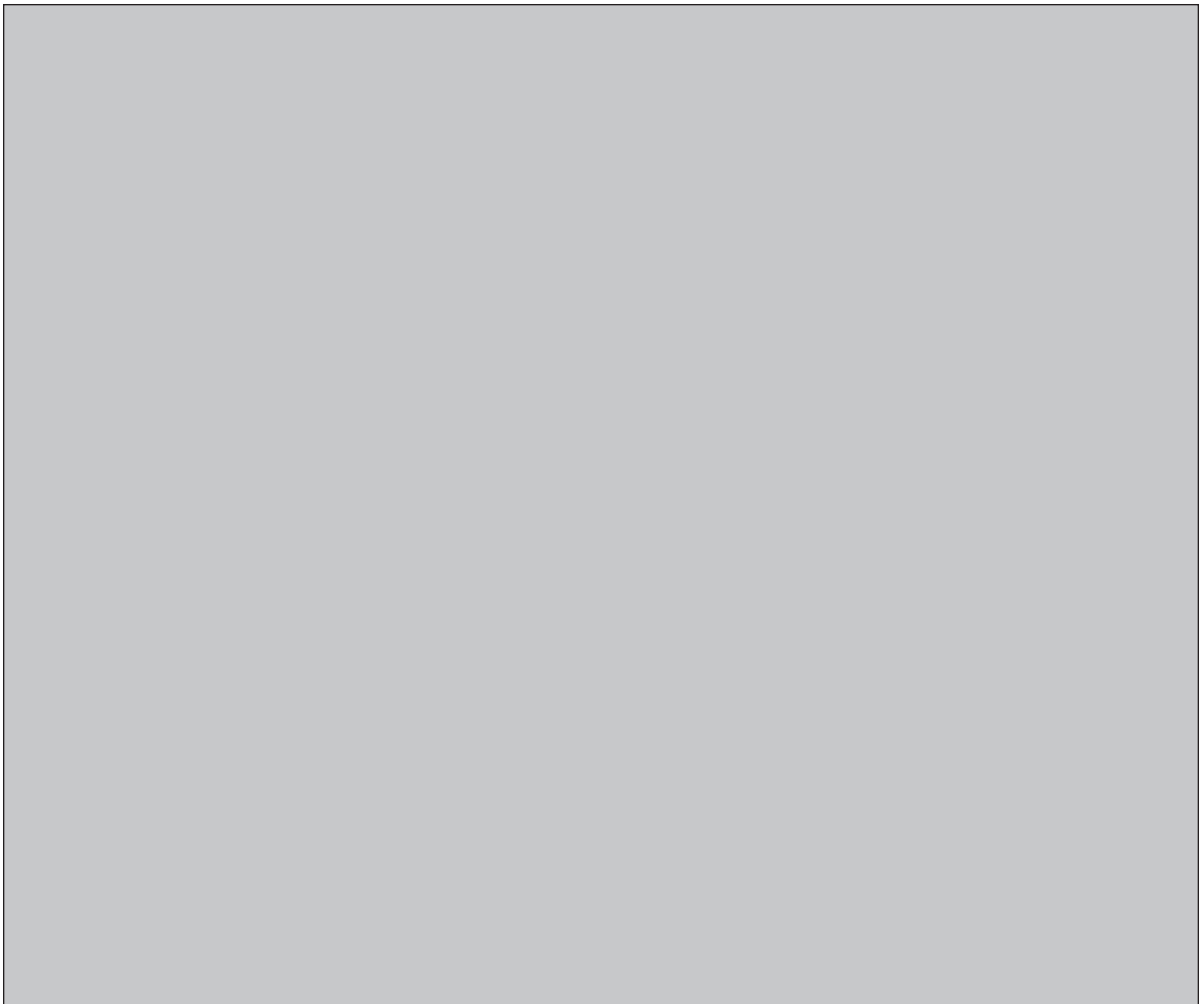


NWMO BACKGROUND PAPERS
6. TECHNICAL METHODS

**6-6 STATUS OF TRANSPORTATION SYSTEMS OF HIGH-LEVEL RADIOACTIVE WASTE
MANAGEMENT (HLRWM)**

Wardrop Engineering Inc.



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.

Disclaimer

This report does not necessarily reflect the views or position of the Nuclear Waste Management Organization, its directors, officers, employees and agents (the “NWMO”) and unless otherwise specifically stated, is made available to the public by the NWMO for information only. The contents of this report reflect the views of the author(s) who are solely responsible for the text and its conclusions as well as the accuracy of any data used in its creation. The NWMO does not make any warranty, express or implied, or assume any legal liability or responsibility for the accuracy, completeness, or usefulness of any information disclosed, or represent that the use of any information would not infringe privately owned rights. Any reference to a specific commercial product, process or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement, recommendation, or preference by NWMO.

TABLE OF CONTENTS

1.0	FORWARD	2
2.0	DISCLAIMER	3
3.0	BACKGROUND - HIGH LEVEL NUCLEAR WASTE AND USED NUCLEAR FUEL	4
3.1	DEFINITIONS.....	5
3.1.1	HIGH LEVEL WASTE.....	5
3.1.2	LOW LEVEL WASTE	5
3.1.3	INTERMEDIATE LEVEL WASTE	5
3.2	HOW MUCH USED NUCLEAR FUEL IS THERE IN CANADA?	5
3.3	HOW SAFE IS USED NUCLEAR FUEL?	7
	WHO IS RESPONSIBLE FOR THE WASTE?	8
4.0	REGULATORY FRAMEWORK	9
4.1	CANADA	9
4.2	INTERNATIONAL	10
4.2.1	EMERGENCY RESPONSE.....	10
4.2.2	CONTAINERS.....	11
4.2.3	VESSELS.....	12
5.0	TRANSPORTATION OF USED FUEL: AN INTERNATIONAL PERSPECTIVE	14
5.1	US.....	14
5.2	INTERNATIONAL	17
	FRANCE AND THE UK	17
5.2.2	JAPAN.....	19
5.2.3	INTERNATIONAL SEA TRANSPORT.....	21
5.2.4	GERMANY	22
5.2.5	SWEDEN	23
5.2.6	FINLAND.....	24
6.0	TRANSPORTATION-THE CANADIAN CONTEXT	25
6.1	TRANSPORTATION OF DANGEROUS GOODS	26
6.2	THE CANADIAN PHILOSOPHY FOR SPENT NUCLEAR FUEL TRANSPORTATION.....	27
	TRANSPORTATION OF CANDU FUEL BUNDLES: FROM PRODUCTION TO CONSUMPTION.....	28
6.3.1	PRODUCTION	28
6.3.2	CONSUMPTION	28
6.4	USED FUEL TRANSPORTATION CONTAINERS.....	29
6.5	IRRADIATED FUEL TRANSPORT CONTAINER (IFTC).....	30
6.5.1	SAFETY TESTING.....	31
6.5.2	OTHER CONTAINERS	31
6.6	DRY STORAGE CONTAINERS (DSCs)	31

6.6.1	SAFETY TESTING OF THE DSC	33
6.6.2	ON-SITE TRANSPORTATION AND HANDLING	33
6.6.3	A QUESTION OF SAFETY	34
6.7	DSC vs IFTC.....	36
6.8	TRANSPORTATION ORIGIN OF USED FUEL.....	37
6.9	FUTURE MODES OF TRANSPORTATION IN CANADA	38
6.9.1	ROAD.....	38
6.9.2	RAIL.....	41
6.9.3	VESSEL.....	42
	TRANSPORTATION ROUTES	45
6.10	TRANSPORTATION SECURITY PLANS	46
6.10.1	THREAT ASSESSMENT.....	46
6.10.2	DESCRIPTION OF TRANSPORTATION MODE AND VEHICLE.....	47
6.10.3	SECURITY MEASURES.....	47
6.11	ASSESSING THE RISK.....	48
7.0	PUBLIC PERCEPTION	49
7.1	SEABORN REPORT	49
7.2	NWMO DISCUSSIONS.....	50
7.3	INTERNATIONAL	50
7.3.1	YUCCA MOUNTAIN	50
7.3.2	EUROPE.....	51
8.0	REFERENCES	52

3.0 BACKGROUND - HIGH LEVEL NUCLEAR WASTE AND USED NUCLEAR FUEL

In Canada, high level nuclear waste is currently stored at various sites throughout the country, but no long term solution for disposal has been established. Used nuclear fuel in Canada is currently stored on-site at the nuclear power generating stations, in wet or dry storage (Figure 1). Long term solutions have been developed for some types of short lived wastes (decay) and others (dilution). Among possible storage/disposal methods for high level nuclear waste under consideration by the Government of Canada are a central storage facility and a deep geological repository. Both of these options would require high level nuclear waste to be transported by road, rail, or water.



Figure 1. Douglas Point fuel storage silos, Ontario, (www.nuclearfaq.ca/drystrge.htm)

In 1978, the governments of Canada and Ontario enlisted AECL to research deep geological storage of High Level nuclear waste (used fuel) in stable rock formations in the Canadian Shield. As a result of the same Federal-Provincial agreement, Ontario Hydro (now Ontario Power Generation) was commissioned to develop interim storage and transportation technologies.

When a used fuel bundle comes out of a reactor, only 1-2 % of the Uranium is used (note 67% of the fissile U-235 is used). But because of the changes undergone by the fuel bundle in the reactor, by-products are produced which begin to inhibit fission reactions, and the fuel bundle is no longer efficient. However, it is possible to reprocess the uranium.

Presently, the process is costly and complex, and is not considered feasible in Canada. Other countries that use enriched uranium transport their used fuel to reprocessing plants in Europe to reprocess the used fuel. It is economical in such cases due to the high cost of enriching natural uranium. Canada, on the other hand, uses natural uranium.

Of the various types of nuclear fuel cycle wastes, the focus of this discussion will be on used fuel that is removed from nuclear power and research reactors. This material consists of the used fuel plus the fabricated fuel bundle materials containing the fuel. As part of the international perspective, the paper will also include the transportation of radioactive reprocessing waste.

3.1 DEFINITIONS

3.1.1 *HIGH LEVEL WASTE*

High level waste consists mostly of used nuclear fuel bundles. Used fuel makes up 99% of all radioactive waste (in terms of radioactivity) from nuclear power plants. Because of its high level of radioactivity, and its potential to remain radioactive for thousands of years, used fuel is the focus of long term nuclear waste management in Canada. Used fuel may also go by different names: spent fuel, high level waste, nuclear fuel waste. The focus of this report is High Level Waste, but more specifically, used fuel.

When a fuel bundle is removed from a reactor core, it emits both particle (alpha and beta rays) and penetrating (gamma rays) radiation. Used fuel transportation casks are constructed of either thick steel or concrete so that neither particle nor penetrating radiation can pass through the shielding.

3.1.2 *LOW LEVEL WASTE*

Low level waste is typically produced by items/tools that may have been slightly irradiated through everyday operations at a nuclear power plant: contaminated rags, mops, clothing, tools, paper, etc. Basically, it's a small amount of radioactivity in a large amount of material. It also includes medical and industrial isotopes from hospitals and laboratories.

Low-level waste can be handled without radiation shields. However, it contains radioactive substances. If the radioactive substances enter the body, for instance through the air, they may cause considerable radiation doses. Therefore, low-level waste must be isolated from the biosphere for 50-100 years. Canada has extensive experience safely transporting low-level waste.

3.1.3 *INTERMEDIATE LEVEL WASTE*

Intermediate level waste consists mostly of used reactor components. It makes up approximately 3% of all non-fuel waste. Examples of intermediate level waste are: filters, scrap metal, insulators, and heat exchangers. One million packages of low and intermediate waste are safely transported in Canada every year.

3.2 HOW MUCH USED NUCLEAR FUEL IS THERE IN CANADA?

Currently there are approximately 1.5 million used fuel bundles in Canada (enough to fill the ice

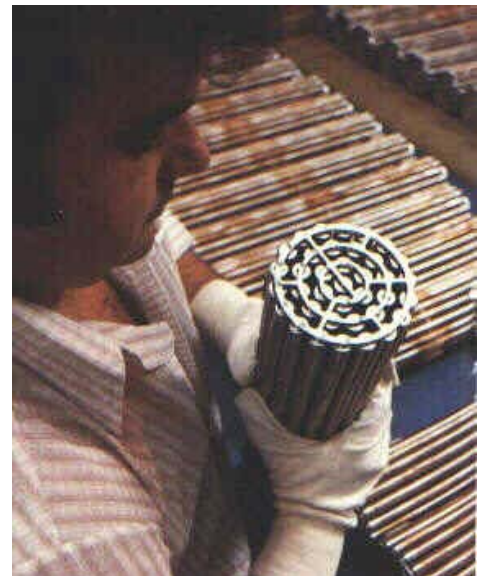


Figure 2. CANDU fuel bundle (http://www.nuclearfaq.ca/cnf_sectionJ.htm#images)

surface of three hockey arenas to the boards). Provided no new reactors are built, the last reactor in Canada is predicted to be in service until 2035 (Darlington). The projected quantity of used fuel bundles in 2035 is 3.6 million fuel bundles.

A typical CANDU fuel bundle weighs approximately 24 kg (Figure 2), and contains approximately 19 kg of Uranium. The balance is made up primarily of the zirconium alloy sheaths. Approximately 85 000 used fuel bundles are produced per year, from the five operational nuclear power stations in Canada:

- Darlington (ON),
- Bruce B (ON),
- Pickering A & B (ON),
- Gentilly 2 (PQ), and
- Point Lepreau (NB).

Ontario Power Generation (Formerly Ontario Hydro) owns the Darlington, Bruce and Pickering Stations and therefore owns 90% of the used nuclear fuel in Canada. The Bruce Station is leased and operated by a private company by the name of Bruce Power, which provides electricity back to the grid for use by residents of Ontario. Hydro Quebec owns and operates Gentilly 2, and Point Lepreau is owned and operated by New Brunswick Power (NBP).

Atomic Energy of Canada Ltd. (AECL) operated a demonstration reactor (Nuclear Power Demonstration reactor (NPD)) near Chalk River, Ontario and the first commercial reactor in Canada, at Douglas Point, Ontario. They have since been decommissioned, and the waste is stored at Chalk River and Douglas Point respectively. Table 1 shows a breakdown of the waste and its owners in Canada.

Table 1. Location and Responsibility of Used Fuel in Canada

Location	Responsibility	# of Fuel Bundles in Storage***	
		Dry	Wet
Pickering (ON)	OPG	79,266	400,534
Point Lepreau (NB)	NBP	48,600	40,814
Darlington (ON)	OPG	0	191,522
Bruce A & B* (ON)	OPG	0	692,204
Gentilly-1 (PQ)	AECL	3213	0
Gentilly-2 (PQ)	Hydro-Quebec	48,000	32,525
Chalk River (ON)	AECL	4853	0
Douglas Point** (ON)	AECL	22,256	0
Whiteshell Research Laboratories (MB)	AECL	360	0

* Though Bruce A & B are currently leased and operated by Bruce Power, OPG is responsible for the used fuel produced at that site.

**The decommissioned Douglas Point Facility is located between Bruce A and Bruce B, and in some cases, the fuel count is added to that of the Bruce.

*** As of December 31, 2001

3.3 HOW SAFE IS USED NUCLEAR FUEL?

Used Nuclear fuel is treated as a hazardous substance. In some ways, it is less dangerous than other types of toxic waste because the “toxicity” of used nuclear fuel decreases with time. Used fuel is solid: it is not in a liquid or gas state and will not pour, spread, or evaporate. Minimal off gassing may occur from gaseous isotopes (Kr, I, C, etc.) contained in the fuel bundle. It is not flammable or explosive.

About three meters of water are sufficient to absorb the radiation emitted initially by the used fuel. After at least ten years it can be transferred to dry storage. While in the dry-storage phase about 50 cm of reinforced concrete suffices. A person could stand beside a dry storage container at this point without protective gear with relatively no health risk. It is this 10-year cooled (has been removed from the reactor core for 10 years) fuel that could potentially be transported offsite.



Figure 3. Concrete Dry Storage Containers with 10-year cooled used fuel. (“Pickering Waste Management Facility Phase II Information Package”, OPG).

The unit of radiation exposure in humans is the Sievert. *Unshielded*, the radiation dose measured at a distance of 30 cm from a used CANDU fuel bundle, one year following discharge, would be about 50 - 60 Sv/h, which is lethal after a few minutes' exposure. The radiation level drops to about 1 Sv/h after 50 years, 0.3 Sv/h after 100 years, and less than 0.001 Sv/h after 500 years. At this time the major hazard from the used fuel is no longer one of external exposure; for example, by these estimates, spending an hour about a foot away from a 500-year-old CANDU fuel bundle would result in radiation dose about 1/3 of the average annual background exposure, and thousands of times less than what is known to lead to radiation sickness.

A significant hazard is associated with the potential for *internal* exposure to radionuclides remaining in the used fuel (for example, from long-lived plutonium isotopes), and therefore an effective long-term

protective strategy addresses the need to isolate the used fuel and prevent significant uptake of the isotopes contained in the used fuel into the biosphere.¹



Figure 4. “Pencil” (left), fuel pellet (centre), penny (right). (NWMO “Nuclear Waste in Canada Factsheet”).

3.4 WHO IS RESPONSIBLE FOR THE WASTE?

The Government of Canada is responsible for ensuring that the long-term management (including disposal) of radioactive waste is carried out in a safe, environmentally sound, comprehensive, cost-effective and integrated manner. Canada's approach to radioactive waste management is that the producers and owners of radioactive waste are responsible for the funding, organization, management and operation of disposal and other facilities required for their wastes.²

If an owner/producer of nuclear waste no longer exists (i.e. the company has gone out of business), then the government of Canada assumes responsibility for their waste. It is for this reason that a long-term solution to nuclear waste management is required immediately: so that the current producers can be held responsible for a storage solution. During transportation to a centralized storage facility, the original ‘owner’ of the waste remains responsible for the waste.

The power generating companies in Canada that currently use nuclear power are obligated by the government to pay into a trust fund specifically for nuclear fuel waste management, therefore reducing the financial burden on future generations.

¹ Nuclear FAQ website (<http://www.nuclearfaq.ca>)

² Natural Resources Canada
(<http://www2.nrcan.gc.ca/es/erb/english/View.asp?x=494>)

4.0 REGULATORY FRAMEWORK

4.1 CANADA

In 1996 the Government of Canada released the Policy Framework for Radioactive Waste, regarding the institutional and financial aspects for disposal of nuclear waste. The onus is on the waste producers and their owners to set up funding for long-term disposal plans. Responsibility of radioactive wastes in Canada lies with the producers/owners of the waste. If a company goes out of business, then the government of Canada takes over responsibility for their waste

The federal legislative framework for nuclear energy and long-term management of nuclear fuel waste in Canada comprises:

- *The Nuclear Safety and Control Act;*
- *The Nuclear Liability Act;* and
- *The Nuclear Fuel Waste Act.*

The *Nuclear Safety and Control Act* (NSCA) came into effect May 31, 2000. The NSCA replaced the *Atomic Energy Control Act* of 1946 with new, more effective and explicit legislation to regulate the activities of the Canadian nuclear industry. The NSCA also provided for the establishment of the Canadian Nuclear Safety Commission (CNSC), which replaced the Atomic Energy Control Board (AECB).³

The Canadian Nuclear Safety Commission (CNSC) now regulates the nuclear industry in Canada, including transportation. Every part, design, transportation plan, modification or procedure change at a nuclear facility must be approved by the CNSC. CNSC inspectors ensure that the proper regulations are abided by, whether it is a nuclear power plant, a medical clinic, or a nuclear waste facility.

In April 2001, the federal government introduced legislation entitled “An Act Respecting the Long-Term Management of Nuclear Fuel Waste”, also called the ‘Nuclear Fuel Waste Act’ (NFWA). The Act requires nuclear energy corporations (including OPG, New Brunswick Power and Hydro-Quebec) to establish a Nuclear Waste Management Organization (NWMO). The NWMO is to undertake a study of the various approaches for managing nuclear fuel waste, including the transportation of used fuel, and provide that study and its recommendations to the federal government. The federal government will then decide which approach for the long-term management of used nuclear fuel to adopt for Canada. Once the government makes their decision, the NWMO is to implement that approach. The NFWA also requires the nuclear energy

³ Natural Resources Canada
(<http://www2.nrcan.gc.ca/es/erb/english/View.asp?x=496>)

corporations to establish a trust fund to finance the management approach that is selected by the federal government⁴.

The NFWA requires the study to be completed within three years of the legislation's coming into force by Parliament, anticipated some time in the fall of 2005. The federal government will then decide which approach will be adopted for Canada.

In addition, OPG, Hydro-Quebec, NBP and AECL established special funds in 1999 to pay for the management of spent nuclear fuel and station decommissioning. To date, over \$1 billion has been contributed to the fund. This fund is to ensure that the producers of nuclear waste are the ones who pay for its disposal, and to prevent future generations from bearing the financial burden.

Two authorities govern transportation of nuclear waste in Canada: approval from both the CNSC and Transport Canada Dangerous Good Directorate is required for all modes of transportation (both containers and vehicle). Radioactive Waste management sites and transportation routes are also regulated by the Canadian Environmental Assessment Act.

4.2 INTERNATIONAL

The International Atomic Energy Agency (IAEA) serves as the world's central intergovernmental forum for scientific and technical co-operation in the nuclear field, and as the international inspectorate for the application of nuclear safeguards and verification measures covering civilian nuclear programmes⁵. CNSC regulations and guidelines are modelled after the IAEA's regulations and guidelines as a minimum standard for safety. Most countries that ship nuclear waste have adopted legislation enacting the IAEA's Regulations for the Safe Transport of Radioactive Material.

4.2.1 *EMERGENCY RESPONSE*

The IAEA requires that in the event of accidents or incidents during the transport of radioactive material, emergency provisions, as established by relevant national and/or international organizations, shall be observed to protect persons, property and the environment.

Emergency procedures must also provide for the formation of secondary substances as a result of reactions between the transported material and the environment.

⁴ OPG, "Pickering Waste Management Facility - Phase II Information Package"

⁵ IAEA website (www.iaea.org)

In addition, the IAEA has set up the International Nuclear Events Scale (INES) for transportation incidents in order to keep various national authorities, the media and public informed on international transport incidents to better understand the risks involved and the safety implications of such events. The INES was passed in 1992 for Nuclear Plant incidents, and was extended to include transportation incidents in 2001. One of the intended uses of the INES is to add a general reassurance that the transport of used fuel is held to a very high standard of safety.

“In the history of the nuclear industry, there have been no transport incidents involving nuclear fuel cycle materials having significant radiological consequences for the public or the environment.”

IAEA

Transport incidents are assigned a rating on a scale of 0-7 depending on its severity, and can range from improperly labelled packages to a release of radioactive material involving radiation doses to individuals. In the history of the nuclear industry, there have been no transport

incidents involving nuclear fuel cycle materials having significant radiological consequences for the public or the environment.

4.2.2 CONTAINERS

IAEA approved ‘Type B’ packages are required to transport used fuel, regardless of the mode of transportation. For license approval, the container must pass stringent accident performance tests. The IAEA test requirements are (Figure 6):

- Nine metre drop onto a unyielding surface;
- One metre drop onto a steel spike;
- Fire test, where the package is subjected to an engulfing fire of 800 degrees C for 30 minutes; and
- Immersion into at least 200 metres of water for 8 hour (200 metres is generally deeper than most coastlines).

Containers must have labels that show the proper shipping name, emergency response identification number, and the shipper’s name and address. The labels must also describe the level of radiation contained in the packaged. Only qualified people are allowed to handle packages containing used fuel.



Figure 5. Drop Test. (WNTI Annual Review, 2002)

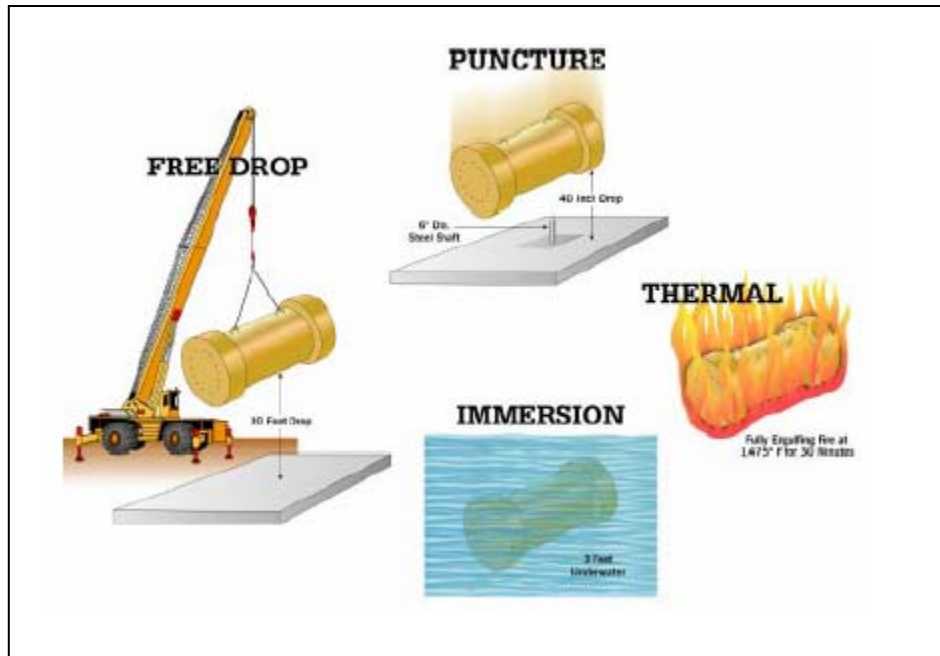


Figure 6. Testing of containers
 (http://www.ocrwm.doe.gov/wat/pdf/snf_trans.pdf)

4.2.3 *ADDITIONAL REQUIREMENTS FOR MARINE TRANSPORT*

The International Maritime Organization (IMO) was established by a United Nations conference in 1948 to develop international regulations for all matters affecting the safety of shipping and the protection of the environment.

Shipments of used fuel must comply with all the regulations adopted by the IMO, including:

- The International Convention for the Safety of Life at Sea (SOLAS)
- The International Convention for the Prevention of Pollution from Ships (MARPOL)
- The International Maritime Dangerous Goods (IMDG) Code
- International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on Board Ships (INF Code)
- United Nations Convention on the Law of the Sea (UNCLOS)

SOLAS sets standards for the general safe operation of vessels, including the carriage of dangerous goods.

MARPOL regulations require that any loss or likely loss of dangerous goods or pollutants must be reported to the nearest country to which the incident has occurred. Any safety threats to the vessel must also be reported.

IMDG Code covers the transport of all dangerous goods, including radioactive materials. It has adopted the appropriate sections of the IAEA Regulations for the Safe Transport of Radioactive Material Radioactive materials, pertaining to QA, stowage, contamination/decontamination, documents, accidents, and labelling and handling.



Figure 7. INF3 Ship, Pacific Sandpiper.

INF Code sets standards for a vessel transporting radioactive goods, above those set by the SOLAS Convention for conventional ships. The Code requires:

- Damage stability;
- Fire protection;
- Temperature control of cargo spaces;
- Structural considerations;
- Cargo securing arrangements;
- Electrical supplies;
- Radiological protection equipment; and
- Management, training and shipboard emergency plans.

The code assigns different criteria depending on the radioactivity of the cargo. Certification is divided into three categories: Class INF 1, Class INF2, and Class INF3. Class INF 3 ships are certified to carry used fuel. An INF 3 ship must be built specifically for INF 3 cargo.

UNCLOS specifies that vessels carrying nuclear substances must carry documents and observe special precautionary measures when passing through territorial seas.

5.0 TRANSPORTATION OF USED FUEL: AN INTERNATIONAL PERSPECTIVE

Radioactive materials have been transported around the world for over 40 years. In that time, there have been no accidents that resulted in the release of significant amounts of radioactivity. It is estimated that a few hundred packages of used fuel are shipped every year around the world by road, rail and sea. The bulk of the transportation occurs in Europe. The method of transport (i.e. Road, rail, sea, etc) is based on various factors: size and weight of packages, the distance to be shipped and the availability of transportation facilities and infrastructure.

The term transportation system refers to several different components used for moving used fuel from one site to another, including:

- The used fuel bundle transportation cask used to store/transport the fuel;
- The types of vehicles used;
- Cask tie-downs;
- On-site handling equipment;
- Transfer equipment (cranes, booms, etc.);
- Transportation infrastructure (Roads, railways, docks, etc); and
- Transfer facilities.

5.1 US

Used fuel has been shipped in the US for more than 30 years. Nearly 3000 shipments of commercial used fuel have been transported over 2.5 million km in that time. The Atomic Energy Commission and the United States Department of Energy (US DOE) have documented 72 nuclear waste transportation incidences in 53 years. None of these incidents have resulted in a significant release of radioactive material into the environment, or exposure to workers.



Figure 8. Crash test into solid concrete wall: *cask remains intact.*
(http://www.nuclearfaq.ca/cnf_sectionJ.htm#images)

The majority of the shipments to date have been between different reactors owned by the same company. Other shipments have been made for research purposes. With the construction of Yucca Mountain, an underground, high-level waste repository, the number of shipments (by rail and road) is expected to increase. The US has no plans to reprocess used fuel.



Figure 9. Locomotive Crash test: *cask remains intact*
(http://www.nuclearfaq.ca/cnf_sectionJ.htm#images)

The transportation of nuclear materials in the US is jointly regulated by Nuclear Regulatory Commission (NRC) and the US Department of Transportation, much like the regulatory framework in Canada.

Used fuel is transported in IAEA approved containers. A typical road container weighs approximately 23 metric tonnes, with a total diameter of 1.8 m and 6.1 m in length. A typical rail container weighs approximately 114 metric tonnes, with a total diameter of 3.4 m and 7.6 m in length. Typically, for every ton of used fuel, there are approximately 4 tons of shielding. Transportation vehicles are accompanied by armed escorts.



Figure 10. Four-axle tractor trailer. (WNTI Annual Review, 2002).

Various tests of containers above and beyond the IAEA test requirements have been conducted around the world. In the US, Sandia National Laboratories drove a truck carrying a cask at 96 km/h into a concrete wall. The cask was dented, but the damage did not result in a radioactive release. (Figures 8 & 9)

In 2002, the US government approved the Yucca Mountain site in Nevada as a federal repository for nuclear waste. Yucca Mountain is located approximately 160 km from Las Vegas. The US is proposing a combination of transportation modes (rail and road) to move used fuel from 131 sites in 39 states to Yucca Mountain. The shipments would begin in 2010.

Once the Yucca Mountain site is licensed, there would

be a total of approximately 4300 shipments in a 24-year period. At an average of 175 shipments per year, it's a small amount compared to the 300 million annual shipments of hazardous materials in the US (1.2 million/working day) and the 3 million radioactive shipments (other than used fuel) per year. For perspective, there are approximately 50 000 deliveries of gasoline each day in the US. On average, each delivery contains enough gasoline for an explosive charge capable of levelling several city blocks.⁶

The US federal government prefers using rail to ship waste 95 percent of the time. All spent nuclear fuel and high level radioactive waste shipped will be in the solid form for transportation and disposal. The waste materials will be transported to the repository in large certified container casks.

Nuclear Waste Shipment Routes

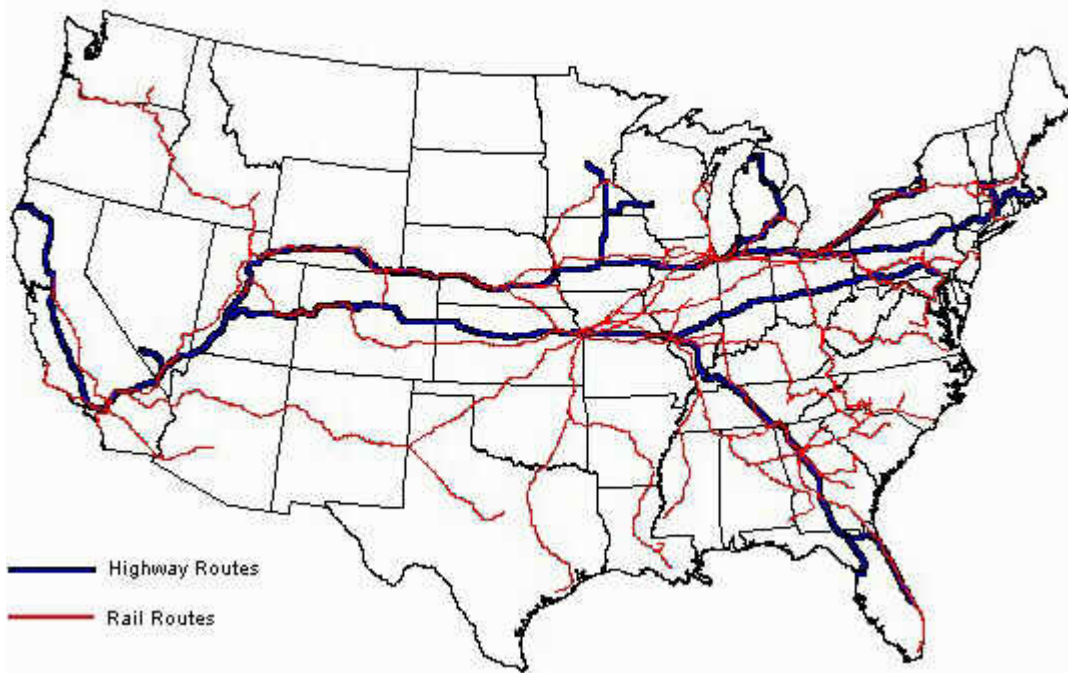


Figure 11. Proposed transportation routes (rail and road) in US to Yucca Mountain Repository. (<http://www.state.nv.us/nucwaste/states/us.htm>).

The United States Department of Transportation (US DOT) and the Nuclear Regulatory Commission (NRC) track the shipments by 24-hour satellite. An armed escort would accompany the shipments, and there must be advance route approval and notification to each of the states the shipment passes through. Each state governor can provide preferred routes to the US DOT, and emergency response teams have already been trained in 34 of the 39 states where

⁶ <http://www.skullvalleygoshutes.org/transportation.html>

shipments will occur. The US government reports no harmful release of radiation in more than 2700 shipments in over 30 years.⁷

5.2 INTERNATIONAL

Used fuel and high level reprocessing waste have been transported in Europe, particularly France, Germany, and the UK without serious incidents for over 25 years. More than 70 000 metric tonnes of spent nuclear fuel has been transported in this time. The UK and France combined average 650 shipments per year, through counties much more densely populated than Canada. In addition, used fuel and high level reprocessing waste has been transported by sea between Europe and Japan.

Average one-way distances in Europe are 1000 km. Average one-way distances between Japan and Europe are 15 000 km.

5.2.1 FRANCE AND THE UK

France and the UK have transported nuclear waste for over 30 years. Used fuel is removed from the reactors and stored in on-site cooling pools for approximately one year. The used fuel is then transported to either the La Hague (France) or Sellafield (UK) reprocessing plants (Figure 12), where they are unloaded into water pools for at least two more years before being reprocessed.

Over 15 different cask designs in Western Europe have been licensed under IAEA regulations for road and/or rail and/or sea transportation, though most have been licensed for rail transport.

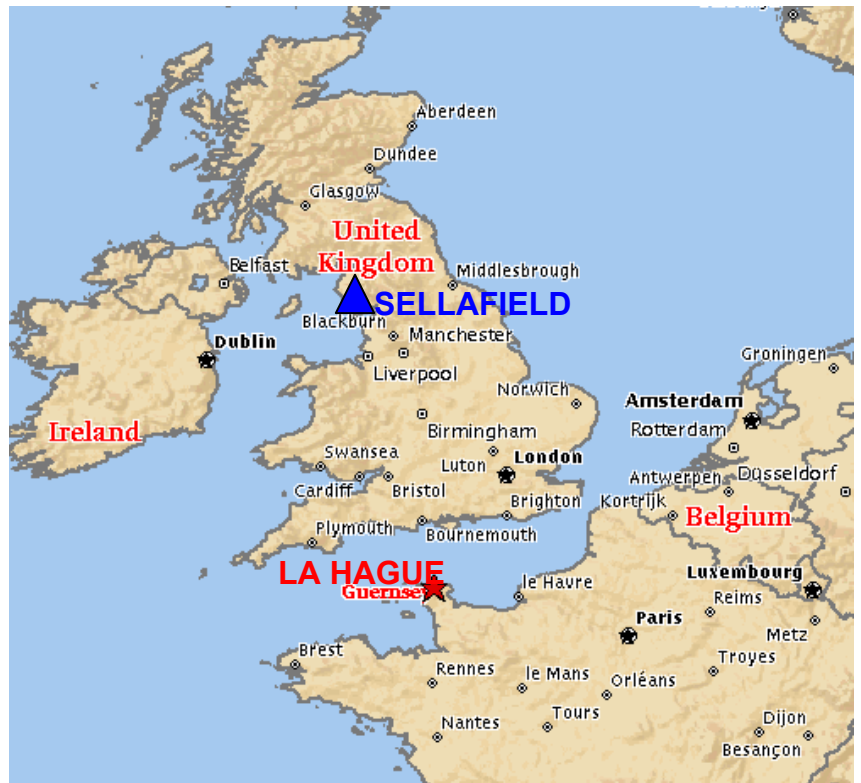


Figure 12. Locations of Sellafield, UK, and La Hague, France.

⁷ House Research Department, Minnesota House of Representatives, Short Subjects, October 2002.



Figure 13. Cask maintenance facility, La Hague, France.
(Cogema Logistics Ltd.)

Most Transportation casks designed in Europe have gas or water cooling systems (other than air-cooling). Because the fuel remains in the cooling pools for only 6 months, it still emits a significant amount of heat, and contains higher levels of radioactive material. Note that Canadian transportation containers do not have cooling systems, because they are designed for 10-year cooled fuel, at which point, they no longer emit the same amount of heat, and are significantly less radioactive.

Reprocessing a fuel bundle involves extracting the unused uranium and plutonium. This process results in a

highly radioactive liquid waste. The liquid waste is reduced through an evaporation process. The residue is then mixed with molten glass. The liquid mixture is poured into 1.3 metre high stainless steel canisters to cool and create a solid form (vitrification). Each container contains 100-150 L of liquid waste. The liquid high level waste is locked into the glass once it becomes solid (vitrified). In its' vitrified state, the waste is stable and resistant to leaching. Lids are then welded on to the canisters to seal them. This vitrification process renders the waste safe for transportation.

All High-level waste shipped within France and the UK is predominantly by rail, though some shipments are made by road. Ultimately, spent fuel arrives at La Hague or Sellafield by rail, in specially designed rail cars, which are compliant with international guidelines. Transportation from the railhead to the La Hague reprocessing plant is performed by a specially designed transfer vehicle, much like they use in Sweden (Section 5.2.5).

Transportation casks are monitored for radiation before they leave their point of origin and when they arrive at their destination. They are also monitored at any stop or transfer point. They are not monitored on-route, as the casks are not accessible during transportation. Any exceedences to the allowable limits of radiation must be reported.

Both France and the UK adhere to the principles set by the European Parliament for transport, notably:

- To apply the shortest distance possible; and
- To avoid, when possible routing shipments through densely populated areas.

Obviously, on occasion these two principles are at odds. For example, three of the routes used in the UK (from three reactor sites in the south-east UK) pass through London. However, the distance of travel would be greatly increased if the shipments were re-routed to avoid passing through London. A special unit of the London Fire Brigade (as well as other emergency staff throughout the UK) is trained to respond in the event of an accident involving nuclear waste.

It is also general practice to avoid when possible, tunnels and bridges in order to minimize the severity of an accident should one occur. Shipments are also



scheduled to avoid two trains carrying hazardous cargo so that they do not follow each other on the same line. Trains carrying used fuel are not allowed to travel at speeds exceeding 72 km/hr.

The majority of spent fuel transported in the UK arrives by train in Sellafield. The rail industry in the UK is a privately-run network. A subsidiary company of British Nuclear Fuels Ltd (BNFL), Direct Rail Services (DRS) is a private company with ISO9002 certification that owns and operates the trains that transport nuclear fuel from within the UK to Sellafield. They own 27 locomotives and employ more than 30 drivers with specialized training.

Figure 14. Loading rail cars. (WNTI Annual Review, 2002)

The nuclear transportation industry in the UK has an excellent safety record. Thousands of shipments over 10 million km have been delivered and no accident or incident has occurred resulting in the release of radioactivity.

La Hague and Sellafield receive high-level waste from Germany, Belgium, the Netherlands, and Switzerland for reprocessing. They also receive waste transported by vessel from Japan. The reprocessed waste is vitrified (hard and in a glass-like formation), and stored on site in air-cooled rooms for future deep geological disposal, or transported back to its' country of origin. The reprocessed fuel is also returned to the customer.

Research containers tested in the UK in 1984 were hit by a 140 tonne train travelling at 160 km/h. The train was demolished, but the cask received only superficial damage.

5.2.2 JAPAN

In the last 35 years, more than 160 shipments of used fuel from Japan to Europe have been received at either Sellafield or La Hague for reprocessing.

Spent fuel remains in on-site storage for some time at the reactor site. It is then transported by ship to France, usually via the Panama Canal, for reprocessing.

February 1995 the first shipment of vitrified high-level waste departed from France for Japan. Though the fuel was shipped to and reprocessed in France, the ownership of the waste does not change. The waste belongs to the ten Japanese power utilities who are ultimately responsible for its safe storage and eventual disposal. All high-level reprocessing waste will ultimately be returned to Rokkasho in Japan for long-term (30-50 year) storage prior to final disposal. A total of 760 containers of vitrified waste have been shipped from France to Japan since 1995. A breakdown of the shipments is shown in Table 2.

Table 2. Breakdown of Vitrified Waste shipments by Sea from France to Japan

<i>Year</i>	<i>Origin</i>	<i>Destination</i>	<i>Type</i>	<i># Casks</i>
1995	France	Japan	VRW	28
1997	France	Japan	VRW	40
1998	France	Japan	VRW	60
1999	France	Japan	VRW	40
1999	France	Japan	VRW	104
2000	France	Japan	VRW	192
2001	France	Japan	VRW	152
2003	France	Japan	VRW	144
TOTAL				760

VRW: Vitrified Reprocessing Waste

(Data from the Uranium Information Centre (UIC), Australia.)

Each canister contains 150 litres of glass and weighs 400 kilograms. The canister emits less than 1.5 kilowatts of thermal energy (heat).



Figure 15. Loading cask into ship's hold. (WNTI Annual Review, 2002)

The steel canisters are transported in specially engineered, heavily shielded steel casks. The cask, when filled, holds 28 canisters (approximately 11 tonnes of waste), and weighs approximately 100 tonnes. The casks are IAEA certified, and are very similar to those for transporting the spent fuel from Japan to Europe.

Reprocessing waste in Europe is expected to halt in 2005, with the construction of a reprocessing plant at Rokkasho-mura, Japan. Rokkasho-mura has been receiving used fuel from Japan's 53 reactors since 1999 in anticipation of its operation.

Japanese utilities have contracts with BNFL and Cogema for the reprocessing of some 7000 tonnes of spent fuel. A total of more than 3000 canisters of high

level reprocessing waste will be returned to Japan, in about 110 casks. Two thirds of this will be from Cogema and the rest from BNFL.⁸

5.2.3 INTERNATIONAL SEA TRANSPORT

Pacific Nuclear Transport Ltd. (PNTL) operates a fleet of six purpose-built ships capable of carrying all categories of nuclear material from the UK and France to Japan. PNTL is owned by BNFL, COGEMA and the Japanese Utilities. The ships are built specifically for the nuclear industry, and contain many safety features not found on a regular cargo ship. The ships have covered over 4.5 million miles transporting used fuel without an incident resulting in the release of radiation to an individual or the environment.

The first ship was built in 1976, and the fleet has evolved through the years because of necessities observed from operating experience, safety audits, and new container designs and changing regulations. The older vessels have been updated with necessary retrofits.

One of the major IAEA requirements for used fuel transport vessels is to stay afloat after sustaining damage from collision or grounding. To meet Japanese requirements, the ships are built with double hulls. All the ships are classified to the highest safety rating (INF3) for any ship carrying radioactive materials.

The following features found on the PNTL ships, with which traditional cargo ships are not equipped, are:

- Double hull;
- Enhanced buoyancy
- Dual navigation, communications, cargo, monitoring and cooling systems;
- Satellite navigation and tracking
- Twin engines and propellers
- Additional fire fighting equipment

Casks used for transport between Europe and Japan weigh approximately 70 tonnes, and are designed for fuel that has been cooled in pools for at least 6 months. The capacity of each cask is 14 Boiling Water Reactor (BWR) or 5 Pressure Water Reactor (PWR) fuel elements. No one cask design can be used for all possible handling and transport requirements.



Figure 16. Loading used fuel into ship's hold. (WNTI Annual Review, 2002)

⁸ Uranium Information Centre, "Japanese Waste and MOX shipments from Europe", Nuclear Issues Briefing Paper 23, June 2003,.

A study conducted in the UK concluded that the probability of a ship sinking while transporting a cargo of used fuel is extremely low. It also concluded that in the event that a ship does sink, in 200 – 2000 m of water, the radiation dose to the population would be within limits of International Commission on Radiological Protection.

5.2.4 GERMANY

Transportation of used fuel and high level reprocessing waste in Germany was suspended between 1998 and 2001 in order to investigate exceedences on the surface of casks and wagons above regulated radiation levels. An in-depth investigation uncovered the sources of these exceedences, and remedial measures were taken to prevent further incidences.

Transportation of used fuel in Germany is predominantly by rail. Used fuel is transported by private carriers under government issued licenses. An Agreement

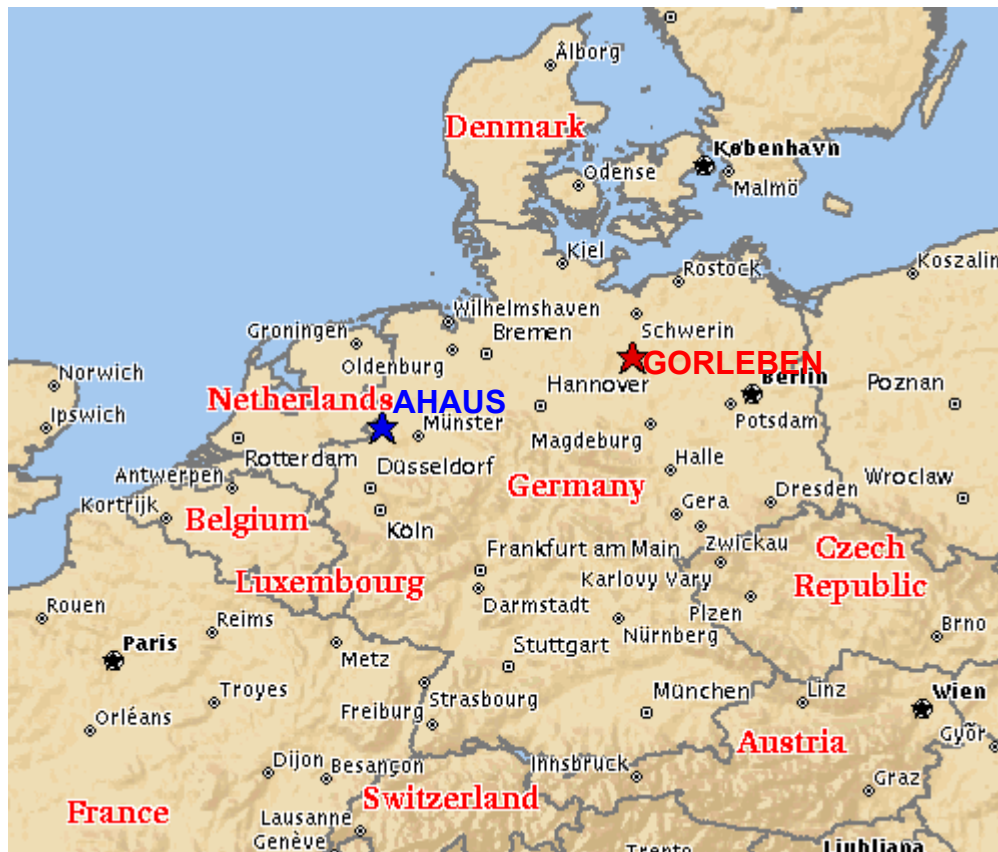


Figure 17. Locations of Ahaus and Gorleben, Germany.

between the German power industry and the government will see reprocessing and most international transport of used fuel stopped by 2005. Central interim dry storage facilities are located in Ahaus and Gorleben (Figure 17). Transportation to the two interim dry storage facilities from various reactor sites within Germany will continue. Shipments will be delivered predominantly by rail.

5.2.5 SWEDEN

SKB, a nuclear waste management company owned by the four (4) Swedish power utilities, is responsible for the storage, transport and disposal of high-level waste. Sweden has a total of eleven nuclear reactors at four different sites (Figure 18).

Used fuel is stored in cooling water pools at the nuclear power stations. After a minimum of 10 months, fuel is moved to a transport cask. This process is completed underwater. The transport cask is constructed of 30 cm thick steel. The cask is fitted with copper cooling fins to transfer heat away from the fuel.

The transport casks exceed IAEA licensing requirements. The cask seal has been tested to sustain the external pressure exerted on an object by 4000m of water. The IAEA regulations only require an immersion test of 200 m.

The casks of used fuel are transported to The Central Interim

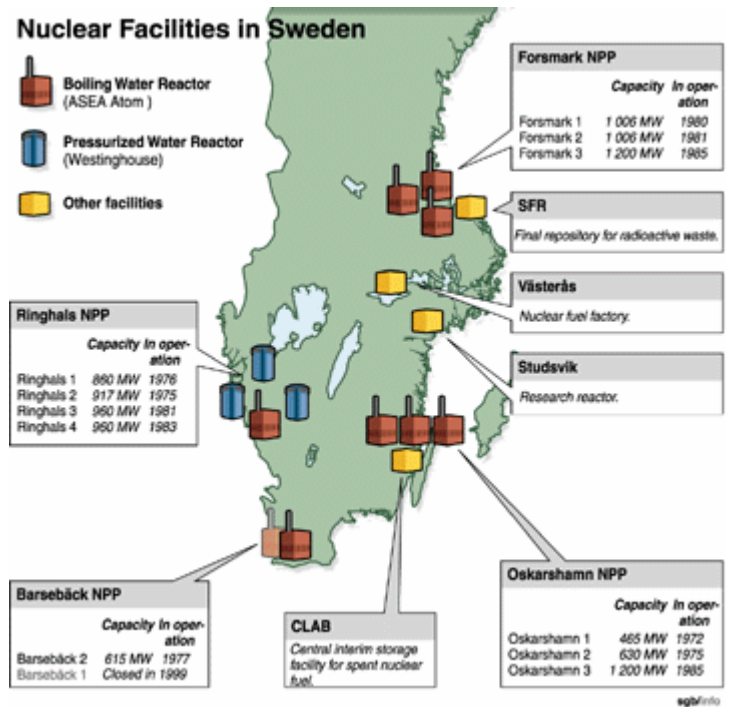


Figure 18. Locations of nuclear facilities in Sweden. (SKI –Swedish Nuclear Power Inspectorate).



Figure 19. Locations of Oskarshamn (Sweden) and Okiluoto (Finland).

Storage Facility for Spent Nuclear Fuel (CLAB) and stored between 30-40 years in water-filled pools since 1985. The facility is located at the Oskarshamn (Figure 19) nuclear power plant and has been in operation since 1985. Future plans are to dispose of the used fuel in a deep geological repository.

It is estimated that by 2010, there will be approximately 8,000 tons of used fuel in storage

The Swedish nuclear power stations are located on the coast and have their own ports, which facilitates sea transport. The M/S Sigyn makes several trips every year

between the nuclear power stations and CLAB. See Figure 18 for site locations.

The M/S Sigyn is specially designed to transport radioactive cargo. The sea position of the vessel can be determined at anytime: communication between the vessel and a monitoring centre is continuous.



Figure 20. Transport cask (left). M/S Sigyn (middle). Storage pool at CLAB (right). (Source: www.ski.se).

5.2.6 *FINLAND*

Used fuel produced from Finland's two reactors is currently stored on-site. Once removed from the reactors, the used fuel is cooled and shielded in water cooling pools in the reactor buildings. After a few years in the pools, they are loaded into safe, collision-resistant transfer casks and moved to on-site interim storage, where the used fuel is transferred to a second set of cooling pools. The used fuel remains in interim storage until final disposal. To date, used fuel has not been transferred from interim storage.

Finland selected a site for a final deep geological repository in 2000 at the power plant in Okiluoto (Figure 19). It is located in 70-100m of crystalline bedrock, approximately 500 m below surface. Fuel will be encased in copper canisters embedded in bentonite (very fine clay seal) and stored in the bedrock chambers. Construction of the site is scheduled to begin in 2020.

Finland has two reactor sites. The permanent disposal site is located at Okiluoto (one of the reactor sites), therefore used fuel will be transported from only one location. Finish law stipulates that the import of foreign nuclear waste is prohibited, therefore transportation in the future will be limited to shipments from one nuclear reactor site.

6.0 TRANSPORTATION-THE CANADIAN CONTEXT

Small used-fuel research shipments have been made in Canada since the late 1940s, and have been shipped by road. No serious incidents have been associated with any of these shipments.

Canada has extensive experience in low/intermediate waste transportation. Low level and intermediate level waste from Ontario Nuclear Power Stations has been transported to the Bruce for storage for over 20 years. Waste from Pickering and Darlington is loaded into specially reinforced and shielded transportation packages and trucked to the Western Waste Management Facility (WWMF) in Bruce County, on the east shore of Lake Huron (near the Bruce Nuclear Generating Station). Low level waste is put in plastic bags, then in special shipping containers, and transported to the Bruce facility. At the Bruce facility, they compact and incinerate the waste to reduce its volume, then store it in concrete buildings. All the waste is continuously monitored. In one year, OPG will make 1000 deliveries of low and intermediate waste.

AECL operates similar storage facilities for their research waste, as well as receiving commercial, medical and industrial nuclear waste collected from facilities across Canada.

As yet, used fuel has not been transported off-site (other than for research purposes). Some of the long term disposal proposals under government examination require transportation and storage off-site.



Figure 21. Dry storage at the Gentilly-2 nuclear station, Québec. (www.nuclearfaq.ca/drystrge.htm)

Until a disposal facility or a centralized storage facility is approved and operational, used fuel transportation will continue to be limited to small shipments, mostly to AECL facilities, for research purposes.

6.1 TRANSPORTATION OF DANGEROUS GOODS

Three million tonnes of dangerous goods (including hazardous waste) are transported in Canada every year by road, rail, sea and air.

Canadian National railway (CN) estimates that 10% of their traffic is dangerous goods.

Hazardous waste is the toxic by-product of many of the items and processes we use everyday to maintain our current standard of living. Eliminating the use of these substances is not an option. Reducing toxic chemicals, recycling them and safely disposing of them are all options. In the case of recycling and disposal, transportation of hazardous waste is necessary. Therefore it is important to implement regulations and strategies that minimize the risk to human health and the natural environment.

As described in Section 4.1, Transport Canada – Transportation of Dangerous Goods Directorate regulates the transportation of hazardous waste in Canada. Transportation of Dangerous Goods Regulations classifies hazardous waste in one of nine classes. Class 7 refers to radioactive material, and includes low, intermediate and high level waste (including used fuel).

“The *TDG Act, 1992* defines the term “handling” as meaning the loading, unloading, packing or unpacking of dangerous goods in a means of containment or transport for the purposes of, in the course of or following transportation and includes storing them in the course of transportation.

To this end, representative committees from industry, government, environmental groups, and others develop standardized designs and methods of manufacturing packaging or means of containment for particular types of dangerous goods. These standards in containment are referred to as Safety Standards and are adopted by the regulations.”⁹



Figure 22. Transport Canada’s Dangerous Goods labels for various classes of materials.

⁹ “Transporting Dangerous Goods Primer”, Transport Canada Dangerous Goods Directorate

CANUTEC, the Canadian Transport Emergency Centre, provides 24 hr/day bilingual emergency service. The Centre is staffed with professional chemists who assist qualified emergency responders in emergency/accident scenarios.

There are approximately 27 million shipments of hazardous waste in Canada every year. Approximately 1000 of those shipments are low/intermediate nuclear waste shipments. To date, there have been no transportation incidents that have involved a radiation exposure risk to human health or the environment. Table 3 shows the breakdown of calls to CANUTEC reporting emergency situations during the transport of Dangerous Goods (all Classes). It also shows the total number of Class 7 incidents in a given year. Note that Class 7 includes low, intermediate and high level waste.

The CNSC works in conjunction with Transport Canada to ensure the safe transport of radioactive material in Canada.

Table 3.
Percentage of Annual Hazardous Waste Shipments Resulting in Emergency Situations

<i>Year</i>	<i>Road</i>	<i>Rail</i>	<i>Marine</i>	<i>Multi-modal</i>	<i>Total</i>	<i># of Class 7 Incidents</i>
2002	0.0009%	0.0009%	0.00003%	0	0.002%	0.00003%
2001	0.0008%	0.001%	0.00007%	0	0.002%	0.00003%
2000	0.0009%	0.001%	0.00005%	0	0.002%	0.00003%
1999	0.0008%	0.0008%	0.00007%	0.000004%	0.002%	0.00003%
Note: Percentage of shipments based on an approximate total of 27 million hazardous waste shipments/year (all modes of transport, all classes of material)						

Source: <http://www.tc.gc.ca/canutec/en/stats/stats.htm>

6.2 THE CANADIAN PHILOSOPHY FOR SPENT NUCLEAR FUEL TRANSPORTATION

In order to transport, store, transfer, package, or dispose of nuclear material in Canada, a CNSC license is required. The Canadian philosophy is that the responsibility for safety is on the licensee. A licensee must prove to the CNSC that all aspects of a spent fuel facility, transportation cask, or transportation mode will be safely operated and maintained for its entire life span. The requirements for licensing ensure the risks to workers, the public, and the environment are as low as reasonably possible. The CNSC does regular reviews of licensees to ensure that they are constantly meeting or exceeding their license requirements.

6.3 TRANSPORTATION OF CANDU FUEL BUNDLES: FROM PRODUCTION TO CONSUMPTION



Figure 23. Cogema's McClean Lake Mine, Saskatchewan.

A fuel bundle may potentially be transported at various stages of its life. From mining the uranium through to storage of used fuel, infrastructure, regulations, and procedures exist to safely transport used and unused fuel bundles.

6.3.1 PRODUCTION

Canada is world's largest producer of uranium: approximately 25% of the world's Uranium is mined in Canada. Saskatchewan has the only operational Uranium mines, though uranium has been mined in the past in the Northwest Territories and Ontario. Potential mining sites have been identified in Nunavut, BC and Newfoundland. Two uranium refineries are located in Ontario.

Uranium ore is transported from the mines in Saskatchewan to two Uranium refining plants in Ontario (Blind River and Port Hope). Uranium dioxide ceramic fuel pellets are assembled in a zirconium alloy sheath, known as a pencil. Pencils are arranged in a 'fuel bundle', approximately the size of a log. One fuel bundle has enough potential energy to heat a home for 50 years.

The legal transportation requirements for uranium ore and unused fuel are similar to those required for the transportation of used fuel. A transportation license must be obtained from the Canadian Nuclear Safety Commission (CNSC). In order to obtain a license, an in-depth Risk Assessment (see Section 9), which includes an environmental and social component, and a detailed Security Plan (Section 10) must be submitted and approved. Most of the Uranium mined in Canada is shipped to the US, Europe and Asia. Shipments within Canada and to the US are made by road and rail. International shipments (to Asia and Europe) are made by sea or by air.



Figure 24. Remote controlled fuelling machine, refuelling a CANDU reactor core.

6.3.2 CONSUMPTION

In Canada, natural uranium fuel bundles (CANDU bundles) are used in the reactor cores at Nuclear Power Stations in Ontario (Bruce, Darlington, and Pickering), Quebec (Gentilly), and New Brunswick (Point Lepreau). A fuel bundle is loaded into the fuel channels of the reactor core with a remote controlled fuel

handling machine (Figure 24), where it acts as an energy source to produce steam which powers turbines and makes electricity. A fuel bundle stays in the reactor core approximately one year, when it is removed by the fuelling machine and stored in on-site cooling pools (Figure 29).

Because CANDU fuel is not enriched, there is less “burnup” of the fuel bundle. This results in more waste than other types of reactors. However, because of the lower burn-up, the heat load of a used bundle is much less, therefore the storage and transportation systems for used CANDU bundles are less complex.

6.4 USED FUEL TRANSPORTATION CONTAINERS

Nuclear waste has been produced in Canada since 1930s. The vast majority of transported nuclear waste in Canada is currently limited to low and intermediate level waste. A small amount of irradiated fuel bundles are shipped for research and development purposes.

Strict international regulations must be adhered to when transporting radioactive materials. These regulations are updated and enforced by the IAEA, as described in section 4.2, and are very specific regarding the design of transportation containers.

“Perhaps the most important aspect of handling is the packing of dangerous goods into a means of containment; it is generally believed that if the packaging is suitable, the risk of a serious incident occurring is greatly reduced.” *Transport Canada*

If Canada decides to go with centralized storage or deep geological storage as a long-term solution to nuclear waste management, then spent fuel would be transported from the nuclear plants to the centralized management facility. Currently, nearly all spent fuel produced in Canada is stored on-site. Part of the mandate of the NWMO is to explore long term solutions for spent fuel management.

One million packages of low level waste (see Section 2.1.3) are transported in Canada every year by road, rail, sea, and air. In 2000-2001, there were 19 incidents reported, with 7 incidents resulting in an ‘emergency situation’ (Table 4). There was no exposure of workers or public to radiation and no significant environmental effects as a result of those 19 incidents. Most involved incorrect labels, documents, or preparation of packages.

The main difference between transportation systems for used fuel and other hazardous substances are the containers in which they are transported. The design of the transport cask is the main safety feature in used fuel transport.

Currently, two different containers are licensed in Canada for large-scale transportation of used fuel. The Irradiated Fuel Transport Container (IFTC) is licensed for road, rail and water transport, and the Dry Storage Container Transportation Package (DSCTP) is currently licensed for rail and water transport.

6.5 IRRADIATED FUEL TRANSPORT CONTAINER (IFTC)

In the mid 1980s, OPG developed a used fuel transport cask for large-scale transportation. The cask was specifically designed for road transportation, but may also be used for rail or water transport.

The rectangular, stainless steel cask measures 1.6 x 1.9 x 1.8m, and is designed to carry 192 used fuel bundles. The wall thickness of the cask is 270 mm. The weight of the cask when full is approximately 35 tonnes. The bundles are stored in two 96-bundle modules. The casks are designed of stainless steel so that they are less brittle and more crack resistant, and easy to decontaminate than concrete.

The lid is bolted on with 32 heavy duty stainless steel bolts and sealed with two "O" rings. The cask is designed to absorb lateral force through the cask walls, and not through the lid, to minimize the chance of the bolts shearing and the lid "popping" off. An impact limiter made out of redwood and

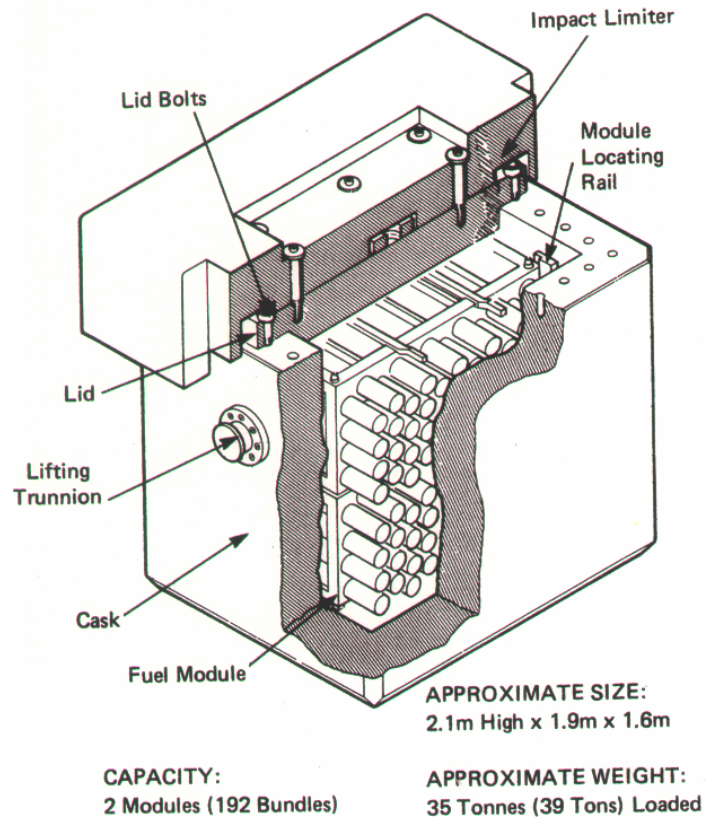


Figure 25. Preliminary design of the Irradiated Fuel Transportation Cask.¹²

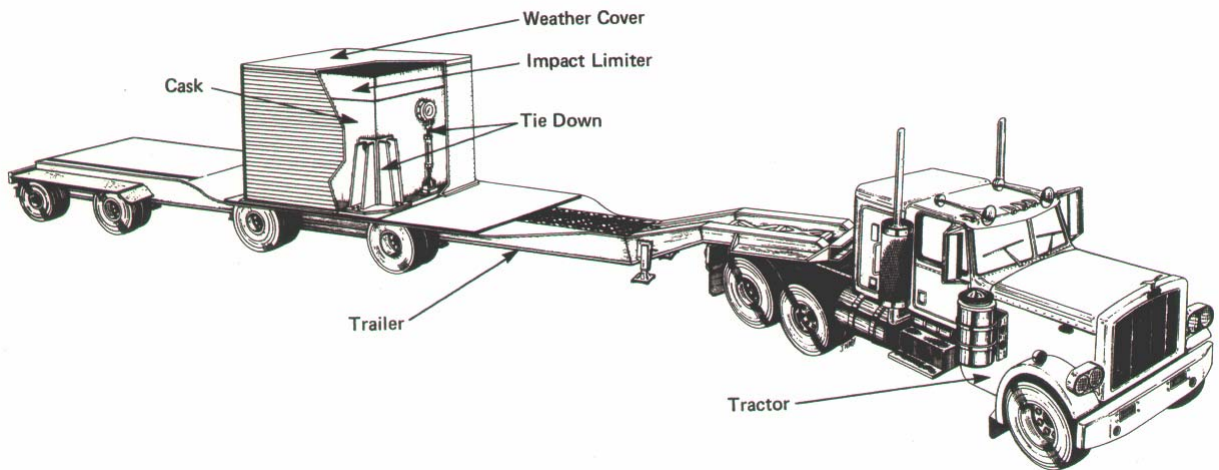


Figure 26. Irradiated Fuel Transportation Cask Tractor/Trailer.¹⁰

covered with stainless steel fits over the lid to protect the lid and bolts from impact and fire.

Redwood was selected because of its energy absorbing and insulation properties and its ability to resist combustion. This latter feature is important should the stainless steel sheathing fail during an impact.¹⁰

Vents and the drain on the cask are sealed with “O” rings. Two large bolts, or trunions, are located on the sides of the cask for lifting and tie-down during transportation.

6.5.1 SAFETY TESTING

After successfully passing the IAEA safety tests, (Section 4.2), the cask was licensed by the CNSC for road, rail and water transport.

In addition to the tests required by the CNSC/IAEA, OPG performed testing on the shock and vibration effect on fuel bundles, various seal performance tests, Impact Limiter testing, and UO₂ oxidation. The testing was performed to simulate different ‘disaster’ and accident scenarios, and the behaviour of the cask and the fuel bundles, in the absence of the safety features required for licensing, to better understand what could potentially happen in an emergency.

6.5.2 OTHER CONTAINERS

In the last 30 years, there have been more than 500 shipments of used fuel in Canada. The transfer of used fuel has been done using specially designed, tested and approved containers. Three different casks, designed for shipments of 2, 25 and 70 fuel bundles each, have been used. There has never been a release of radioactive materials from these shipments.

Transportation of these casks has been for research purposes, typically between research stations. The casks were designed to ship fuel that had been in the used fuel bays for a short period of time.

6.6 DRY STORAGE CONTAINERS (DSCs)

The DSC was designed by OPG in order to have a dry storage container that could also be transported. In addition to the DSC, OPG has designed dry storage facilities for interim storage of the DSCs.

Dry Storage Containers and Used Fuel Dry Storage Facilities provide safe, interim storage until a long-term management program is in place. At Pickering, the used fuel has been transferred from the used fuel bay to a Dry Storage Facility (on-site)

¹⁰ K.E. Nash, “Design and Testing of a Cask for Transporting Irradiated CANDU Fuel”

since 1996. Ontario Power Generation has recently built a similar facility near the Bruce Nuclear Generating Station, named the Western Used Fuel Dry Storage Facility, which is now operational. Plans are underway to construct a dry storage facility at Darlington. Similar dry storage systems are used in the US.



Figure 27. DSC Cross Section (Pickering Waste Management Facility - Phase II Information Package)

The rectangular DSC container measures 2.1 x 2.4 m and stands 3.5 m tall. Containers are constructed of reinforced concrete, 60 cm thick, and are lined on the inside and outside with 13 mm thick heavy gauge steel. At this thickness, both the steel and the concrete will be an effective barrier to radiation. The walls of the container are resistant to earthquakes up to a magnitude of 6.5 on the Richter scale. The containers have been licensed for transportation for a 50-year life span.

The licensed design consists of a specially designed overpack, comprising large polyurethane foam “impact limits” sheathed in stainless steel and held together with high density steel wire rope. The impact limits feature a thick stainless steel armoring to prevent projectiles from piercing the foam overpack and damaging the containment weld or outer DSC skin. The DSC and the overpack are referred to as the Dry Storage Container Transport Package (DSCTP).

This design has been proven in scale model impact tests and extensive modelling using complex computer codes, which predict the response of the packaging to high energy impacts.

Four fuel modules (96 fuel bundles/module) are loaded into the DSC. Fuel is stacked horizontally in the modules. When full of fuel (4 modules, 384 fuel bundles), the container weighs 70 tonnes, and the loaded DSCTP weighs 100 tonnes.

The main disadvantage of the DSC is its weight. Many transportation factors are limited by weight, such as mode of transport, vehicle type, route, and season of transport.



Figure 28. X-ray of weld on DSC (Pickering Waste Management Facility - Phase II Information Package)

6.6.1 SAFETY TESTING OF THE DSC

DSCs are designed so that even in extreme accident scenarios, they maintain their integrity, preventing any exposure to radiation. The IAEA/CNSC licensing procedures and the testing requirements (Section 4.2.2) ensure that the design meets these safety requirements.



Figure 29. Cooling pool. (OPG Facsheet “Pickering Waste Management Facility”)

Irradiated fuel from the fuel bays is transferred only when the bays begin to reach capacity and only after a minimum of 10 years after removal from the reactor core.

The DSC is lowered into the fuel bay, and the bundles are inserted into the container underwater by a

6.6.2 ON-SITE TRANSPORTATION AND HANDLING

Used fuel bundles are removed from the reactor core by remote control fuelling machines and placed in the cooling pools. The spent fuel remains in the cooling pools for at least 10 years, when the heat and radiation produced from the bundles has reached a manageable level (around 6 Watts/bundle), therefore the DSCs do not require cooling systems. In Europe, fuel is removed from the cooling pools after 6 months, and placed in transport casks. This practice requires the cask to be engineered for cooling as well as shielding, as the 6-month cooled fuel still produces a significant amount of heat.

Since 1996, used fuel at Pickering has been transferred from the cooling pools after at least 10 years to dry storage containers. The new Western Used Fuel Dry Storage Facility in Bruce County was completed in 2002, and is now operational. Previously, all fuel at the Bruce was stored in cooling pools.



Figure 30. OPG Transporter (Pickering Waste Management Facility - Phase II Information Package)

crane. The lids are clamped in place, and the container is removed from the fuel bay, drained, and decontaminated. The process is completed in the fuel bays to ensure the shielding of water protects workers from exposure to radiation.

A specially equipped vehicle, called “Transporter” (Figure 30) then moves the loaded DSC to the on-site storage facility. The Transporter travels at 4 km/hr.

Once inside the facility, the lids are welded in place by robotic equipment and the welds are X-rayed to completely inspect each weld for potential defects. Any defects are repaired as required (Figure 28). The interior of each DSC is vacuum-dried and subsequently filled with helium.

Finally, all valves and drains are also welded shut. The DSCs are then fitted with seals and inspected by a representative from the International Atomic Energy Agency (IAEA). Routine checks are made on used fuel dry storage containers by OPG staff, the CNSC and inspectors from the IAEA.

Storage Capacity at WUFDSF is approximately 500 DSCs with extensive capability to 2000.

Phase I of the Pickering Waste Management Facility can currently store 700 dry storage containers (384 bundles/container). The proposed Phase II of the facility, with a potential capacity of an additional 700 DSCs, is currently undergoing an Environmental Assessment review.

Plans are also underway to construct a dry fuel storage facility at Darlington. Once the dry fuel storage facility is completed at Darlington, the facility will be able to contain up to 1,500 DSCs, each holding up to 384 used fuel bundles. The facility would be able to accommodate all the waste produced on-site until the end of the plant’s service life.



Figure 31. DSC being moved by crane.

6.6.3 A QUESTION OF SAFETY

WHAT’S THE RISK OF AN ACCIDENT WHILE LOADING A DSC OR TRANSPORTING IT TO THE STORAGE FACILITY?

Based on rigorous design, testing and operating procedures, supported by the safety assessment and actual operating experience at a waste management facility, the risk is small. The handling areas are equipped with special crash pads to limit the consequences of any handling accidents while loading (in or out of the bays) takes place, and when the DSCs are transferred to the transporter vehicle. The DSCs will be lowered under water by a heavy-duty crane and loaded by remote control in the water-filled fuel bays within the station. Loading crews will

be protected from radiation exposure by the shielding of the water above the loading level. Initially, the DSC lid is fastened (but not welded) to the base, using a special re-usable clamping device, for transit to the processing building. This clamping device is designed to remain in place even under credible accident scenarios and has been extensively analyzed. The lid is then welded to the base at the processing building, before it is transferred to storage.

HOW WILL THE DSCs BE MONITORED?

The waste management facilities will be monitored for air emissions as part of OPG's comprehensive radioactive emissions monitoring program. The DSCs in the Storage Buildings are regularly monitored and inspected by OPG staff, the CNSC and inspectors from the IAEA. In addition, the welds and casings of the Dry Storage Containers (DSCs) will be inspected annually. Because the fuel bundles are made of solid materials and encased in a dry, inert environment within the DSC, liquid leaks or spills are not possible.

What is OPG doing to prevent accidents?

The Environmental Management System (EMS) at the Western Waste Management Facility describes the methods used to manage the Environmental Aspects. An Environmental Aspect is an element of an activity or service that can impact on the environment.

The WWMF has eight Significant Environmental Aspects (SEA) ranked to determine which are significant based on environment risk, regulatory scrutiny, stakeholder concern and business risk. One of the SEAs is "Radioactive Release During Transport".

The EMS is based on the ISO 14001 Standard, which provides a tool for ensuring and demonstrating a high standard of environmental responsibility. It ensures that an environmental policy is in place, legislative compliance is mandatory, programs exist to meet environmental objectives, and performance is reviewed and managed to ensure continuous improvement.

The WWMF received ISO 14001 registration in 1999. The registration is renewed every 3 years, but is audited annually. No major non-conformances have resulted from the audits.

As described in the EMS, Radioactive release during transport has the potential to contaminate air, soil and water. The objective is to minimize the likelihood of release of radioactive materials to the environment during highway transport. Progress made in 2002 includes the development and implementation of a vehicle maintenance program, which ensures transportation vehicles are in good working condition. An electronic shipping system is in the process of being built and implemented.

6.7 DSC vs IFTC

Cogema Logistics Ltd. (Cogema Logistics), a company owned by the French Government, conducted a feasibility report studying both the IFTC and the DSCs as transportation packages. The report concluded that all fuel stored in DSCs at the time transportation begins, could be transported in the Dry Storage Container Transport Package (DSCTP), but that the remaining fuel bundles in wet storage and in fuel baskets should be transported in lighter packages similar to the IFTC.

DSCs are or will be loaded with fuel modules at all the operational facilities in Ontario for interim storage and eventual transportation. However, at the Gentilly, Douglas Point, Point Lepreau storage sites, fuel in wet and dry storage is stored in fuel baskets, not fuel modules.

Fuel baskets store 60 fuel bundles in the vertical position, and are wider than fuel modules. Baskets are 55 cm tall and 107 cm in diameter. Nine baskets (540 bundles) are stacked on top of each other in concrete silos for dry storage. A Gantry crane would be required to transfer baskets from the concrete silos to transportation containers at Gentilly, Douglas Point and Point Lepreau. The IFTC could be more readily adapted for fuel baskets than the DSC. The IFTC would need to be enlarged to better accommodate the fuel baskets currently used. Advantages and disadvantages of the two packages are listed in the **Table 4**, below.

Table 4. Advantages and Disadvantages for Transportation of IFTCs and DSCTPs

TRANSPORT CASK	ADVANTAGES	DISADVANTAGES
DCTP	<ul style="list-style-type: none"> • 2/3 of fuel bundles will already be loaded in DSCs by the time of first shipment • Currently licensed for rail and water transport in Canada • Reusable overpack 	<ul style="list-style-type: none"> • Not currently licensed for road transport in Canada • One time use of DSC • Heavier load, may not be suitable for road transport
IFTC	<ul style="list-style-type: none"> • Currently licensed for road, rail, and water transport in Canada • Reusable 	<ul style="list-style-type: none"> • Smaller capacity • Would require modification for baskets.

6.8 TRANSPORTATION ORIGIN OF USED FUEL

Used fuel in Canada is “owned” by its producer. In Canada, the following companies “own” used fuel:

- Ontario Power Generation (OPG);
- Hydro Quebec;
- New Brunswick Power (NBP);
- Atomic Energy of Canada Limited (AECL).

Table 5 shows the different sources of used fuel in Canada (excluding research waste stored at Chalk River and the Whiteshell), and where it is stored. During the decommissioning of the Douglas Point Reactor, its used fuel was stored in dry storage silos on-site. Small shipments of used fuel were transported to the Whiteshell Research Laboratories (AECL). The Douglas Point site is located between Bruce A and Bruce B, so ultimately they share a common point of origin in any transportation scheme.

Used fuel from the decommissioned Nuclear Power Demonstration reactor is stored at Chalk River. At reactor sites still in operation, the used fuel is currently stored on-site.

Table 5. Transportation Origin of Used Fuel

Reactor	Owner	Storage Site	Type of Storage
Pickering A and B	OPG	PNGS, PUFDSF	<ul style="list-style-type: none"> • Modules in Wet Bays • Modules in DSCs
Bruce A and B	OPG	BNGS WUFDSF	<ul style="list-style-type: none"> • Trays in Wet Bays • Modules in DSCs
Douglas Point	AECL	Douglas Point	<ul style="list-style-type: none"> • Baskets in silo canisters
Douglas Point	AECL	Whiteshell Research Laboratories	<ul style="list-style-type: none"> • Baskets in silo canisters
Darlington	OPG	Darlington NGS	<ul style="list-style-type: none"> • Modules in Wet Bays • Future plans for Modules in DSCs
Point Lepreau	NBP	PLNGS	<ul style="list-style-type: none"> • Baskets in silo canisters
Gentilly 1	AECL	GNPGS	<ul style="list-style-type: none"> • Baskets in silo canisters
Gentilly 2	Hydro- Quebec	GNPGS	<ul style="list-style-type: none"> • CANSTOR Vaults
NPR Reactor	AECL	Chalk River	<ul style="list-style-type: none"> • Baskets in silo canisters

6.9 FUTURE MODES OF TRANSPORTATION IN CANADA

Though large-scale shipments of used fuel are not currently conducted in Canada, it is a distinct possibility in the future. If Canada decides to go with Centralized Storage or Deep Geological Disposal for used fuel, then a transportation system for used fuel will become necessary. Some details of possible transportation systems are provided below, and are based on IAEA requirements and reports, current international practice, and a conceptual design study conducted by Cogema Logistics.

Cogema Logistics was commissioned by OPG, Hydro-Quebec, New Brunswick Power and AECL to conduct a conceptual design study for Used Fuel Transportation Systems (UFTS) in Canada. Some of the areas studied were vehicles of transportation, modes of transportation, transportation containers, and loading/unloading systems. Cogema Logistics described three (3) possible UFTS in Canada:

- Road Transport System;
- Combination Rail/Road System; and
- Combination Ship/Road System.

6.9.1 ROAD

Advantages of road transport are flexibility, existing infrastructure and short turn-around times. For road transport to be the most economical, high payload vehicles must be used. However, there are regulatory constraints on the

maximum gross vehicle weight. As the DSCs weigh approximately 70 tonnes, a nine-axle trailer would be necessary, with permission from the Minister of Transportation.

Road transport vehicles would not vary much from a traditional transport trucks/trailers. However, dedicated trailers would be used because of special tie down requirements to secure shipments of high-level radioactive waste. As a general rule, loads not greater than 40 t could be shipped by road.

TRANSPORTATION CONTAINERS

The system proposed by Cogema Logistics recommends that only the IFTC be used for road transport, though they indicated that the DSC could be licensed for road transport, and a nine-axle trailer could be used.

Using the IFTC as the only container, an average of 12 truckloads/week, with a total of 18747 shipments would be required to move the estimated 3.6 million fuel bundles from their storage sites to a central facility. This system would also involve the unloading of modules from DSCs at OPG storage sites into IFTCs. A breakdown of the shipments from their respective origins (at the end of their estimated lifespan) is provided in Table 6.

Once a central storage or disposal location is chosen, the roads to the location would likely require upgrading.

Table 6. Breakdown of Shipments of Used Fuel for Road Transportation⁸

<i>Origin</i>	<i>Number of shipments</i>	<i>Number of DSCs unloaded</i>
Whiteshell*	3	0
Bruce	7848	2869
Pickering	4852	1552
Darlington	4583	1386
Gentilly	767	0
Point Lepreau	664	0
Chalk River	30	0
*Number of shipments does not include experimental fuel stored at Whiteshell and Chalk River.		

The Cogema Logistics report also recommends modifying the IFTC design resulting in a larger cavity. Presently, the IFTC is designed to hold two fuel modules, but is not suited for the wider geometric configuration of a fuel basket. A larger cavity would permit the use of the IFTC by both fuel modules and fuel baskets. Aluminium inserts would be added when the IFTC is loaded with fuel modules, to compensate for the extra space.

In order to enlarge the cavity, but not the exterior dimensions of the IFTC, Cogema Logistics recommends studying the feasibility of reducing two of the four

wall thicknesses by 10%. The modified IFTC would still be able to carry two (2) fuel modules, but would be alternatively capable of carrying three (3) fuel baskets.

A 'universal' container would be more efficient for transportation, loading/unloading and storage purposes. It would require only one mode of transportation, one vehicle type, and type of handling gear.

TRANSPORTATION VEHICLE

Road transport would be restricted by inclement weather to 275-300 transportation days in a calendar year. Note that transportation requirements with respect to seasons/weather are stricter with heavier payloads.

A fleet of dedicated trailers would be used. The trailer would be a typical 48-foot flatbed trailer, modified with the regulatory tie-down system. It would be equipped with four axles for the IFTCs, or nine axles for the DSCTPs (Figure 32). In either situation, the trailer would be loaded with only one container. The trailers would have air-ride suspension to absorb impact and vibration during transport. A rolling removable plastic weather cover would be provided to prevent the casks from rain.



Figure 32. Nine axle trailer. (Cogema Logistics Ltd)

A standard tractor could be used to haul the trailer. For IFTCs, a 9.07 t industry standard tractor would be required, versus an 11 t tractor for DSCs. The average travel speed for the IFTC (including stop time) would be approximately 50 km/hr. The average travel speed for the DSCTP would be lower. The vehicles would travel on Class A roads.

If the DSCs were used for transport, the UFTS would be modelled after the system currently used in France. France has been transporting used fuel by truck for decades. They use 120t payload, on an 8-axle trailer. The tractor-trailer travels at 40 km/h, and is escorted by two police vehicles (due to payload, not security).

The purchase of the tractor is recommended (as opposed to a contract), to ensure control over modifications, maintenance and safety.

The system would comply with all international, national and provincial regulations, including hours of work by drivers.

6.9.2 RAIL

Shipment by rail is practical for loads exceeding 40 tonnes, and is therefore practical for shipping large quantities of used fuel. Like transport trailers, rail cars do not vary much from a traditional car. A flatbed rail car can be adapted to carry one DSC or two IFTCs. Rail shipment can be more economical than road shipment, due to the higher payload.

Existing rail lines in Ontario could be used to transport used fuel in Canada, though additional feeder lines or spurs would have to be constructed/extended. If construction of a railroad to the actual central location is not possible, a combination road/rail system could be applied. The same goes for spur extensions at the nuclear generating stations.

Cogema Logistics recommended transporting all the DSCs currently used as storage as is, but the fuel remaining in wet storage would be transported in IFTCs.



Figure 33. Rail Car (Cogema Logistics Ltd.)

One hundred ton (100t) rail flat cars with shock absorbing couplers would be loaded with one (1) DSC or two (2) IFTCs (Figure 33). Up to five loaded cars would be used per train, along with a locomotive, caboose and at least two buffer cars: one buffer car between the locomotive and the loaded cars, one buffer car between the loaded cars and the caboose. The train may also be outfitted with extra cars for security escorts. The rail flat cars would likely be purchased, to ensure control and safety for modifications and maintenance.

The dedicated trains would travel directly to the final location, and therefore would not require storage time in rail yards. The average train speed is assumed to be 60 km/hr (20 km/hr including stop time).

A possible combination of road/rail transport would have used fuel transported by tractor-trailer (see Section 6.2.1) from the Whiteshell and Chalk River directly to the central location in IFTC containers.

Assuming that a railroad does not exist and cannot be built to the central disposal site, used fuel from Pickering, Darlington, and Gentilly would be transported by

rail to a central road transfer facility at the railhead. There, the casks would be transferred from the rail cars for final transport to the central disposal site by road (see Section 6.2.1).

Used fuel from the Bruce and Point Lepreau would be transported by road to a railhead, and then transferred to a rail car. They would then be transported to the road transfer facility described above.

Table 7. Breakdown of the # of Shipments from the Points of Origin to a Central Disposal Facility¹¹

<i>Origin</i>	<i>Mode</i>	<i># shipments to Transfer Facility</i>	<i># shipments to Central location</i>
Whiteshell	Road	N/A	3
Bruce	Road/Rail/Road	4979/814	
Pickering	Rail/Road	498	
Darlington	Rail/Road	474	12960
Gentilly	Rail/Road	77	
Point Lepreau	Road/Rail/Road	664/67	
Chalk River	Road	N/A	30

The combined rail/road system would deliver approximately eight (8) truck loads/week to the central site. A total of 1930 rail shipments and 12960 connecting/additional road shipments would be required to move 3.6 million used fuel bundles. Compare this to the 650 shipments currently transported every year in the UK and France. A breakdown of the shipments is shown in Table 7.

In addition to the additional rail spurs, upgrades would be necessary to roadways.

Rail transport is largely unaffected by seasonal requirements, so ultimately there would be 365 transport days in one calendar year. Transporting used fuel by rail would comply with all relevant international, national and provincial regulations.

The construction of new rail lines would require their own Environmental Assessments, in addition to EA's required for the actual transportation of radioactive materials.

6.9.3 VESSEL

A third possibility for transportation of used fuel in Canada studied by Cogema Logistics is by water. One of the main advantages of a vessel transport is that many of the reactor sites are located on a body of water. Another advantage is that there is existing technology and precedence. There is a long history of used fuel shipments by sea within Europe and between Europe and Japan (see Section 6.4). Most of the transportation by ship in Canada would be limited to in-land waters (St. Lawrence Seaway and the Great Lakes).

Though the routing of shipments depends on the final selection of a central disposal site, it is highly unlikely that the entire route to the site chosen will be accessible by waterways, making it necessary to combine water transport with some form of land transport (rail or road).

Vessels suitable for transport of used fuel (Class 7 material) are readily available in the commercial market. It is recommended that a vessel should be purchased new at the time the shipments begin. If the vessel is contracted, the lease should be for the total length of the transportation program, with provisions that transportation staff have authority over modifications, maintenance, loading and unloading, stowage, tie-downs, routing, satellite tracking, radiation monitoring, scheduling and emergency response. A qualified marine inspector would conduct an initial suitability study.

Though the routing would be through inland waters, a sea vessel would be used. The expected cargo capacity of a vessel would be 15 DSCTPs or 32 IFTC. The vessel would travel at a maximum of 15 knots.

The total length of the vessel would be 100 m, with a width of 8m. The dead weight of the ship would be approximately 5000 dwt. The vessel would be strengthened for ice, and fitted for freshwater travel in the Great Lakes. The decks would be strengthened for heavy cargo.

The vessel would be equipped with manoeuvrability equipment to allow for unassisted entry and exit into ports for docking. The vessels would have easy access to the cargo space to allow for constant monitoring of transportation packages. They would also be fitted with modern communications equipment and emergency generators.



Figure 34. Loading used fuel into ship's hold. ("WNTI Annual Review", 2002)



Figure 35. Ship with on-board crane. (Cogema Logistics Ltd.).

Used fuel would be transported by tractor-trailer (see Section 6.2.1) from the Whiteshell and Chalk River directly to the central location in IFTC containers.

Used fuel from the Bruce, Pickering, Darlington, Point Lepreau and Gentilly would be transported by vessel to a central land transfer facility. There, the casks

would be transferred from the vessels for final transport to the central storage or disposal site by road (see Section 6.2.1). It is likely that this final leg of transport would be by tractor/trailer, though it may be possible by rail. Table 8 shows the breakdown of shipments from the reactor sites to the central storage or disposal site.

Table 8. Breakdown of the # of Shipments from the Points of Origin to a Central Disposal Facility¹¹

<i>Origin</i>	<i>Mode</i>	<i># shipments to Transfer Facility</i>	<i># shipments to Central location</i>
Whiteshell	Road	N/A	3
Bruce	Ship/Road	268	
Pickering	Ship/Road	169	
Darlington	Ship/Road	164	12927
Gentilly	Ship/Road	25	
Point Lepreau	Ship/Road	21	
Chalk River	Road	N/A	30

The ship could be loaded at one or more reactor sites. Dock construction and/or upgrading would have to be conducted at each reactor site. The ship would be equipped with high speed cranes, so that loading/unloading equipment would not be required at each of the reactor sites, or at the road transfer station. Open waterways are assumed from mid-April to mid-December, therefore there would be approximately 245 shipping days in one calendar year.

LOADING AND UNLOADING

Methods for loading and unloading spent fuel are based on industrial practices currently used for other kinds of freight shipments.¹²

¹¹ Cogema Logistics, Ltd. “Conceptual Designs for Transportation of Used Fuel to a Centralized Facility”

¹² IAEA Guidebook on Spent Fuel Storage, Second Edition.



Figure 36. Ship to Road transfer (Cogema Logistics Report).

6.9.4 *TRANSPORTATION ROUTES*

Several transportation routes were proposed during the Seaborn Panel EA for the purpose of probability studies – determining the likelihood of different accident scenarios, possible effects on the local communities, etc. Most of the routes proposed were through Northwestern Ontario. Other routes considered were from the current storage sites, and to facilities in central Ontario.

The report concluded that any transportation routes would have to be discussed and accepted by the local communities, which would be most likely affected. Negative effects on the local communities were identified, and not only included the effects related to an accident during transportation, but also the effects on local communities during the construction period required for upgrading infrastructure, increased traffic, and detrimental environmental effects.

6.10 TRANSPORTATION SECURITY PLANS

In order to obtain a CNSC license for transporting used fuel, a written transportation security plan must be completed, that includes:

- The name, quantity, radiation level, chemical and physical characteristics and isotopic composition of the nuclear material;
- A threat assessment consisting of an evaluation of the nature, likelihood and consequences of acts or events that may place prescribed information or nuclear material at risk;
- A description of the transportation method and vehicle(s);
- The proposed security measures;
- The communication arrangements made among the licensee, the operator of the vehicle transporting the nuclear material, the recipient of the material, and any response forces along the route;
- The arrangements made between the licensee and any response force along the route;
- The planned route; and
- The alternate route to be used in case of an emergency¹³.

The security plan and the threat assessment take into consideration the type of material being transported. For example, the security plan for used fuel would be considerably more thorough than the security plan required to ship low level waste.

Any changes to the procedures outlined in the transportation security plan after a license has been granted must be reviewed and approved by the CNSC. A license is typically valid for one year, and for a specified number of shipments within that year.

6.10.1 *THREAT ASSESSMENT*

The CNSC receives intelligence information from federal security agencies regarding known criminals and extremist/terrorist threats. Any information of this type will be considered during the licensing process.

The licensee is required to communicate with law enforcement agencies to identify possible credible security threats, and determine whether these threats are low, medium or high.

¹³ Section 5, *Nuclear Security Regulations*

6.10.2 *DESCRIPTION OF TRANSPORTATION MODE AND VEHICLE*

The description of the transportation mode and vehicle should cover all aspects of transportation from the time the material leaves its origin until it reaches its final destination. It should include descriptions of the type, size and weight of containers, and any tie-down system used to secure the container to the vehicle.

When more than one mode of transportation is used, the details for each segment should be provided including the methods of transferring the package from one mode to another. These details should include:

- Date, time and location of the planned transfers;
- The names of the persons responsible for the transfers; and
- Verification of the integrity of the packages after each point of transfer.

The transportation security plan should also describe the maintenance procedures to ensure that transportation vehicles are properly and regularly maintained.

6.10.3 *SECURITY MEASURES*

Depending on the risk identified, the following measures may be required for licensing:

- Armed or unarmed guards, escort personnel or escort vehicles;
- Plans for response forces along the transport route;
- Procedures on how to contact response forces during transportation in the event of an incident;
- Security searches prior to shipment;
- Contingency plans in the event of mechanical breakdowns of the transport vehicles or delays in the scheduled arrival times;
- Procedures for scheduled stops; and
- Plans for unscheduled stops due to natural or other hazards.

If the CNSC does not think that the Security Plan is adequate, a transportation license will not be granted.

6.11 ASSESSING THE RISK

If used fuel is not transported off-site, than the obvious alternative is that it stays on-site at each of the reactor stations. Most of the reactor stations are within 100 km of major Canadian centres (Table 9). Most of the reactor stations are also located on the shores of large bodies of water.

Table 9. Proximity of Nuclear Sites to Densely Populated Areas

Reactor	City	Population	Distance (Km)	Body of Water
Pickering A & B	GTA	4,400,000	40*	Lake Ontario
	Oshawa	241,000	15	
	Mississauga	612,000	68	
Bruce A & B, Douglas Point	GTA	As above	250*	Lake Huron
Darlington	GTA	As above	100*	Lake Ontario
	Oshawa	As above	50	
	Belleville	87,000	83	
Point Lepreau	St. John	91,000	40	Bay of Fundy
	Fredericton	54,000	80	
Gentilly 1 & 2	Trois Riviere	130,000	7	St. Lawrence Seaway
	Quebec City	680,000	123	
* Distance to downtown Toronto				

As part of the Environmental Assessment for the siting of storage/disposal facility, a Risk Assessment must be performed. A Risk Assessment for each proposed route must be completed. Generally, the route chosen will minimize time/distance of transportation, minimize the number of transfers, and avoid when possible densely populated areas.

Primary issues that need to be addressed in a Risk Assessment for the transportation of used fuel are:

1. Identify what accident scenarios could result in a radiation release;
2. Evaluate the likeliness of a serious accident occurring;
3. Evaluate the likely extent of radiation released during such an accident;
4. What affect would a radiation release have on human health and the natural environment;
5. How would such a radiation release be contained and cleaned.

Note that because of the rugged design of the licensed transportation casks in Canada, it is unlikely that an accident would result in a serious release of radioactive material.

7.0 PUBLIC PERCEPTION

In general, the transportation of used fuel is a contentious issue. The issue is often associated with a pro-nuclear power movement. It is important when addressing the public that these issues are separated. Canada has an existing store of used fuel in need of disposal (and likely transportation), whether or not we continue to use nuclear power as an energy source, today, tomorrow, or 100 years in the future.

7.1 SEABORN REPORT

The Seaborn report evaluated AECL's proposal for long-term disposal of nuclear waste in Canada. Named after the chairperson, Blair Seaborn, the Seaborn panel was commissioned by the government of Canada in 1989 to conduct an environmental assessment of AECL's deep geological disposal of nuclear waste concept. The panel was further commissioned to:

"...examine the criteria by which the safety and acceptability of a concept for long-term waste management and disposal should be evaluated" (Report of the Nuclear Fuel Waste Management and Disposal Concept, Seaborn Panel).

The panel was to evaluate the proposed disposal methods on technical competence and safety as well as public acceptance.

Some of the following public concerns relating to nuclear fuel waste transportation were voiced during the panel's public review forums:

- Safety of Canadian highways,
- Accidents and terrorism
- Testing and integrity of shipping casks
- Emergency preparedness
- Notification and rights of communities along the routes
- Storage/transportation/construction in northern communities and their affect on Aboriginal people.

Some participants related that their concerns regarding the safety of used fuel transportation were so great, that they would oppose any option that involved off-site storage.

The panel concluded that though the option of storing high level nuclear waste in deep geological storage was technically sound, it lacked the public support necessary.

“A deeply entrenched fear and mistrust of nuclear technology exists within some segments of our society. This “dread factor” is real and palpable. It is an important element in the decision-making processes concerning nuclear matters, as it will undoubtedly affect the public confidence resulting from such processes...Although experts may challenge or debate the perception that nuclear fuel wastes pose unprecedented hazards due to their extreme toxicity and longevity, these challenges are not, by themselves, likely to materially reduce the dread factor”. (Nuclear Fuel Waste Management and Disposal Concept – The Nature of the Problem, Seaborn Panel”

7.2 NWMO DISCUSSIONS

The NWMO conducted fourteen discussion groups in late 2002 to determine public attitudes on nuclear waste transport and disposal. The report concluded that the public (by its own admission) does not feel it will ever be capable of knowing enough about the subject of used fuel transport and disposal to form an informed opinion. People in general were willing to trust recommendations of the NWMO, as long as studies were (most importantly) independent of government and the nuclear industry, directed by science, and competently managed.

7.3 INTERNATIONAL

In general, public acceptance of nuclear waste transportation is sceptical. Much of the opposition stems from groups that oppose nuclear power in general. The Seaborn panel determined that “no country has achieved the social consensus necessary to build a disposal facility for high-level nuclear waste” and that “It is becoming more clear that societal acceptance will be more difficult to achieve than scientific and technical acceptance”. Though centralized storage seems to garner more support than deep geological storage, it also involves transportation of nuclear waste, of which the general public seems uneasy.

7.3.1 YUCCA MOUNTAIN

Public opinion towards the concept of deep geological storage at Yucca Mountain by the scientific community is generally accepted, while in the community-at-large it is sceptical. Much of the controversy surrounding the subject is related to the transportation of high-level waste. The most notable objection to the Yucca Mountain initiative is from the State of Nevada.

The state of Nevada objected to the approval of Yucca Mountain as a federal repository for nuclear waste, claiming the EIS was not compliant with the National

Environmental Policy Act and the Nuclear Waste Policy Act. The state filed suit against the US DOE. One of the primary complaints of the state of Nevada was that the EIS for transportation of high-level waste was inadequate. The state suggested that the US DOE develop a draft national transportation plan for used fuel, along with a state plan that would identify possible transportation routes, and a six month comment period for the public to express comments/concerns of those who live along the proposed transportation routes. The suit failed in the US district court, but Nevada appealed the decision in the US court of Appeals. The case is currently before the court.

7.3.2 *EUROPE*

Acceptance of transportation in Europe varies from country to country. It is generally best accepted in France and the UK, where nuclear power in general receives broader acceptance by the public.

Protests against the transportation of nuclear fuel have been organized throughout Europe by anti-nuclear groups. Most notable are the protests in Germany. Anti-nuclear protesters have gathered on railroad tracks prior to scheduled shipments of nuclear waste to France and to the interim storage facilities within Germany. The protests did not affect the safe delivery of the nuclear shipments.

In January 1999, a survey conducted by NUKEM and commissioned by the Department of Environment, Transport and the Regions, was undertaken in response to public concerns over transport safety in the UK. The survey dealt with compliance with regulations, potential effects of casks contamination levels and effectiveness of spent fuel cask inspections. The survey concluded that transport of radioactive materials was safe and induced no health risk to the public or to anyone involved in the transport operations¹⁴.

¹⁴ World Nuclear Association Worldwide, "Advances in Radioactive Waste Management Report", 1999 (<http://www.world-nuclear.org/waste/report99/chapter2.htm#transport>)

8.0 REFERENCES

Papers and Reports

- AECL Ltd., "A Summary of Energy, Electricity and Nuclear Data", Atomic Energy of Canada Limited, 2002, Ontario.
- Bennett, D., J. Fitzpatrick, "Transport Studies for Candidate Near-Surface Repository Sites", In *Transportation for the Nuclear Industry*, 289-302, D.G. Walton and S.M. Blackburn, ed. New York: Plenum Press, 1989.
- Blomeke, J. O. "A Review and Analysis of European Industrial Experience in Handling LWR Spent Fuel and Vitrified High-Level Waste", Oak Ridge National Laboratory, National Technical Information Service. Virginia: U.S. Department of Commerce, 1988.
- Braybrook, I.K., P.J. Abbott, "A Review of Rail Transport for the Nuclear Industry", In *Transportation for the Nuclear Industry*, 395-407, D.G. Walton and S.M. Blackburn, ed. New York: Plenum Press, 1989.
- BNFL, "Transporting Nuclear Materials", BNFL. www.bnfl.com
- CNSC, "Canadian National Report for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management", Canadian Nuclear Safety Commission, Minister of Public Works and Government Services Canada, 2003.
- CNSC, "CNSC Annual Report for 2002 on the Canadian Nuclear Power Industry", Canadian Nuclear Safety Commission, May 2003.
- CNSC, "Regulatory Guide – Transportation Security Plans for Category I, II, or III Nuclear Material", Canadian Nuclear Safety Commission, March 2003.
- Cogema Logistics, "Conceptual Designs for Transportation of Used Fuel to a Centralized Facility", Cogema Logistics, April 24, 2003.
- Duke Engineering & Services (Canada) Inc. "Inventory of Radioactive Waste in Canada", Low-Level Radioactive Waste Management Office, Ottawa, November 1999.
- Government of Canada, "Transporting Dangerous Goods Primer", Transport Canada, Dangerous Goods Directorate, <http://www.tc.gc.ca/tdg/menu.htm>.
- Government of Canada, "Packaging and Transport of Nuclear Substances Regulations", Canada Gazette Part II, Vol. 134, No 13., May 31, 2000.
- Halstead, R.J., F. Diliger, "How Many Did You Say? – Historical and Projected Spent Nuclear Fuel Shipments in the United States, 1964-2048", Nevada, February 2003.
- IAEA, "Guidebook on Spent Fuel Storage", International Atomic Energy Agency, Second Edition, Vienna, 1991.
- IAEA, "Regulations for the Safe Transport of Radioactive Material -1996 Edition (Revised)" International Atomic Energy Agency, Vienna, 2000.

- Middleton, J.E. , S. Blackburn, "Experience in the Transport of Spent Nuclear Fuel", In *Transportation for the Nuclear Industry*, 303-319, D.G. Walton and S.M. Blackburn, ed. New York: Plenum Press,1989.
- OPG, "Pickering Waste Management Facility - Phase II Information Package", OPG, www.opg.com.
- Oyinloye, J.O., R.J. Williams, J. Fields, "Application of Risk Assessment Methods to the Transport by Rail of Radioactive Materials on the Sellafield Site", In *Transportation for the Nuclear Industry*, 261-275, D.G. Walton and S.M. Blackburn, ed. New York: Plenum Press,1989.
- Nash, K. E. "Design and Testing of a Cask for Transporting Irradiated CANDU Fuel", In *2nd International Conference on Radioactive Waste Management Conference Proceedings*, 158-162. Toronto: Canadian Nuclear Society, 1986.
- Navigator, "Report on Discussion group Findings", Nuclear Waste Management Organization, January 2003.
- Nuclear Waste Trains Investigative Committee "Scrutiny of the Transportation of Nuclear Waste by Train Trough London", London, October 2001.
- Ribbons, D.J. "Road Cask for the Transportation of CANDU Irradiated Fuel", In *Transportation for the Nuclear Industry*, 1-12, D.G. Walton and S.M. Blackburn, ed. New York: Plenum Press,1989.
- Seaborn, B. et. Al., "Report of the Nuclear Fuel Waste Management and Disposal Concept Environmental Assessment Panel", Seaborn Panel, Minister of Public Works and Governments Services Canada, 1998.
- Shelter, A. P. " Systems for Transporting Used CANDU Fuel by Road, Rail, and Water", In *2nd International Conference on Radioactive Waste Management Conference Proceedings*. Toronto: Canadian Nuclear Society, 1986.
- Schwarz, G., F. Lange, "Transportation of Nuclear Materials in the Federal Republic of Germany", In *Transportation for the Nuclear Industry*, 335-345, D.G. Walton and S.M. Blackburn, ed. New York: Plenum Press,1989.
- Spink, H.E. "Design of Ships for the Transport of Spent Nuclear Fuels", In *Transportation for the Nuclear Industry*, 115-125, D.G. Walton and S.M. Blackburn, ed. New York: Plenum Press,1989.
- UIC, "Japanese Waste and Mox Shipments from Europe", Nuclear Issues Briefing Paper 23, Uranium Information Centre, June 2003, Australia.
- US EPA "Public Health and Environmental Radiation Protection Standards for Yucca, Nevada – Final Background Information Document for Final 40 CFR 197", US EPA, June 2001.
- WNTI, "Radioactive Materials Transport:: The Current Context", Information paper no.3, World Nuclear Transport Institute.
- WNTI, "Transport of Spent fuel Mixed Oxide (MOX) Fuel and Vitrified High-Level Waste, Fact Sheet No. 3, World Nuclear Transport Institute.
- World Nuclear Association Worldwide, "Advances in Radioactive Waste Management Report", <http://www.world-nuclear.org/waste/report99/chapter2.htm#transport>, 1999

Websites

Atomic Energy of Canada Ltd. (www.aecl.ca)
BNFL – British Nuclear Fuels Ltd. (www.bnfl.com)
Canadian Nuclear FAQ (www.nuclearfaq.ca)
Canadian Nuclear Safety Commission (www.nuclearsafety.gc.ca)
Hydro-Quebec (www.hydro.qc.ca)
International Atomic Energy Association (www.iaea.org)
International Maritime Organization (www.imo.org)
Ontario Power Generation (www.opg.com)
Natural Resource Canada – Nuclear Fuel Waste Bureau (www.nfwbureau.gc.ca)
Nevada State Website (www.state.nv.us/nucwaste/)
New Brunswick power (www.nbpower.com)
SKB – Swedish Nuclear Fuel and Waste Management Company (www.skb.se)
Swedish Nuclear Power Inspectorate (www.ski.se)
Transport Canada – Dangerous Goods Directorate (www.tc.gc.ca/tdg/en/menu.htm)
Uranium Information Centre (www.uic.com.au/)
US Nuclear Regulatory Commission (www.nrc.gov)
US Department of Energy – Office of Civilian Radioactive Waste Management
(www.ocrwm.doe.gov)
World Nuclear Transport Institute (www.wnti.co.uk)
World Nuclear Association Worldwide (<http://www.world-nuclear.org>)