuclear FAQ- Section E: Waste Management

Web address: http://www.nuclearfaq.ca/cnf_sectionE.htm
Summary: This website explains how high-level nuclear waste is managed in Canada. It discusses brief procedures for interim storage, cooling, and shielding of nuclear fuel. Further research and development plans on deep geological disposal (DGD), high-level nuclear waste site, are discussed as well. In addition, Government special organizations, NWMO being one of them, to overcome the problem of nuclear storage and disposal are also mentioned in this article.

21 Waste disposal issues in North and South America

Web address: http://www.platts.com/features/nukewastedisposal/amerissues.shtml
Summary: This website expands on some of the current measures taken by Canada, the United States, and South America for the disposal of nuclear waste.

22 Energy Nuclear – The power of people

Web address: http://www.entergy-nuclear.com/Nuclear/environment/fuelStorage.asp
Summary: The above website is owned by Entergy Nuclear. Entergy operates ten nuclear units at eight plant sites:

- Arkansas Nuclear One Units 1 and 2 near Russellville, Ark.
- Grand Gulf Nuclear Station in Port Gibson, Miss.
- River Bend Station in St. Francisville, La.
- Waterford 3 in Taft, La.
- Pilgrim Nuclear Station in Plymouth, Mass.
- Indian Point Energy Center Units 2 & 3 in Westchester County, N.Y.
- James A. Fitzpatrick in Oswego County, N.Y.
- Vermont Yankee in Vernon, Vermont
  Spent fuel storage information along with location and detailed information is available for all the sites given above on the website.

23 Nukeworker.com – United States

Web address:
http://www.nukeworker.com/nuke_facilities/North_America/usa/nrc/region4/rancho_seco/index.shtml
Summary: This website provides information about the nuclear facilities in United States. In addition, facilities around the world are listed as reference links. It covers a broad range of topics, and hence, is very useful in expanding knowledge of the nuclear field. Facilities are clearly marked on maps, and the user can click on a facility for more information. Being an interactive website, it makes navigation for a broad range of topics much simpler.

24 Southern Company-United States

Web address:
http://www.southerncompany.com/southernnuclear/home.asp?mnuOpco=soco&mnuType=sub&mnuItem=sn
Summary: This website has a brief description and links for all the nuclear plants owned by southern company in United States. It also explains the details regarding the management of

nuclear used fuel in these plants. Southern Company also owns coal plants which are discussed in this website as well. Finally, the Environment section on the website discusses the hurdles and achievements of Southern company in maintaining clean air, water, land and soil for the public.

25 Constellation Energy Group – United States

Web address: http://www.constellation.com/generation/ccnpp.asp
Summary: Constellation Energy Group is another company in United States, which owns numerous power plants. These plants can be categorized into nuclear, fossil fuel, and hydro. Details of all nuclear power plants are given with interesting key facts. Fact sheets also add a unique element to the description given for each nuclear plant. Specific environmental concerns are explained in brief. The Website is a good reference for finding out the location, and current status of nuclear power plants in United States.

26 Yankee Rowe's used nuclear fuel – United States

Web address: http://www.yankee.com/fuel.html
Summary: Yankee Rowe Nuclear power plant is decommissioned and the used nuclear fuel is stored at the site using dry storage. The website gives an overview and a description of the importance of the dry storage method at this site.

27 Prairie Island Nuclear Generating Plant – United States

Web address: http://www.nmcco.com/about_us/locations/prairie_island.htm
Summary: NMC operates six nuclear plants: Duane Arnold Energy Centre in Palo, Iowa; Kewaunee in Kewaunee, Wis.; Monticello in Monticello, Minn.; Palisades in Covert, Mich.; Point Beach in Two Rivers, Wis.; and Prairie Island in Welch, Minn. Since Prairie Island site stores used nuclear fuel, information for this site was gathered. The Website describes the history and the specifications of the nuclear reactor at this site

28 Minnesota – United States

Web address: http://www.eqb.state.mn.us/EnergyFacilities/nuclear.html
Summary: Information for storage methods of used nuclear fuel is available on this web site for nuclear power plants in Minnesota, United States. A background paper is also provided which explains some of the historical events concerning the dry storage methods currently used.

29 ŠKODA HOLDING – Dry Cask Design

Web address: http://www.skoda.cz/produkty.asp?Q853A=C0J2P1T1K90ID3679
Summary: ŠKODA HOLDING makes dry casks for the storage of spent nuclear fuel. In the referenced web site above, a specific dry cask design is considered. This particular Dry Cask design is named Castor V-21. Detailed specifications for this design given on the website are likely aimed at customers interested in buying the specific design as well as for public interest.

30 TN-24 Dry Cask – Cogema Logistics

Web address: http://www.cogemalogistics.com/servlet/pdf/cogemalogistics/modules/tn_24.pdf
Summary: The TN-24 Dry Cask is used at a number of reactor sites in the United States. The TN-24 design is described in detail on the Cogema Logistics' web site, since this design is one of their products. As stated on the web site, "COGEMA LOGISTICS provides comprehensive and tailor made solutions for all radioactive materials transportation and dry storage technologies, from package design to transport operations."

31 Nuclear Regulatory Commission – United States

Web address: http://www.nrc.gov/reading-rm/doc-collections/news/1998/98-050iii.html
Summary: VSC-24 Dry Cask Design information is available on the Nuclear Regulatory Commission (NRC) website. NRC is a United States government organization which controls all nuclear related activities including the management of used fuel. NRC must approve dry Cask designs for all sites before any casks are considered, which implies that NRC must have the design specifications and any other relevant information for approval.

32 Nuclear Waste Project Office's Web site – published article

Web address: http://www.state.nv.us/nucwaste/trans/1pic11.htm
Summary: The Nuclear Waste Project office has listed an article on the website, which was published in September 1996 by Planning Information Corporation. This article was named "The Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste". One section of this article discusses about the various cask designs used in United States at that time. Although technologies have advanced significantly since then, the information available does provide a background for the casks used, and the companies involved in providing these designs.

33 Office of Personal Management – Federal Documents (United States)

Web address: http://www.opm.gov/fedregis/2001/66-0035469-a.pdf
Summary: The Office of Personal Management (OPM) publishes federal documents themselves or in cooperation with other federal agencies. One of the documents searched provided

information on NUHOMS-24P dry cask design used in United States. OPM states that all other federal register documents are available from the National Archives and Records Administration.

34 NRC – NUHOMS-24PT1 Dry Cask Design

Web address: http://www.nrc.gov/reading-rm/doc-collections/news/2002/02-149.html
Summary: The website is a collection document by NRC, which discusses on the NUHOMS-24PT1 Dry Cask Design. A range of design information was collected to identify the availability of designs and the options for storing used nuclear fuel.

35 Holtec International – United States

Web address: http://www.holtecinternational.com/drystoragecasks.html
Summary: Holtec International, a company in United States, is involved in providing design solutions in spent fuel system, nuclear fuel components, and fossil power. Holtec International produces dry storage casks of different designs. Two most common designs used are HI-STAR and HI-STORM.

36 Nuclear Energy Institution – United States

Web address: http://www.nei.org/
Summary: The Nuclear Energy Institute web site gives all the relevant data for nuclear industry and research areas in the United States. Spent fuel storage statistics are also provided in this web site. All facilities currently storing spent fuel are mentioned. Nuclear data comprises of perspective on public opinion, nuclear power plants, license renewal for each plant, changes in nuclear plants' ownership and management, environmental aspects, fuelling or refuelling requirements, used fuel storage, amount of nuclear waste, reactors currently shut down or decommissioned, costs and funding of nuclear reactors, and finally, a short history of each nuclear plant.

37 Surry Power Station-United States

Web address: http://www.etceteraweb.com/IYNC/11-22-02.Surry-store.pdf
Summary: The above website links to a document, which explains the plans for Surry Power station relating to the storage of used fuel. Until a permanent repository is built, Surry Power decided to store the used fuel at the site. Other nuclear plants around the world are taking similar actions.

38 International Atomic Energy Agency

Web address: http://www.iaea.org
Summary: This website is a link to the International Atomic Energy Agency. It gives detailed information on the organization, their key aspects. The International Atomic Energy Agency (IAEA) serves as the world's foremost intergovernmental forum for scientific and technical co-operation in the peaceful use of nuclear technology. They place information on annual reports, recent publications, and documents, meeting minutes, periodicals and other relevant programs.

39 Nuclear Energy Agency (NEA)

Web address: http://www.nea.fr/
Summary: This website is a link to the Nuclear Energy Agency. The Nuclear Energy Agency (NEA) is a specialized agency within the Organisation for Economic Co-operation and Development (OECD), an intergovernmental organisation of industrialised countries, based in Paris, France. NEA assists its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for the safe, environmentally friendly and economical use of nuclear energy for peaceful purposes.

APPENDIX B

SELECTED OBSERVATIONS ON DRY STORAGE OF USED NUCLEAR FUEL

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APPENDIX B: SELECTED OBSERVATIONS ON DRY STORAGE OF USED NUCLEAR FUEL

B.1 INTRODUCTION

In Canada, used fuel is stored in fuel bays at nuclear reactor facilities for a nominal period of ten years, to allow for cooling and radioactive decay. After cooling, the used fuel is transferred to above ground canisters or concrete modules at reactor sites. As a consequence of the potential radiological hazard and the need to safeguard the inventory of fissile material in the spent fuel, the reactor site storage systems must satisfy stringent safety, security, engineering and environmental requirements while at the same time being both economically viable and acceptable to the public.

This appendix provides some background information on the evolution of dry storage in Canada. In addition, based on the availability of information in the public domain, a number of comments are also provided on dry storage of used nuclear fuel in the United States and elsewhere.

In Canada, consideration of dry storage as an alternative to wet storage was initiated by Atomic Energy of Canada Limited (AECL) and Ontario Power Generation (OPG) in the mid 1970's. Initially, AECL evaluated engineered concrete canister designs using electrical heating as a power source. The next phase evaluated the impact of used fuel storage on the canister design through the loading of two canisters with used CANDU reactor fuel from WR-1 or from Douglas Point respectively.

The AECL program also included a materials test component to evaluate the effects of storing fuel materials, which defect during service, or which were otherwise removed from protective fuel cladding.

AECL's demonstration project continued for approximately 25 years even though data collected early in the program had confirmed the viability of concrete canister storage as a safe alternative for the interim storage of used fuel.

Based on the results of the demonstration program [2, 3, 4, 5] commencing in 1977, canisters were routinely used for the storage of WR-1 used fuel at Whiteshell. Following the shutdown and defueling of the WR-1 reactor in 1985 to 1989, all remaining WR-1 fuel was transferred to canister storage [6]. Therefore, routine use of the dry interim storage option at Whiteshell represents over 25 years of experience. Routine surveillance monitoring has indicated no problems to date and the planned canister lifetime of up to 100 years appear viable.

Ontario Power Generation (OPG) uses a standard OPG designed canister called a DSC (Dry Storage Container). This standardized container has been used since day 1 at Pickering and is currently used at Bruce. It will also be used at Darlington.

Prior to the Pickering Dry Storage Facility going into operation, OPG had an experimental prototype called the CIC – Concrete Integrated Cask, which was similar, but had a bolted lid and circular footprint. Only two of these were built. At the end of the test period, the fuel was retrieved and the containers scrapped.

In the United States, cask designs differ with size, density, shielding factor, cooling time and maximum burn up rate. Companies also produce different designs based on the type of reactor, PWR (pressurized water reactors) or BWR (Boiling Water Reactor). Since companies in US also import their designs, specific designs are dependent on the climatic and environmental conditions of the country.

Overall, as noted in the main text, dry storage appears to offer a viable approach to managing used nuclear fuel either at reactor or in a central location. This appendix provides an brief overview of dry storage systems currently in use in Canada, and to add perspective, a brief description of the status of dry storage system in the United States and elsewhere.

B.2 CANADA

B.2.1 AECL DRY STORAGE SYSTEM

The Whiteshell waste management area in shown in Figure B-1 with the dry storage area shown in the lower left of the figure.

FIGURE B–1
WR-1 USED FUEL STORAGE

The type of canister used at the Whiteshell Storage Facility [27] is a structurally continuous hollow vertical cylinder of reinforced concrete, approximately 5.4 m high with a diameter of 2.6m and an internal bore of 0.8m. The top is fitted with a 0.9 m thick reinforced concrete closure plug. The canister cavity is lined with a steel pipe of 9.5 mm wall thickness (see Figure B-2). The fuel is packaged in cylindrical steel baskets 0.76 m in diameter by 0.59 m in height, which are stacked vertically in the canister cavity. Each canister accommodates a stacking of six baskets. A schematic of a typical basket configuration is shown in Figure B-3. All fuel loaded undergoes a minimum cooling period of 18 months to ensure a maximum total decay heat load in each canister of 4.4 kW.

FIGURE B-2
ELEVATION VIEW OF CANISTER

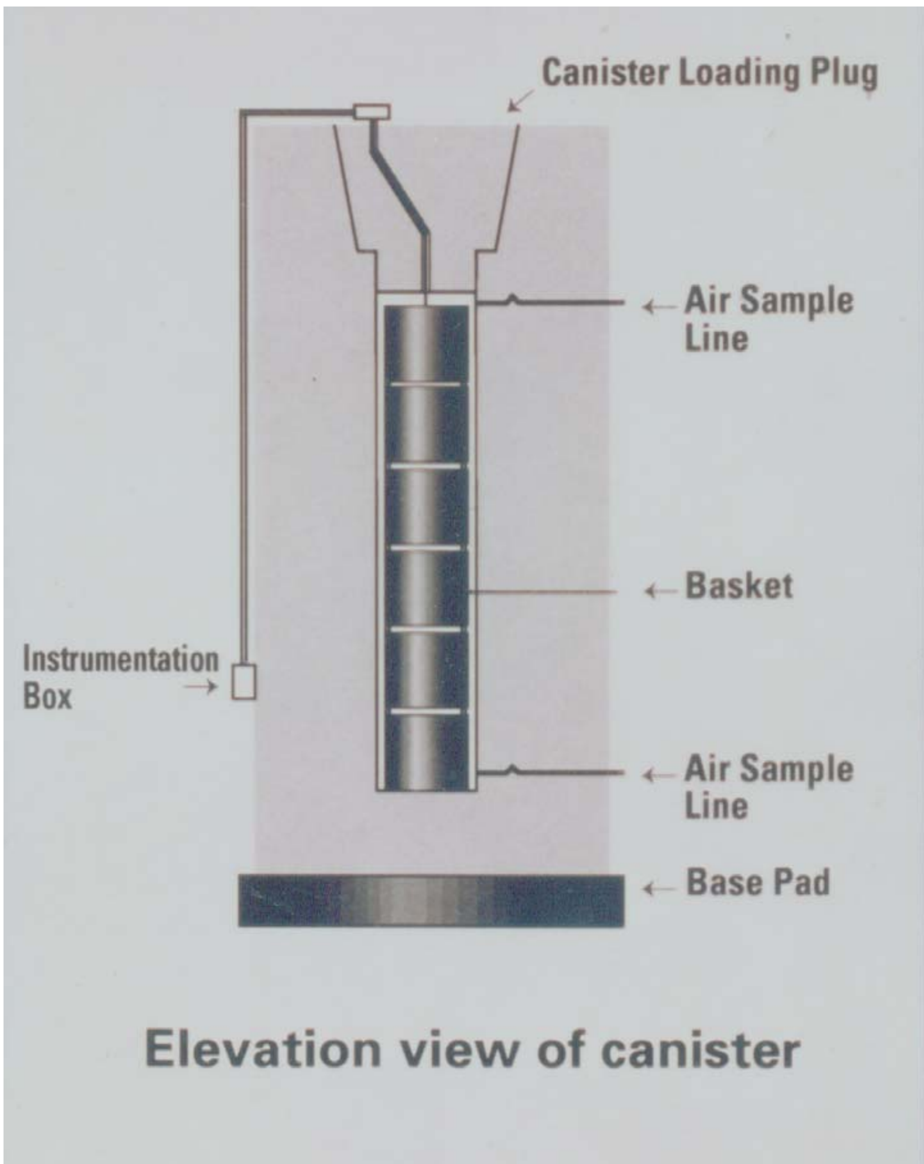
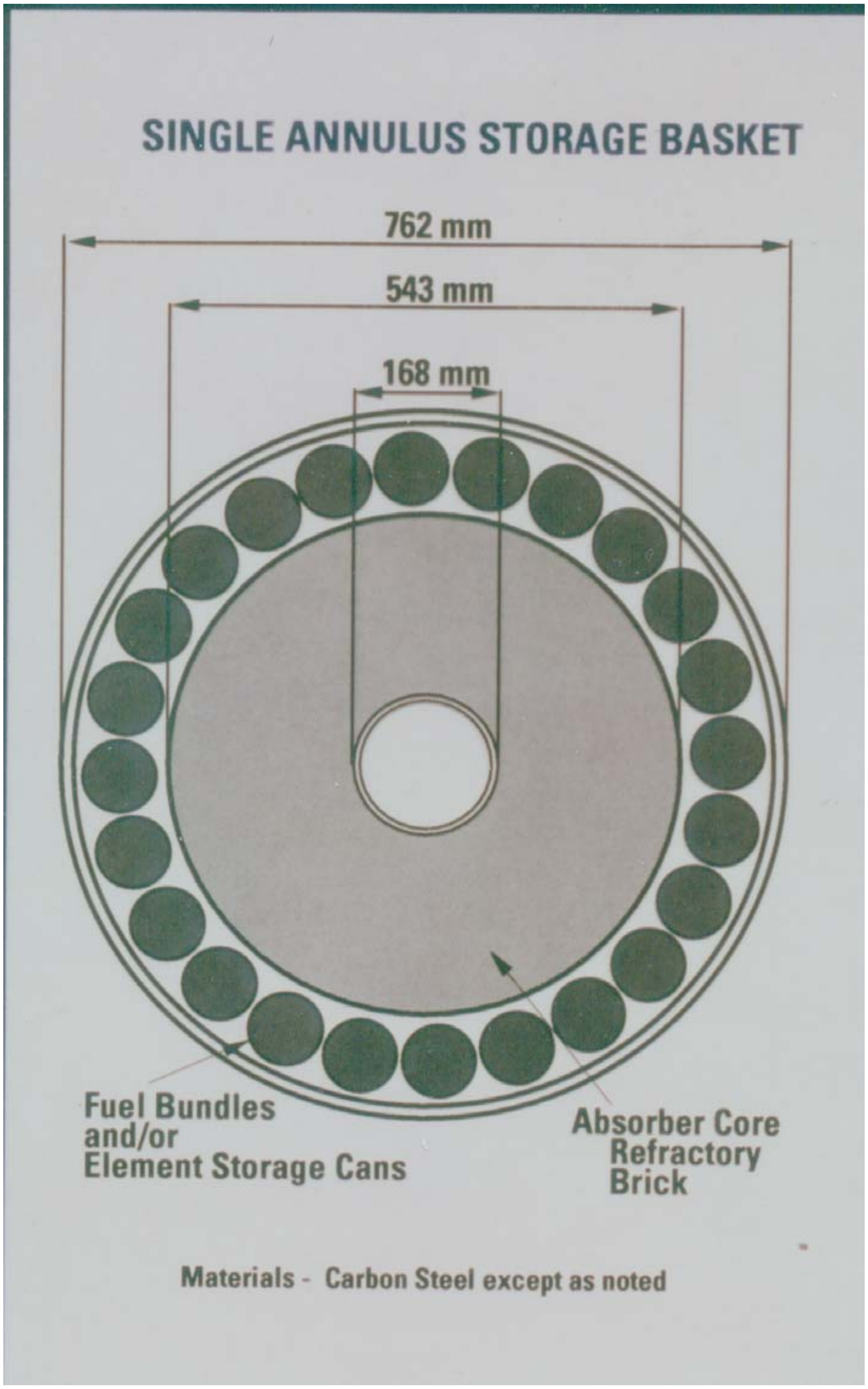


FIGURE B-3
SINGLE ANNULUS STORAGE BASKET



B.2.2 OPG (DSC) - Dry Storage Container (Standardized)

All facilities at Ontario Power Generation (OPG) are currently using a standard design for dry storage. This design is known as Dry storage Container (DSC). A DSC is a reinforced container with an inner steel liner and an outer steel shell. It is made of two sub-assemblies, a lid and a base. The base provides the storage space for the used fuel. This specific DSC can store 384 used fuel bundles in four standard storage modules.

Each module has a capacity to hold 96 bundles. Outer dimensions of the DSC are 2.120 x 2.149 m by 3.55 m in height. Inner dimensions are 1.022 x 1.321 m by 2.520 m in height. The thickness of each carbon-steel shell is 13 mm. The Maximum total weight of an empty DSC is approximately 60 Mg, and 70 Mg for completely filled DSCs, which includes the 11 Mg weight of the lid. The space between the inner liner and outer shell is filled with reinforced high-density concrete, with a density in the range of 3.5 to 3.7 Mg/m^3 and a full strength of 40 Mpa, which provides radiation shielding and maintains heat dissipation.

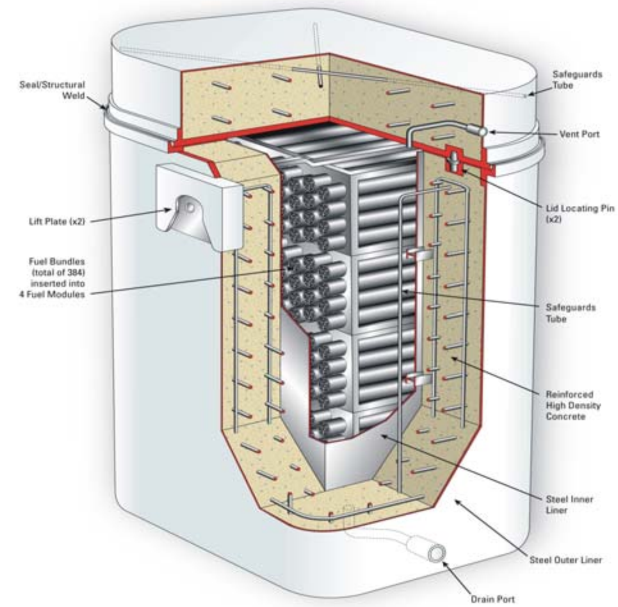


Figure B.4: Dry Storage Container (DSC)

Two separate U-shaped 25.4 mm outer diameter stainless steel tubes are embedded in the DSC walls and floor of the outer reinforcing grid. Similarly, two tubes are embedded in DSC lid, which run diagonally across the lid. These tubes provide for the installation of two different types of IAEA seals.

B.2.3 Other Sites in Canada

Based on the success of the canister storage program and Whiteshell's experience with routine use for WR-1 fuel, dry canister storage was extended to other AECL facilities. Fuel from several demonstration and/or prototype reactors was also stored in concrete canisters. The canisters used in these storage facilities incorporate the original Whiteshell design features but vary in height, and in some cases diameter, to accommodate local storage needs (e.g. space availability). Canister use at other sites includes:

- As part of shutdown and decommissioning activities for the Nuclear Power Demonstration reactor at Rolphton, Ontario, all used fuel was transferred to a new canister storage facility constructed at the Chalk River Laboratories site. The facility uses a modified canister that is ~1m taller than the original canister with an extended internal cavity accommodating stacking of 9 fuel storage baskets.

- Concrete canisters have been used to store the used fuel from the Douglas Point prototype reactor (Bruce Nuclear site) and from the Gentilly-1 reactor at the Hydro Quebec Nuclear site. Both facilities use the taller canister design. The Gentilly-1 canister storage facility is located inside an auxiliary building adjacent to the reactor.

- Concrete canisters are also used for routine fuel storage at the New Brunswick Point Lepreau reactor site. The design is similar in height to the NPD and Douglas Point canisters but incorporates an increased diameter to accommodate larger diameter fuel storage baskets.

B.2.4 MACSTOR –AECL

Drawing on over 30 years of experience in above-ground storage of used fuel, a subsequent addition to the AECL dry storage program was the development of the MACSTOR (Modular Air Cooled Storage) system (Figures B-5, B-6). MACSTOR provides highly efficient heat rejection and shielding capability and permits easy fuel retrieval. The design utilizes a monolithic concrete block arrangement with individual access ports accommodating fuel storage baskets in a vertical rectangular array. The MACSTOR facility is currently used by Hydro Quebec at Gentilly-2. That system accommodates stacking of 10 baskets and provides a highly compact and efficient storage option. When compared to the Point Lepreau canister storage facility, the MACSTOR unit uses approximately 50% of the land area required for the canister facility housing the same amount of fuel. The MACSTOR system is planned for commercial marketing by AECL.

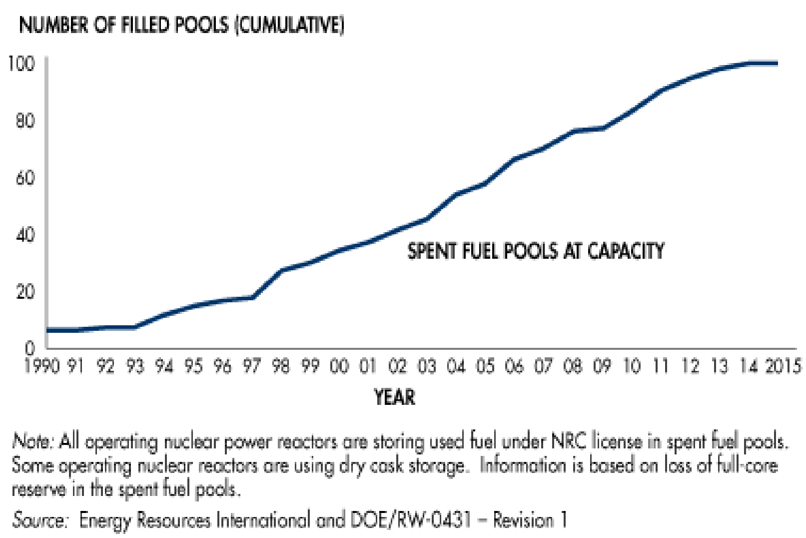
FIGURE B-5
A MACSTOR AT GENTILLY-2

FIGURE B-6
A MACSTOR AT GENTILLY 2

B.3 UNITED STATES

The United States stores used nuclear fuel from nuclear reactors in specialized containers in water pools, to provide cooling and to allow radioactive and thermal decay, and in dry storage containers for up to 40 years. The pools in United States are running out of space as illustrated in the graph shown below.

FIGURE B.7
FILLED POOLS SINCE 1990 IN THE UNITED STATES[1]



[1] www.nrc.gov

Some 20 commercial nuclear power plants in United States at 17 sites currently use on-site dry used fuel storage:

TABLE B.2.2
LIST OF NUCLEAR REACTORS USING DRY STORAGE TECHNOLOGY

	Plant Name	Owner
1	Oyster Creek	Exelon
2	Surry 1 & 2	Dominion
3	North Anna 1 & 2	Dominion
4	Arkansas Nuclear One 1 & 2	Entergy
5	H.B. Robinson 2	Progress Energy
6	Oconee 1, 2, & 3	Duke Energy
7	Calvert Cliffs 1 & 2	Constellation
8	Palisades	Consumers Energy
9	Prairie Island 1 & 2	Northern States Power
10	Point Beach 1 & 2	Wisconsin Electric Power Company
11	Davis Besse 1	First Energy
12	Susquehanna 1 & 2	Pennsylvania Power & Light
13	Hatch 1 & 2	Southern Company
14	Peach Bottom 2 & 3	Exelon
15	Dresden 1 & 2	Exelon
16	McGuire 1 & 2	Duke Energy
17	Ft. Saint Vrain	Decommissioned nuclear plant
18	Rancho Seco	Decommissioned nuclear plant
19	Maine Yankee	Nuclear plant being decommissioned
20	Yankee Rowe	Nuclear plant being decommissioned

Additional Storage will be required by 20 nuclear reactors at 17 sites by 2006.

The United States has been planning to build a permanent underground nuclear fuel storage repository at Yucca Mountain. The United States Nuclear Regulatory Commission (NRC) has given the approval, and the construction of the site is under way. However, it may take decades before the construction is completed since it involves the storage of used nuclear fuel from all areas of the United States and various areas of the world. Therefore, most reactor sites in the United States are currently storing spent nuclear fuel on site, and continuously expanding their sites for future storage.

This section provides some general comments on the kinds of dry storage used in the United States. Table B.2-1 is a summary of current practice in the United States.

TABLE B.2.1
DRY STORAGE TECHNOLOGIES AT DIFFERENT SITES IN UNITED STATES[2]

U.S. GENERATING COMPANIES WITH ON-SITE DRY STORAGE COMMITMENTS

OWNER/OPERATOR	REACTOR	DRY STORAGE TECHNOLOGY	LICENSING METHOD (1)	FACILITY Date (2)
Dominion Generation	Surry 1 & 2	Metal Casks (3)	Site Specific	1986
Progress Energy (CP&L)	H.B. Robinson	NUHOMS-07P	Site Specific	1986
Duke Energy	Oconee 1, 2, & 3	NUHOMS-24P	Site Specific	1990
Public Service Company of Colorado	Fort St. Vrain	Foster Wheeler MVDS	Site Specific	1991
Constellation Nuclear	Calvert Cliffs 1 & 2	NUHOMS-24P	Site Specific	1992
Consumers Energy	Palisades	VSC-24, NUHOMS 32PT	General License	1993
Nucler Management Company (Xcel Energy)	Prairie Island 1 & 2	TN-40	Site Specific	1993
Nuclear Management Company (WEPCO)	Point Beach 1 & 2	VSC-24, NUHOMS 32PT	General License	1995
First Energy	Davis Besse	NUHOMS-24P	General License	1995
Entergy Operations	Arkansas Nuclear One 1 & 2	VSC-24	General License	1996
Dominion Generation	North Anna 1 & 2	TN-32	Site Specific	1998
PP&L	Susquehanna 1 & 2	NUHOMS-52B	General License	1999
Exelon Generation	Dresden 1	Holtec HI-STAR	General License	2000
Exelon Generation	Peach Bottom 2 & 3	TN-68	General License	2000
Southern Nuclear Operating Company	Hatch 1 & 2	Holtec HI-STORM	General License	2000
Duke Energy	McGuire 1& 2	TN-32/ NAC UMS	General License	2001
Portland General Electric	Trojan	Holtec	Site Specific	Planned
Sacramento Municipal Utility District	Rancho Seco	NUHOMS-MP187	Site Specific	2001
Amergen	Oyster Creek	NUHOMS - 61BT	General License	2002
Yankee Atomic Electric Company	Yankee Rowe	NAC MPC	Site Specific	Planned
Energy Northwest	WNP2	Holtec HI-STORM	General License	Planned
Consumers Energy	Big Rock Point	BFS Fuel Solutions	General License	Planned
Arizona Public Service	Palo Verde 1, 2, 3	NAC UMS	General License	Planned
Entergy	Fitzpatrick	Holtec Hi-STORM	General License	2002
Maine Yankee Atomic Power	Maine Yankee (4)	NAC UMS	General License	2001
Connecticut Light & Power	Haddam Neck	NAC MPC	General License	Planned
Vermont Yankee Atomic Power	Vermont Yankee	Holtec HI-STORM	General License	Planned
Tennessee Valley Authority	Sequoyah 1 & 2	Holtec HI-STORM	General License	Planned
Southern California Edison	San Onofre 1, 2 & 3	NUHOMS -24PT	General License	Planned
Pacific Gas & Electric	Diablo Canyon, Humboldt Bay	HI-STORM 100	Site Specific	Planned
Exelon Generation	Dresden 2 & 3	HI-STORM 100	General License	Planned
Entergy	Grand Gulf	HI-STORM 100	General License	Planned
Entergy	River Bend	HI-STORM 100	General License	Planned
Nuclear Management Company	Duane Arnold	NUHOMS - 61BT	General License	Planned
Tennessee Valley Authority	Browns Ferry 1, 2, 3	Holtec HI-STORM	General License	Planned

(1) Site specific licenses are granted in accordance with 10 CFR 72. General licenses refer to the storage of spent fuel in certified casks in accordance with 10 CFR 72 Subpart K.

(2) Facility dates for reactors with site specific licenses earlier than 1996 refer to the date that the license was issued by the NRC. Site specific facility dates in 1998 or later are the dates the utility expects to receive a license from the NRC. For reactors using dry storage with Certificates of Compliance under a general license, the facility date refers to the approximate date that the utility plans to first load fuel into dry storage.

(3) Virginia Power has spent fuel stored in metal casks of various designs.

(4) Maine Yankee loaded GTCC waste into dry storage containers in 2001. Spent fuel loading is expected to begin in 2002

NOTE: Additional utilities are in the process of evaluating dry storage alternatives for implementation in 2001 through 2005. However, no formal announcements have been made regarding selection of a storage technology.

Energy Resources International, Inc. June 2002

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[2] http://www.nei.org

B.3.1 CASTOR V/21[3]

These cask types were originally designed, developed and licensed by the German company, GNB. The CASTOR V/21 is designed for the transport and storage of 21 spent fuel assemblies from PWRs. This design consists of a thick-walled cylindrical cask body made of ductile cask iron with horizontal fins machined into the outer surface. A fuel basket with 21 loading positions is located in the cask cavity. A double-lid system constructed of stainless steel with metal and elastomer seals is tightly bolted to the cask body, guaranteeing safe, monitored long-term containment of the fuel assemblies. At the top and bottom ends, trunnions are attached for handling. The cask complies with the international regulations of the International Atomic Energy Agency (IAEA), and has been licensed by the NRC for the dry storage of irradiated fuel assemblies.

B.3.2 TN-24[4], TN-32, TN-68

The TN-24 cask is a dual-purpose transport and storage cask designed to be stored vertically. There are many sub-models in the TN-24 family. The TN-24P design is most common in United States. This specific model can store 24 PWR fuel assemblies with a maximum burn up of 33,000 MWd/tU, after a cooling time of 5 years. The forged steel body design shields the gamma rays and neutrons with shielding provided by a layer of boronated resin enclosed between the forged steel body and the external shell. Longitudinal heat conductors made of copper and aluminium plates carry the heat of the fuel assemblies from the forged steel body to the external shell through the resin. Compact spacing of spent fuel assemblies is provided by the boronated aluminium construction of the inner basket.

The TN-32 has a similar design as the TN-24. However, it is designed to store 32 PWR fuel assemblies with expected cooling time of 7 years. The maximum burn up of this design is 45,000 MWd/tU.

TN-68 is also similar in design to TN-24, but it is sized to store 68 BWR fuel assemblies. Expected cooling time for this design is 10 years, to accommodate fuel with a maximum burn up rate of 40,000 MWd/tU.

B.3.3 VSC-24[5]

The VSC-24, designed by Sierra Nuclear, is a vertical system made up of two casks, one inside the other. The VSC-24 ventilated cask can also store 24 PWR assemblies. The outer container

[3] http://www.skoda.cz/produkty.asp?Q853A=C0J2P1T1K90ID3679
[4] http://www.cogemalogistics.com/servlet/pdf/cogemalogistics/modules/tn_24.pdf
[5] http://www.nrc.gov/reading-rm/doc-collections/news/1998/98-050iii.html

is 18 feet high with an 11-foot diameter and can hold 24 spent fuel assemblies. The outer walls are made of steel-reinforced concrete greater than two feet thick, with an inner steel lining. The inner container, known as the multi-assembly sealed basket, has two separately welded lids, which cover the assemblies.

B.3.4 NUHOMS-24P[6], NUHOMS-52B, NUHOMS-61BT, NUHOMS-24PT1

The NUHOMS concrete modules are designed by Vectra Technologies for storage of canistered PWR or BWR (Boiling Water Reactor) assemblies.

The NUHOMS-24P design was licensed in 1989 for storage of the assemblies. This design is currently in use at Oconee, Calvert Cliffs, and Rancho Seco. The NUHOMS–24P storage system include a horizontal canister system composed of a steel dry shielded canister (DSC), a reinforced concrete horizontal storage module (HSM) and a transfer cask (TC). The welded DSC provides confinement and criticality control for the storage and transfer of spent nuclear fuel. The concrete module provides radiation shielding and allows cooling of the DSC and fuel by natural convection during storage. The TC is used for transferring the DSC between the spent fuel pool building and the HSM.[7] This design has a maximum burn up of 47,000 MWd/tU and expected cooling time of 5 years.

The NUHOMS-52B is similar in design to NUHOMS-24P except for the increased storage capacity of up to 52 PWR fuel assemblies. In addition, it can accommodate fuel with a maximum burn up of 45,000 MWd/tU and expected cooling time of 5 years. Similarly, the NUHOMS-61BT design, for the storage of 61 PWR fuel assemblies, accommodates fuel with a maximum burn up of 40,000 MWd/tU and expected cooling time of 5 years.

The NUHOMS 24PT1, the next generation design of NUHOMS-24P, is designed for storage of 24 PWR fuel assemblies as well. However, this cask accommodates fuel with a maximum burn up of 45,000 MWd/tU and expected cooling time of 10 years. This cask design provides improved shielding and the ability to withstand larger earthquakes than the previously approved standardized NUHOMS cask system[8]

B.3.5 HI-STAR 100 AND HI-STORM 100[9]

Holtec International designs HI-STAR 100 and HI-STORM 100. All HI-STAR 100 and HI-STORM 100 components are completely compatible. HI-STAR 100 is an acronym for Holtec

6 http://www.state.nv.us/nucwaste/trans/1pic11.htm
7 http://www.opm.gov/fedregis/2001/66-0035469-a.pdf
8 http://www.nrc.gov/reading-rm/doc-collections/news/2002/02-149.html
9 http://www.holtecinternational.com/drystoragecasks.html

International Storage, Transport, and Repository System. The annex 100 stands for a system weight in excess of 100 tons. HI-STAR 100 is the nuclear industry's first high-capacity, multi-purpose canister (MPC) technology-based system.

HI-STORM 100 is an acronym for Holtec International Storage and Transfer Operation Reinforced Module. It is strictly a storage device. HI-STORM is an upright metal-concrete ventilated structure that promotes passive air-cooling of the stored MPC. HI-STORM is engineered for maximum shielding. Design includes an all-structural steel skeleton and twenty-six inches of concrete enclosed in the annular space between two concentric ductile metallic shells.

B.4 OTHER

Along with the Canada and United States, there has been an increasing interest in other countries for storing used fuel using a dry storage method. Examples of countries currently using some form of dry storage include those shown below in Table B.3-1:

TABLE B.3.1
HLW STORAGE SYSTEM IN DIFFERENT COUNTRIES[10]

Country	High level waste Storage system
Czech Republic	Central interim storage facility at Dukovany plant for spent nuclear fuel Licensed use of New Skoda 440/84 Cask
Russia	Early 2000- thought of development of a spent nuclear storage facility on Kola peninsula to provide safe storage of 60000 spent fuel elements.
Spain	August 1999- preparation of spent nuclear storage facility at the Trillo delayed due to opposition from local community
Hungary	A modular vault dry storage facility was put into operation in 1997
Korea	At Wolsung, 609 tHM dry store facility has been built and a 812 tHM dry store facility is under construction
Ukraine	A dry cask storage facility for use at the Zaporozhe site is under review by regulatory authority

[10]http://www.world-nuclear.org/waste/report2000/chapter2.htm,http://www.world-nuclear.org/waste/report2000/chapter4.htm,http://www.iaea.or.at/worldatom/Periodicals/Bulletin/Bull401/article6.html