NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

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NWMO BACKGROUND PAPERS
6. TECHNICAL METHODS

6-8 REVIEW OF THE FUNDAMENTAL ISSUES AND KEY CONSIDERATIONS RELATED TO THE TRANSPORTATION OF SPENT NUCLEAR FUEL

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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.

BACKGROUND PAPER

REVIEW OF THE FUNDAMENTAL ISSUES AND KEY CONSIDERATIONS RELATED TO THE TRANSPORTATION OF SPENT NUCLEAR FUEL

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EXECUTIVE SUMMARY

Canada is currently weighing its options for managing spent fuel from its nuclear power stations. The transportation of spent fuel is being considered as part of this process.

Spent fuel could be transported from nuclear reactor sites to a central storage or disposal facility in Canada. In addition to road and rail transportation, it is conceivable that spent fuel could be transported by ships if Canada decides to reprocess its spent fuel overseas, to move spent fuel from one side of the country to the other, or to ship it via internal waterways.

Radioactive material is categorized as hazardous. While shipments of radioactive material account for a small proportion of total hazardous material shipments, they are transported in large numbers every day around the world, including in Canada.

The International Atomic Energy Agency is a United Nations agency with 137 member states. It has set the standards by which spent nuclear fuel is transported. The IAEA established a safety philosophy in the 1960s whereby the package in which nuclear material is transported is designed to provide protection to workers, the public and environment in severe accident conditions.

Spent fuel casks are massive structures typically manufactured from forged steel. In line with IAEA standards, these packages must meet a series of stringent regulations covering impact, fire and immersion. Because of the strength of these casks, spent fuel has been transported safely for over forty years.

Ships that move spent fuel are separately regulated by the International Maritime Organization, a United Nations body, which sets standards for their design. This provides an additional layer of protection for sea shipments of spent fuel.

While Canada has so far moved only a limited number of spent fuel casks, there is broad international experience stretching back for forty years. This experience covers accidents and incidents that have happened. It also includes technical studies that have examined a range of accident scenarios, including analyses of what would have happened if spent fuel had been transported during some of the most severe hazardous material accidents.

Studies have also been conducted to evaluate the level of risk associated with transportation of spent fuel. These studies have consistently shown that the levels of risk are very low whether spent fuel is transported by land or sea.

The IAEA has also set standards for the physical protection of nuclear material and produced guidelines for member states to plan for and respond to emergency situations.

Canada will have greater flexibility in dealing with its spent fuel if it has a transport system in place. This will allow optimum choices to be made for storage or disposal

alternatives. In addition to the technical issues, one of the additional factors for Canada to consider is the provision of public information.

1 INTRODUCTION

This paper has been prepared with the general reader in mind. While the paper contains some technical information, the aim has been to use as little technical language as possible.

This paper is a review of fundamental issues and key considerations related to the transportation of spent nuclear fuel. Readers who are relatively new to this subject and who have an interest in learning more about the transportation of nuclear material should find the information contained in this paper to be a good introduction to some of the key facts, concepts and issues. However, this is not intended to be a definitive, comprehensive, in-depth technical study and readers are urged to review some of the documents referenced in this paper if they require more technical information.

Discussion surrounding the safety of nuclear transport often focuses around the issue of "risk". The subject is covered in this paper but readers who wish to have more information about risk assessments can also refer to a large number of books and other publications. I would particularly recommend "Technological Risk" and "Why Flip a Coin?" by H.W. Lewis.

Readers can also obtain a good deal of useful information about nuclear transportation from the World Nuclear Transport Institute (www.wnti.co.uk).

2 TRANSPORTATION OF HAZARDOUS MATERIALS

Millions of shipments of hazardous materials are transported throughout the world every year. In the United States alone, hazardous materials traffic levels now exceed 800,000 shipments per day and 300 million per year. In Canada, three million tonnes of dangerous goods are transported every year and there are 27 million shipments of hazardous waste.

Hazardous shipments of liquids, gases or solids may be transported by road, rail, sea and air, and may have flammable, toxic or corrosive properties. In Canada, hazardous shipments take place within a legal framework set out in the Transportation of Dangerous Goods Act (1992) which requires specific safety procedures. Other nations have adopted similar regulations to govern movements of hazardous materials to ensure that they are carried out safely. The transportation of nuclear materials, along with other aspects of the nuclear industry, is regulated by the Canadian Nuclear Safety Commission (CNSC).

When shipments cross international boundaries they may be subject to regulations from more than one nation. International shipping standards have therefore been developed by nations working under the auspices of international bodies, such as the International Maritime Organization (IMO), and these have been incorporated into national laws by individual governments. The International Maritime Dangerous Goods Code (IMDG Code) of the IMO is an important document in this regard because it has harmonized standards for the shipping of hazardous material around the globe. The objective of the IMDG Code is "to enhance the safe transport of dangerous goods while facilitating the free unrestricted movement of such goods."

The IMDG code has categorized sea shipments of hazardous materials into the following classes. (The order of the classes does not denote the degree of danger). The same categories are used by transportation regulators in most countries around the world, including Transport Canada, Canada's transport department.

Class 1: Explosives
Class 2: Gases
Class 3: Flammable liquids
Class 4: Flammable solids
Class 5: Oxidizing substances and organic peroxides
Class 6: Toxic and infectious substances
Class 7: Radioactive material
Class 8: Corrosive substances
Class 9: Miscellaneous dangerous substances and articles

In each case, the material must be packed and consigned in a particular manner. The distinctive labeling system for hazardous material, for example, has become an important internationally recognizable system for quickly communicating the properties of a package and understanding the precautions that should be taken in normal and accident situations.

The IMDG Code lists nineteen substances that are prohibited from being transported because they are "liable to explode, dangerously react, produce a flame or dangerous evolution of heat or dangerous emission of toxic, corrosive or flammable gases or vapors under normal conditions normally encountered in transport." None of the prohibited substances are related to the transportation of spent fuel.

3 INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)

The IAEA is a United Nations agency headquartered in Vienna, Austria. It was established on 23 October 1956 by the Conference on the Statute of the IAEA and entered into force on 29 July 1957. Its objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world." As of November 2003, the IAEA had 137 member countries.

The IAEA has established regulations to protect workers from the effects of radiation and to protect the public and environment from the effects of radiation when radioactive material is being transported. It has also produced recommendations on other aspects of the nuclear industry, such as the physical protection of nuclear material and emergency response arrangements.

The IAEA transport regulations are documented in "Regulations for the Safe Transport of Radioactive Material". These regulations are widely considered to be the basic international standards for the transportation of radioactive material. The original regulations were produced by nuclear and transportation experts from IAEA member countries and published in 1961. The regulations are under constant review to ensure that they are kept up to date with modern requirements and knowledge gained from any actual incidents or accidents – whether or not these accidents involved nuclear materials. Revisions to the regulations have been issued in 1964, 1967, 1973, 1985 and 1996.

Since the commercial nuclear industry was new and limited in size when the regulations were first produced, the IAEA was able to establish a specific safety philosophy for nuclear shipments. This philosophy is that safety is provided by the package in which the material is being transported. This means that protection provided by the mode of transport in an accident – be it a truck, rail wagon, ship or airplane – is additional and not essential to the overall protection of the public and the environment. In addition to requiring containment of the radioactive contents of the package, the package provides protection by controlling external radiation levels, preventing criticality and preventing damage caused by heat. Because the packages for spent fuel shipments have a passive design, safety is not dependent on human actions by operators or on external systems.

The IAEA's unique safety approach can be the cause of public misunderstandings. Members of the public may come to equate the risks of transporting nuclear materials with the effects of oil spills or traffic accidents, without understanding that the protection in nuclear transportation is provided by the package and that the protection provided by the mode of transport is additional, not primary.

Non-nuclear hazardous materials may be packaged in a particular way, but the packages are not designed according to the same philosophy. The transportation of other hazardous materials, such as oil and flammable gases, relies largely on the mode of transport for protection. Even in the case of oil tankers that are protected by double hulls, the aim of this extra protection is to provide pollution control (i.e. to avoid or minimize spills from a grounding) rather than to protect the vessel from sinking in the event of a collision. Thus the double hulls are relatively narrow.

4 REGULATIONS FOR PACKAGES AND SHIPS

In spite of good planning and preventive measures (i.e. procedures, training, etc.), accidents can happen when hazardous materials are transported. The framework under which nuclear materials are transported does not ensure that accidents will not happen, but it is designed to ensure that the public, workers and the environment are properly protected in normal and accident situations.

International Atomic Energy Agency

Nuclear materials vary in size, form and levels of radioactivity. The IAEA therefore has established a graded approach, requiring different packaging requirements for different categories of nuclear material. Most shipments of radioactive material involve the first three categories. The packages are:

- "Excepted" packages, used for low activities of radionuclides.
- Industrial Packages (such as drums), used for bulk material transport.
- Type A packages, designed for normal conditions of transport of radionuclides with activity below a defined level
- Type B packages, designed to withstand severe accident conditions, to carry material of defined levels of activity such as spent fuel
- Type C packages, designed to withstand enhanced severe accident conditions such as those experienced in aircraft accidents

Spent nuclear fuel is transported internationally by road, rail and sea in large Type B casks. Many shipments involve more than one of these modes. Spent nuclear fuel is not transported by air, although other radioactive materials such as medical isotopes are transported in aircraft.

The Type B casks are designed and built by private or state-owned companies and licensed in the nations where they are transported. The casks are expensive to construct (costing more than $1 million, depending on the size and carrying capacity of the cask) and are cleaned and re-used after the spent fuel has been removed. Operators employ Quality Assurance procedures to ensure that the casks maintain their design specifications and that staff are properly trained to handle them. Casks used within Canada must be licensed by the Canadian Nuclear Safety Commission (CNSC), an independent agency of the Government of Canada which regulates the use of nuclear material. If spent fuel is transported overseas, these casks will also need to be licensed in the other countries in which they are transported. Casks licensed for use overseas would have to be licensed by the CNSC before they can be used in Canada. The licensing process typically involves national regulators authenticating that the casks meet the IAEA requirements. Only those registered by the CNSC to use a certified package can transport nuclear substances and they can only transport those substances for which the package has been designed. Casks can be licensed for unilateral or multilateral use but countries are not obliged to accept certifications for unilateral use.

Casks transported within IAEA member countries, including Canada, must, at a minimum, comply with the requirements set down by the IAEA. This means that the design of Type B casks must satisfy stringent design criteria established by the IAEA to protect the public, workers and the environment. The compliance of a cask design with the criteria can be demonstrated by analysis, testing or a combination of the two. Normally, tests are simulated using scale models of the casks (such as one-quarter size) because the smaller models can be handled more easily and are more cost-effective. The scale models properly simulate what would happen to an actual size cask. Casks that are used in these tests are never reused for actual transport.

Spent nuclear fuel is transported in Type B casks. Type B casks are typically made from forged steel with walls several inches thick. They are usually cylindrical and can weigh 25 tonnes (truck casks) to100 tonnes (rail cask). The largest casks typically carry around 5 tonnes of spent fuel. Shock absorbers are placed on either end of the casks during transport to limit the impact forces in the event of an accident.

The IAEA requirements involve successive tests of the cask's ability to withstand impact, fire and immersion. Impact is tested through a drop test where the cask must survive a drop of nine meters (30 feet) onto an unyielding surface at a temperature set by the regulatory body, typically in the region –20°C to –40°C. Because the surface is unyielding, i.e. reinforced concrete, the test simulates impacts of much greater impact velocities onto yielding surfaces such as rock and soil. The cask must also survive a punch test where it is dropped from 1 meter (3 feet) onto a steel bar (which acts like a spike).

Next, the cask must maintain its integrity in an all-engulfing fire at 800°C (1475°F) for thirty minutes. "All-engulfing" means that the minimum temperature experienced by any part of the cask during the thirty minutes is 800°C. It does not mean the same as "temperatures reaching 800°C". While some fires resulting from actual transportation accidents have reached higher temperatures and burned for longer, such as the Baltimore Howard Tunnel railroad fire, analyses have shown that spent fuel casks would have survived these situations without releasing radioactivity. Fires move (consuming fuel and oxygen) and the hottest parts of fires therefore do not remain in one place for long periods of time.

Next, the cask must survive an immersion test in 200 meters of water for eight hours. Analyses by designers have shown that Type B casks can withstand immersion under several thousands of meters of water.

The success of the Type B tests is reflected in the unparalleled level of safety achieved in many countries over the last forty years when transporting spent fuel. There has never been an accident anywhere that has involved the release of dangerous levels of radioactivity from a Type B cask in thousands of spent fuel shipments.

Regulators and operators have publicly authenticated the IAEA tests by performing realistic demonstrations of the ability of actual casks to withstand accidents. In the United Kingdom, the Central Electricity Generating Board staged a mock accident in 1984 in which a cask was placed on a railway line in its most vulnerable position. A locomotive with two carriages was driven into the cask at 100 mph. The cask maintained its integrity, receiving only superficial damage, whereas the train was completely destroyed. As spectacular as this demonstration was, the impact forces received by the cask were only around one-third of those experienced with the IAEA drop test because the train was a yielding object that crumpled and broke up on impact with the cask. In a special fire test, a cask maintained its integrity when placed over burning fuel for 90 minutes at temperatures reaching 1400°C on the surface of the cask.

In the United States, similar demonstrations have been performed driving a truck carrying a spent fuel cask at 100 mph into a concrete wall and even accelerating a cask into a target using rocket engines. The United States Nuclear Regulatory Commission (NRC) is currently proposing new demonstrations of the strength of cask designs prior to shipments to the repository at Yucca Mountain, Nevada.

These regulatory tests and real-life demonstrations provide considerable assurance that the casks can maintain their integrity in severe accident conditions without releasing their radioactive contents.

International Maritime Organization

A dedicated fleet of purpose-built nuclear fuel carriers was first developed and built by Pacific Nuclear Transport Limited (PNTL) in the 1970s and 1980s to ship spent fuel from Japan to the United Kingdom and France. PNTL is owned by British Nuclear Fuels plc (BNFL), Cogema (France) and Japanese companies. The PNTL fleet set a standard for design that was subsequently used as the basis for IMO regulations that became mandatory in 2001.

The IMO's Code for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium and High Level Wastes in Flasks On Board Ships (INF Code) establishes standards for the design of ships carrying nuclear material according to the type of material being transported. The categories established by the INF Code are:

- **INF1 vessels** can carry radioactive cargoes within specified low levels of radioactivity

- **INF2 vessels** can carry spent fuel or high level waste within specified levels of radioactivity

- **INF3 vessels** can carry spent fuel, high level waste and plutonium with no restriction on the aggregate radioactivity of the material

As with the licensing of spent fuel casks, national regulatory authorities must license vessels for transportation of spent fuel by carrying out a survey of the ship's "structure, equipment, fittings, arrangements and material". The Code establishes standards for damage stability, fire safety measures, temperature control of cargo spaces, structure, cargo securing arrangements, electrical power supplies, radiological protection, management and training, shipboard emergency plans and notification in the event of an accident involving the radioactive cargo.

PNTL currently operates three INF3 vessels, the Pacific Teal, Pacific Sandpiper and Pacific Pintail. Two other ships, the Pacific Swan and Pacific Crane have been recently retired by PNTL. These ships are small compared to other cargo vessels and are very maneuverable. They are 104 meters in length, 16 meters wide and have a deadweight tonnage of 3775 tonnes.

PNTL's INF3 vessels have a series of safety measures not found on other cargo carriers:

- Each ship has a double hull and double bottom. The double hull is designed to provide protection against collisions and extends to 20 per cent of the vessel's beam (width) on each side. It is augmented with reinforced steel plates weighing 400 tonnes.

- The ships have enhanced buoyancy to ensure they remain afloat even in extreme circumstances.

- There are dual navigation, communications and monitoring systems. If cabling were damaged by an accident on one side of the vessel, these systems would still be able to operate using duplicate power cabling on the other side of the vessel.

- The ships have satellite navigation and tracking.

- The ships have twin engines and propellers. If power is lost from one engine, the second engine can generate a speed of around ten knots.

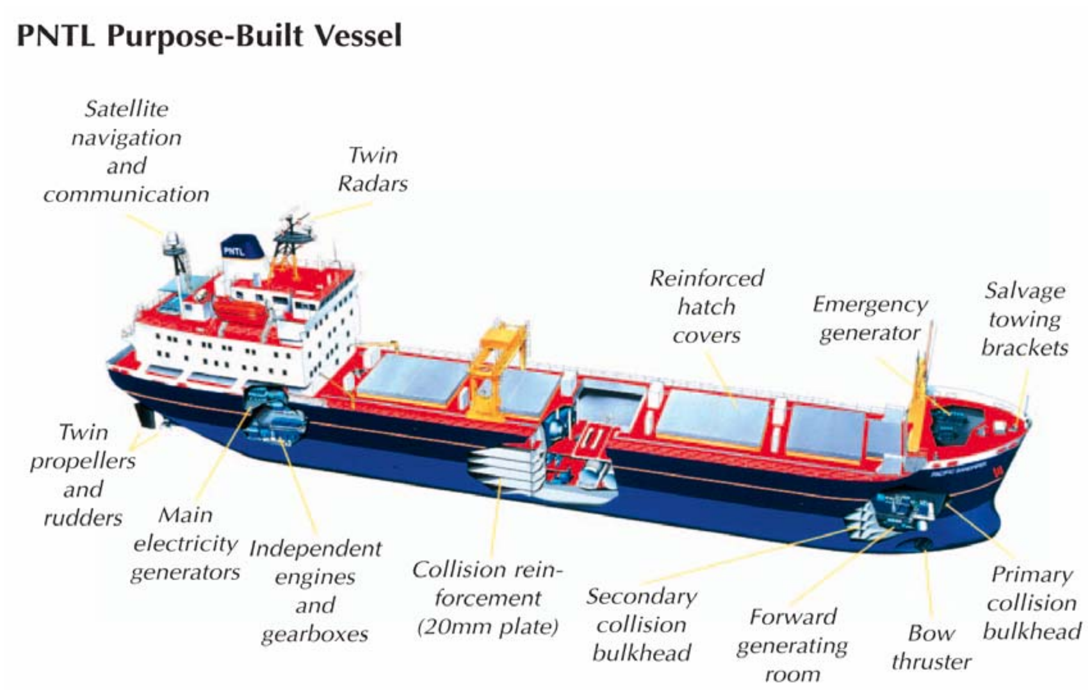
- There is additional fire fighting equipment including a multi-zone and multi-sensor fire detection system and halon gas fire suppression system. If necessary, each of the holds could be filled with sea water to put out a fire or provide a shield against radiation.

- The ships have redundant electrical generating capacity in the bow and stern so that fire fighting equipment could be powered even in extreme circumstances.

- The ships have bow thrusters to provide optimum maneuverability in ports.

- The spent fuel casks are bolted to the ship's structure in the cargo holds.

The PNTL ships are regarded by maritime experts as some of the safest ships on the seas.



5 INTERNATIONAL EXPERIENCE

Over the last 30 years, there have been around 500 shipments of spent fuel in Canada. These have generally been small quantities of spent fuel and have been part of research programs. There are also thousands of shipments of radioactive material in Canada each year, mainly for non-nuclear purposes (medical, industrial, etc.).

While spent nuclear fuel has not been transported widely in Canada, governments, regulators and commercial organizations around the world have extensive experience transporting radioactive and nuclear materials, and with regulating it for safety and security. Government and independent experts in many countries, most notably the United States, the European Union and Japan, as well as the IAEA, have also regularly examined and researched safety issues concerning radioactive material transport. A large body of technical data exists which can be drawn on by regulators, utilities, politicians and the public in preparing any future plans for the transportation of spent fuel. This information has direct application and relevance because Canada, as a member of the IAEA, is obliged to meet the same level of international standards that have been the subject of this study and analysis.

Whatever decisions are subsequently taken regarding the management of spent fuel in Canada, more shipments of spent fuel and other highly radioactive material will take place in other countries in the foreseeable future. Canada has 17 operating commercial nuclear reactors with a generating capacity of around 12,000 MW. These supply around 13 per cent of the nation's electricity. While a spent fuel management/ transportation program is certainly required in Canada, the quantities of fuel that will be moved are substantially less than in countries like the United States, Japan and France.

United States

Each year in the United States, there are some 2-4 million shipments of radioactive materials. With 103 commercial nuclear reactors producing around 20 per cent of its electricity, the United States is the largest producer of nuclear power in the world.

Spent fuel is currently stored at reactor states throughout the United States but is scheduled to be moved to a national repository at Yucca Mountain, Nevada in the future. Since 1964, there have been 3,000 shipments of spent fuel on United States highways and railroads, covering a total of 1.7 million miles. Today there are around twenty shipments of spent fuel each year in the United States, chiefly undertaken by road by specialized trucking companies. If the Yucca Mountain repository operates as currently planned, this repository will receive spent fuel from 72 commercial sites and five Department of Energy sites. The transportation program is scheduled to continue for 24 years. In this program, 40,000 tonnes of spent fuel will be transported across the United States.

Spent fuel is also shipped by sea from various countries under a U.S. Department of Energy program to store U.S.-origin uranium based fuels from foreign research reactors at its Savannah River facility in South Carolina. These are mainly highly enriched uranium fuels.

In addition, the United States has considerable experience in transporting weapons material, such as plutonium and highly enriched uranium.

Europe

The European Union is home to some of the largest users of nuclear energy, including France, Germany, the United Kingdom and Belgium. France has 58 commercial nuclear reactors generating 63,000 MW of electricity. Electricité de France (EdF), the French national generating company, ships approximately 200 spent fuel casks each year to the La Hague reprocessing facility. Most of the casks are transported by rail to a dedicated terminal at Valognes and continue by road to the La Hague complex 30km away.

Spent fuel is also transported extensively by rail within the United Kingdom from the smaller number of British nuclear reactors to the Sellafield reprocessing facility in north west England. Some of the transports pass through urban area, such as Willesden in London. Approximately 600 spent fuel casks (including empty casks) are transported by rail each year between Sellafield and UK reactor sites, covering around 350,000 cask miles.

Spent fuel has been shipped internationally since 1966, when Italian spent fuel was first shipped to the Sellafield reprocessing facility in England. Today, the largest movements of spent fuel between countries in Europe are from German reactor sites to La Hague and Sellafield. Casks of vitrified waste, with similar levels of radioactivity as spent fuel, are returned to the Gorleben site for storage. Spent fuel is transported through several major cities by rail, including Hamburg, Bremen, Bonn and Karlsruhe. To get to Sellafield, spent fuel is transported by rail to Dunkirk where it is loaded onto either the European Shearwater (a small INF3 vessel) or the Atlantic Osprey (a refurbished roll-on roll-off vessel which is classified as INF2) and shipped to the English port of Barrow. From Barrow, the spent fuel casks are moved by rail directly to the Sellafield reprocessing facility some 40 miles away.

Sweden ships spent nuclear fuel by sea on the MS Sigyn from reactor sites to a central storage facility. Australia sends spent fuel from the Lucas Heights research reactor to France for reprocessing. France has shipped spent fuel on the INF2 vessels Bougenais and Fret Moselle.

Japan

Nuclear power is an important part of Japan’s economy. It accounts for approximately 35 per cent of Japan’s electricity generation and is projected to account for 41 per cent by 2011. Japan has 52 reactors with a total output of 45, 742 MW.

To establish nuclear power as a domestic resource, Japan has followed a policy of recycling nuclear fuel. This has involved shipping spent fuel from reactor sites to reprocessing facilities in Europe. These shipments involve transportation by road to reactor ports, then purpose-built vessel to receiving ports in England and France, and rail and road to the reprocessing sites. The vitrified high-level waste and mixed oxide fuel is returned from Europe to Japan. The early sea shipments of spent fuel were on chartered vessels, beginning in 1969. Since then, over 160 shipments have been successfully completed between Japan and Europe without any incident involving the release of radioactivity. Some of these shipments have been the focus of attention from anti-nuclear advocacy groups.

Japan is currently constructing its own reprocessing facility at Rokkasho-mura, which is scheduled to become fully operational in 2005. Nuclear Fuel Transport (NFT) of Japan already ships spent fuel from reactor sites to the port of Mutsu Ogawara from where it is transported to storage ponds at Rokkasho-mura.

In total, almost 10,000 tonnes of spent fuel has been shipped by sea from Japan to the United Kingdom and a similar amount has been shipped to France by sea and land.

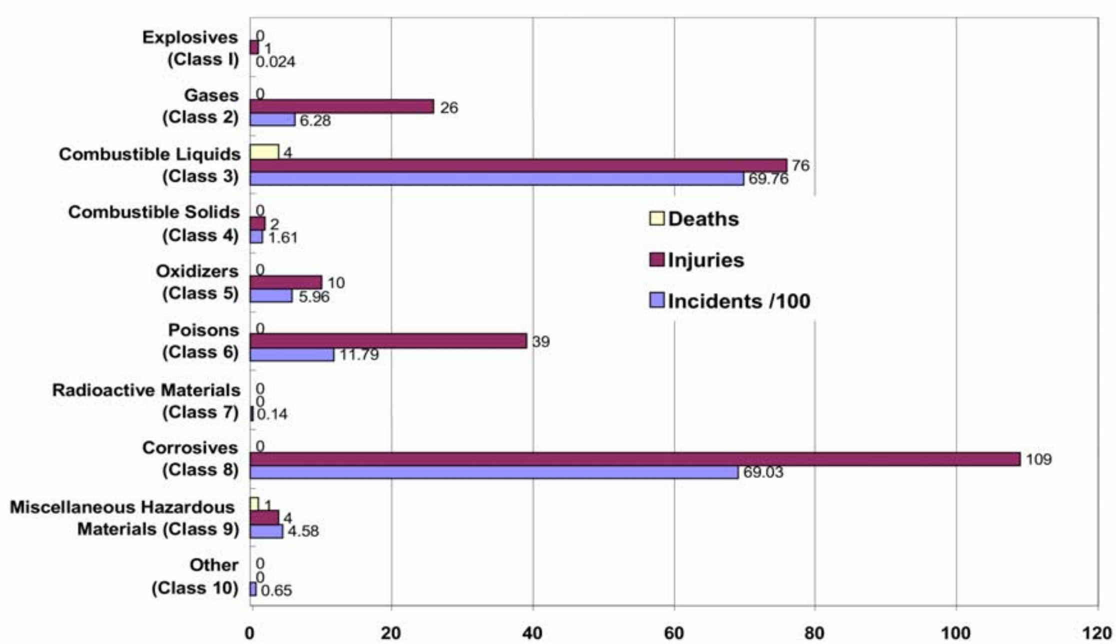
6 ACTUAL INCIDENTS AND ACCIDENTS

The nuclear industry has been transporting radioactive materials since the 1960s and therefore has considerable experience in dealing with potential and actual accident situations. Whereas there have been accidents involving the harmful release of other hazardous materials around the world in this period, the transportation of nuclear materials has been characterized by no major accidents.

Comparisons of Hazardous Material Accidents

With its location at the intersection of east-west world commerce, the Panama Canal is responsible for handling a large number of hazardous material shipments that have origins and destinations in other countries. The Panama Canal Authority handles around 12,000 shipments each year of which approximately one-third contain hazardous materials. All vessels are inspected prior to transit of the Canal to ensure they meet international regulations. A small percentage of the shipments carrying hazardous materials are carrying spent fuel or other radioactive materials. In 1996, at a Special Consultative Meeting of the IMO, the Canal stated that: "The vessels whose cargo present the highest risk to the Panama Canal are… bulk carriers, such as LPG and gasoline tankers, and those with over 5 tons of… (explosives) aboard".

This is borne out by records of hazardous material accidents by category in the United States. As can be seen from the chart below for domestic shipments in the United States, accidents involving non-radioactive hazardous materials are more frequent and have more significant consequences than those involving radioactive materials.



Summary of 1999 Hazardous Material Incident System (HMIS) Report

Surface Transportation of Spent Fuel

All shipments of spent fuel involve some element of land transportation even if it is a short road journey from a nuclear reactor to a port facility or from a port facility to a reprocessing or storage site.

Spent fuel casks are placed on trucks or special vehicles for road transport and on flatbed wagons for rail transport. Like other packages that are transported on flatbeds, the packages are typically covered to minimize exposure to the weather. Trains normally pull several spent fuel casks at a time and therefore offer an economic and practical advantage over trucks. National regulations may place particular requirements on operators. For example, United States regulations stipulate separation requirements for hazardous cargoes in freight trains.

(i) U.S. Incidents and Accidents

In 1971, the United States established a Radioactive Materials Incident Report (RMIR) database to track all accidents and incidents involving radioactive materials. An analysis in 1997 of actual incidents and accidents that occurred in the United States since the database was set up revealed no release of radioactive material from Type B packages.

The analysis identified 1,828 transportation events (accidents, handling accidents and incidents) involving radioactive materials such as industrial gauges, teletherapy sources, low level radioactive materials, nuclear industry material and radioisotopes. The majority of these involved industrial and Type A packages.

In this 26-year period, 90 Type B packages were involved in a total of 59 accidents in the U.S. None of the Type B packages released their radioactive contents. Seven of these accidents involved spent nuclear fuel (three during rail transport and four during highway transport) and all but one resulted in only trivial damage to the cask. The most severe accident occurred on 8 December 1971 in Tennessee when a truck rolled over on U.S.-25 and the spent fuel cask came off its trailer. However, there was no release of radioactive material.

(ii) U.S. Hazardous Materials Accidents Not Involving Spent Fuel

Serious accidents involving non-nuclear hazardous material have, of course, occurred. These accidents inevitably cause the "what if…?" question to arise. What if spent nuclear fuel had been transported in a particular rail derailment or tunnel fire? In April 2003, a paper was published by the United States Department of Energy National Transportation Program that examined twelve actual accidents that took place in the last twenty years. The accidents had been cited by the State of Nevada, which had suggested that the integrity of spent fuel casks might have been compromised if spent fuel had been involved because of the severity of the accident conditions.

In each case it was shown that, despite the severity of each accident, the integrity of spent fuel casks would have been maintained. The experts compared the accidents with United States test requirements, which are based on the IAEA tests. United States regulations for separating hazardous cargoes in freight trains would have eliminated fire exposures in the railroad accidents.

The accidents studied were:

- The collapse of a suspended span of Interstate Route 95 Highway Bridge over the Mianus River, Greenwich, Connecticut on 28 June 1983. Four vehicles plunged 70 feet into the water, which was about eight feet deep at the time. The impact of a spent fuel cask in this accident would have been less than one-third of the impact required by IAEA regulations.

- The collapse of New York Thruway (I-90) Bridge over the Schoharie Creek near Amsterdam, New York on 5 April 1987. Five vehicles fell about 80 feet into waters that were about 30-feet deep. The impact of a spent fuel cask in this accident would have been about one-third of the regulatory impact.

- The collapse of the Cypress Street Viaduct of the Nimitz Freeway in Oakland, California as a result of the Loma Prieta earthquake on 17 October 1989. The most severe circumstances would have occurred if the entire weight of the transverse beam of this two-level structure had impacted the hypothetical spent fuel cask. The cask is able to sustain an impact approximately twice as great as that from this type of accident.

- A collision between a tractor-semi-trailer transporting ten 2,000-pound bombs and an automobile resulting on fire and explosions at Checotah, Oklahoma on 4 August 1985. A crater 27 feet deep and 35 feet wide was caused in the roadway. The explosive force was not sufficient to have caused a spent fuel cask on an adjacent truck to fail and the duration and size of the fire would not have damaged the cask thermally.

- A tanker trailer accident and resulting explosion in Memphis, Tennessee on 23 December 1988. The ignition of the tanker's 9,500 gallons of liquid propane blew the trailer truck a large distance, killing eight people. A hypothetical spent fuel cask at the scene would have been subjected to conditions lower than those required by the regulatory tests.

- A release of yellow phosphorous and molten sulfur following the derailment of a train in Miamisburg, Ohio on 8 July 1986. While a phosphorous fire continued for several days, the temperatures were well below that required for spent fuel casks to maintain their integrity.

- A collision and derailment of locomotives leading to a hazardous materials release at Helena, Montana on 2 February 1989. A spent fuel cask would have been able to sustain the impact of the collision and the resulting fires. Significant structural damage of the cask was not likely to have occurred because of its robust design.

- The derailment of a freight train and butane fire in Akron, Ohio on 26 February 1989. A hypothetical spent fuel cask placed near the leaking cars would have been subjected to lower heat input than is required for the regulatory tests.

- Train derailment and later fire at San Bernadino, California, May 1989. The 100 mph derailment into soft soil would not have led to a release of radioactive material to a hypothetical spent fuel cask and no train was involved in the subsequent fire.

- Freight train derailment and release of hazardous materials near Freeland, Michigan on 22 July 1989. Flammable materials (acrylic acid, trimethylchlorosilane and naptha) burned for several days. The length of the naptha fire, which would have produced the most significant fire threat, was not recorded. Even assuming that it lasted for five hours (the maximum possible in the circumstances) no significant release of radioactive material from a spent fuel cask would have resulted.

- A train collision near Cajon, California on 14 December 1994. The impact would have been approximately one-third of that required by the regulatory tests.

- Freight train derailment near Cajon Junction, California on 1 February 1996. The impact would have left a spent fuel cask intact and a fire would not have led to cask failure.

In each case, a harmful release of radioactivity would not have occurred, even where the authors make the most pessimistic assumptions of what might have happened to a hypothetical spent fuel cask. The Nuclear Regulatory Commission has also completed an analysis of the 2001 Baltimore Howard Street tunnel fire in which there were sustained temperatures of 1000°F, and concluded that exposure of a transportation cask would not have resulted in a radioactive release.

(b) <u>Maritime Transportation of Spent Fuel</u>

In nearly forty years of sea shipments of spent fuel, there have never been any accidents involving a release of radioactivity. PNTL is the world's leading transporter of spent fuel by sea and has safely transported 4,000 casks and covered 4.5 million miles.

The only recorded report of an accident involving a spent fuel cask on a ship occurred on 17 December 1991 during unloading of a PNTL ship in Cherbourg, France due to a malfunction of the shore-based crane. The gearing of the crane winch broke as a spent fuel cask was being removed and it fell onto the deck of the ship. A few of the cooling fins on the outside of the cask were damaged but the containment of the cask was maintained.

There have been maritime accidents involving other nuclear and radioactive cargoes. On 25 August 1984, the French freighter the Mont-Louis, traveling to Russia, was rammed by a ferry 15 km off Ostend and sank on a sand bank at a depth of 15 meters. The Mont-Louis was carrying 30 Type 48Y industrial containers of uranium hexafluoride, all of which were recovered over a period of 3 weeks. None of these containers – which were industrial packages – had leaked and there was no external contamination. One container had a damaged valve that had resulted in the ingress of about 50 liters of water.

In 1997, the container ship Carla sank in heavy seas off the Azores. The Carla was carrying three biological irradiators containing sealed caesium-137 sources in small Type B packages. The vessel sank in 3,000 meters of water and, since the packages were considered to present no radiological hazard, it was decided not to recover them.

7 RISK ASSESSMENT AND IMPACT ASSESSEMENT

The IAEA requirements have been established to protect the public, workers and the environment from plausible accident scenarios. The safety record that has, in turn, been established by these requirements over forty years compares favorably with that of the shipment of all other hazardous materials.

No activity can be undertaken with complete mathematical one hundred per cent safety. At the very least, it is always possible to imagine a highly exceptional event, such as a meteor strike, or an unusual sequence of events, that could affect the safety of a particular operation, be it the shipment of spent fuel, the shipment of other hazardous cargoes – or even taking a walk. No hazardous material would ever be transported if operators and regulators were directed to eliminate the risk of all accidents, however implausible they might be.

Regulators refer to the levels of protection for radioactive materials transport within a system known as "defense in depth". Operators more usually refer to this concept as "safety in depth". It refers to the series of independent barriers that protect workers, the public and the environment from a release of radioactive materials.

As is the case with other hazardous material shipments, values of probability and consequence can be calculated for the series of events that must occur for a hazard to people to arise. From the point of view of risk assessment, it is inappropriate to simply ask, "What would happen if radioactive material escaped from a cask of spent fuel following an accident?" because this ignores all the measures that are taken to prevent such an occurrence. We cannot assume without justification that a series of events will happen (i.e. assign it a probability of one), or that it could well happen.

The IAEA conducted a coordinated research project (CRP) from 1995-1999 to study the "Severity, probability and risk of accidents during maritime transport of radioactive material". The objective of the project was to determine whether the IAEA regulations took adequate account of accidents at sea by assessing: the severity of accidents and their expected frequency; the impact of fire at sea; and the adequacy of the IAEA requirements for sea transport. The CRP evaluated two severe accidents for a ship carrying nuclear material. The first was a collision at sea that sinks the struck ship and leads to the loss of a spent fuel cask. The second was a collision leading to the double failure of the transport cask and a fire that spreads to the hold carrying the spent fuel that burns at sufficiently high temperatures and for long enough for material to escape.

In evaluating these scenarios, the CRP calculated or identified the probability of individual events occurring that had to take place for the overall event to occur (building an event tree). A probability value is first derived for a ship collision at sea. The chance of the struck ship being the one carrying the spent fuel is one in two, a probability of 0.5. The ship could be struck at three separate points – near the bow, stern or midships. The probability of each of these is one in three – 0.33. Since all ships transporting spent fuel carry the casks in the holds in this area, the probability of a cask being positioned midships is 1. And so the process continues, calculating and assigning probability values to each individual event. By multiplying the probability values for each event in the tree, the overall probability of a particular type of severe accident occurring can be calculated.

The CRP figures are set out in the table below, extracted from the final report:

SEVERE SHIP ACCIDENT EVENT PROBABILITIES

Event	Probability	Value
A ship collision occurs while making a 1000 nmi voyage	$P_{collision}$	1×10^{-4}
The RAM ship is the struck ship	$P_{RAM\ ship\ struck}$	0.5
The strike location is midship	$P_{strike/midship}$	0.33
The RAM flask location is midship	$P_{flask/midship}$	1.0
Crush forces are applied to the flask	$P_{crush\ forces}$	0.15
Flask crush causes the flask seal to fail	P_{crush}	$<10^{-2}$
Flask puncture or shear occurs	$P_{puncture/shear}$	$<10^{-1}$
The collision initiates a fire	$P_{fire\ start/collision}$	0.016
The fire spreads to the RAM hold	$P_{fire\ spread}$	$\sim 10^{-3}$
The ship sinks	P_{sink}	3.6×10^{-3}

The probabilities in the two scenarios examined were calculated as being of the order 10^{-6} and 10^{-13} respectively.

Because of the protective measures that are required to be taken when spent fuel is transported, the probability of an accident occurring that is of sufficient magnitude to cause a release of radioactive material has been determined by several other detailed analyses to be very low.

When considering the risk of a severe accident, it is also important to consider the potential consequences. Risk is properly defined as the consequence of an event multiplied by the likelihood of it occurring.

Spent fuel consists of bundles of fuel rods that are designed to survive the extreme temperatures of a nuclear reactor. The contents of the spent fuel casks will not readily disperse into the environment. For there to be a release of radioactive material into the air, onto land or in water, the cask and the fuel rods inside would have to be damaged.

The impact of a release in water has been closely examined in several reports. Japan ships spent fuel along its coastline from reactor sites to the Rokkasho-mura reprocessing facility. The Central Research Institute of Electric Power Industry (CRIEPI) of Japan has produced an analysis of what would happen if a spent fuel cask was submerged in coastal waters at a depth of 200 meters, its seal was broken, and the cask was deliberately not recovered. In this case, there are two ways in which an individual might receive a radiation dose. The first is by close proximity to the package and the length of time spent there. In this example, it is very unlikely that any member of the public would be in the vicinity of the package. The second mechanism is the food chain, with the dose received related to factors such as the rate at which nuclides are released into the sea. In these circumstances, CRIEPI calculated maximum dose rates to members of the public that are a fraction of those received from natural background radiation.

Considering the issues of probability and consequences, the IAEA coordinated research project final report stated that, "Since these accidental exposures augment background doses negligibly and are also quite improbable, accidents during the maritime transport of RAM [Radioactive Material] in Type B irradiated nuclear fuel or VHLW [Vitrified High-Level Waste] packages would seem to be of little concern."

The report concluded that: "Since the probabilities of severe ship collisions and severe ship fires are small and the individual radiation doses that might result should such a collision or fire occur are smaller than background doses, the risks of maritime transport in Type B packages of highly radioactive material such as irradiated nuclear fuel, vitrified high level waste and plutonium are very small."

Professor H. W. Lewis, a former Chairman of the United States NRC Risk Assessment Review Group, stated with regard to sea shipments of vitrified high level waste that, "An accident of any kind is unlikely to happen… and the environmental damage done by any conceivable accident would be thousands of times less than that done by a single oil spill."

These conclusions with respect to sea shipments are in line with those of other studies, including other modes of shipment. In 1977, the U.S. Nuclear Regulatory Commission (NRC) completed what is referred to as its baseline study of spent fuel transportation risks called, "Final Environmental Statement on the Transportation of Radioactive Materials by Air and Other Modes". This led the NRC to conclude that the regulations in place were adequate to protect the public.

In 1987, the NRC sponsored a Modal Study that assessed the level of safety provided by different certified package designs during rail and highway transport. The "Shipping Container Response to Severe Highway and Railway Accident Conditions" paper concluded that, "When considering real cask capabilities to withstand thermal loading conditions beyond the regulatory ones, approximately 99.4% of the truck and rail accidents would result in negligible radiological hazards which are less than those implied by [the] regulations…an additional 0.4% of both highway accidents and railway accidents could result in radiological hazards near the regulatory limits."

The NRC has now recalculated the risk results for rail and highway transportation of spent fuel using modern computer technology which has allowed researchers to be more realistic about what could happen and predict the effects of impact and fire scenarios more accurately. This has dramatically reduced the calculated risk levels from the already low levels previously estimated.

8 SECURITY REQUIREMENTS

During forty years of transportation, there has never been an attempt to illegally procure spent fuel, or to attack a shipment of spent fuel, anywhere in the world. Nevertheless, the question arises of what physical protection should be employed in Canada to protect spent fuel from either being stolen or from being used in a deliberate act of sabotage while it is being transported.

The IAEA has produced guidelines for the physical protection of different types of nuclear material when it is in use, in storage and being transported. The IAEA's "The Physical Protection of Nuclear Material and Nuclear Facilities" was first published in 1972 and, like the requirements for transporting materials, the recommendations are regularly reviewed and revised. They are used by governments in member countries as the basis for national procedures and requirements. The most recent document is INFCIRC/225/Rev.4. The Convention on the Physical Protection of Nuclear Material (1980) also obliges parties to make specific arrangements and meet defined standards of physical protection for movements of nuclear material.

The IAEA recognizes that transport is probably the part of the nuclear industry most vulnerable to the unauthorized removal of material and acts of sabotage. It places nuclear material into one of three categories according to the possibility that unauthorized removal "could lead to the construction of a nuclear explosive device by a technically competent group". Thus international shipments of plutonium and MOX fuel are given the highest Category 1 rating. Spent fuel is Category 2 material for international transport but member states can assign different categories for domestic transport. One of the major distinctions between the handling of Category 1 and Category 2 material for transportation is that armed guards are specified for the former but not the latter.

In Europe, spent fuel is protected in line with the IAEA recommendations when it is transported. Guards, armed or otherwise, are not utilized for movements by road, rail or sea. Armed guards are used for shipments of plutonium, mainly within France, and Mixed Oxide (MOX) fuel. For sea shipments of MOX fuel from Europe to Japan, two armed PNTL ships, the Pacific Teal and Pacific Pintail, travel together providing mutual support. An undisclosed number of armed officers from a police force specially dedicated to the policing of UK nuclear establishments travel on the ships in addition to the regular crew. The independent nuclear regulator in the United States, the Nuclear Regulatory Commission (NRC), requires spent fuel shipments to be protected by armed guards during transportation through heavily populated areas. These requirements exceed the recommendations set down by the IAEA.

In general, hazardous material is not an appealing target for thieves because it is difficult to handle and has relatively little financial or practical value. A spent fuel cask is not an attractive target for theft for a number of additional reasons. First, from a practical perspective, a spent fuel cask is too unwieldy to move quickly to a secure location. Second, the cask is sealed and heavy specialized equipment is necessary to remove its lid.

Since the spent fuel is highly radioactive, the cask would have to be opened in carefully controlled conditions. Third, during and after removal from the cask, the spent fuel would also need to be handled within a highly protective environment. This would require management by individuals skilled and knowledgeable enough to handle spent fuel safely. Fourth, any attempt to use the spent fuel for terrorist activities (such as the production of a "dirty bomb") would be extremely difficult. A "dirty bomb" could be more readily manufactured from radioactive materials procured in other ways. Finally, compared to other hazardous substances, shipments of spent fuel take place relatively infrequently.

If a cask is the subject of a terrorist attack that aims to sabotage the spent fuel inside, the protective measures that are designed to protect the public and environment in the event of a severe accident would also provide considerable protection. A large explosive charge would be necessary to breach the containment of the cask. Even if this is achieved, a dangerous disbursement of radioactive materials will not necessarily occur.

In the United States and in Europe, experts have considered the effect of a High Energy Density Device (HEDD) penetrating a spent fuel cask. The United States Department of Energy evaluated the potential consequences of a severe hypothetical sabotage attack for its Draft Environmental Impact Statement (DEIS) for the Yucca Mountain repository project. While it is not possible to predict the nature of sabotage events should they occur, the U.S. has tested different types of HEDD against steel target plates. Its findings, which are consistent with similar tests carried out in Europe, identify the greatest penetration coming from an HEDD which has its explosive energy concentrated in a very slender penetrator moving at speeds in excess of 2 km/s. The DEIS calculated the possible impact of two acts of sabotage, one on a rail cask and the other on a truck cask, and estimated lower consequences for the larger rail transport cask.

There are many hazardous and non-hazardous substances being transported much more frequently every day that would offer more attractive sabotage options for terrorists than spent fuel casks. In their paper examining the sabotage question, the Sandia National Laboratories experts wrote, "There is no reason to believe that sabotage of radioactive material shipments constitutes an imminent threat to the public health and welfare in the U.S. at the current time."

9 EMERGENCY PLANNING

After forty years of experience, there has never been an accident involving the transport of spent fuel that has led to a release of radioactive material anywhere in the world. Despite the best procedures, accidents happen when materials are transported. In the case of most hazardous materials, an accident can instantaneously cause severe injuries and damage to the environment. Radioactive materials such as spent fuel are deliberately packaged for transport in a way that is designed to prevent such a situation from occurring.

As with the transport of other hazardous material, it is prudent to have plans in place to respond to an accident involving spent fuel, such as a collision or train derailment. With proper planning, teams will be able to respond quickly and control or mitigate any radiological hazard or ensure that radiation safety is maintained if there has been no release of material.

The IAEA has produced a Safety Guide to assist national governments with planning for emergencies during the transportation of radioactive material. "Planning and Preparing for Emergency Response to Transport Accidents Involving Radioactive Material" suggests which responsibilities should fall on the national co-ordinating authority, governments, consignors and carriers, and the site response team.

One example of the difference between emergency planning for spent fuel and other hazardous materials can be illustrated by considering oil tankers and INF3 class vessels. There are many examples of oil tanker accidents and large oil slicks that are difficult for emergency teams to contain. An INF3 class vessel carrying spent fuel should be able to contain an emergency involving a cask by using the systems on board the ship. If required, an emergency team that includes radiological experts is on 24-hour standby to travel to the vessel and direct emergency measures. There is no reliance on emergency personnel from countries closest to the accident. Shippers have also designed additional measures to contain accidents. If necessary, the hold of a PNTL vessel could be deliberately flooded to contain an incident involving the release of radioactive material from a cask, and the ship could still navigate at sea.

Although it is not a regulatory requirement, PNTL vessels are also equipped with a sonar system that can operate in depths over 6,000 meters. This can relay to surface teams the depth and angle of a sunken vessel, whether the vessel is distorted or broken, whether the hatch covers are in place, and the radiation level and temperature in each hold.

Shippers of spent fuel in different countries undertake regular emergency exercises with their emergency services to test responses to a real accident. These may range from desktop exercises to those involving a simulated accident, such as a collision.

If an accident does occur, a further question is how to communicate to the public its level of seriousness. The International Nuclear Event Scale (INES) of the IAEA is designed to communicate this information for a particular unplanned event at a nuclear facility. It takes account of factors such as whether and what amount of radioactivity was released and the consequences that could result. It operates for all incidents and accidents from nuclear facilities in IAEA member countries. The levels of events run from 0 to 7 as follows:

Level 7. Major Accident (Major Release)
Level 6. Serious Accident (Significant Release)
Level 5. Accident with Off-Site Risk (Limited Release)
Level 4. Accident without Significant Off-Site Risk (Minor Release)
Level 3. Serious Incident (Very Small Release)
Level 2. Incident
Level 1. Anomaly
Level 0. No Safety Significance

Because a transportation accident could take place in an urban area or many miles away from any kind of dwelling, the INES does not automatically translate to transportation operations. The European Union has examined ways of applying the INES to transportation accidents. In a paper sponsored by the European Commission Directorate General on Transport and Energy, authors from the French nuclear regulatory body, the IPSN (Institute de Protection et de Sûreté Nucléaire), modified the INES criterion and assessed the degree to which defensive barriers had been breached in a series of actual recent events. The highest graded event identified in the study was the sinking of the MV Carla, the container ship that sank north of the Azores in 1997. This was estimated at Level 3 by the French rating system. However, since there was no release of radioactive material, this experimental system is not necessarily consistent with the one applying to nuclear facilities. Moreover, the industry has often been slow at accurately grading events at land facilities at level 2 and above, often modifying the initial grading downwards after measurements of any release have been taken. Further work can therefore be expected in this area.

10 RATIONALE FOR SHIPPING SPENT FUEL

Approximately 1.5 million bundles of spent fuel are currently stored at Canadian reactor sites. Canada is now investigating a long-term solution for disposing of spent fuel that may involve transporting it to a single purpose-built storage facility or a repository. Another possibility, which is considered unlikely, is to send some or all of the spent fuel overseas so that it can be reprocessed. The recovered uranium and plutonium would be shipped back to Canada, as would the separated high-level waste which would be vitrified for long-term storage.

A wide range of choices exist and the various options will be weighed against each other. Some of the choices involve complex technical and political judgments. For example, if Canada elects to reprocess its fuel, it will have a smaller volume of reprocessed high-level waste to store because vitrification reduces the total amount of high-level waste. On the other hand, some critics of reprocessing argue that this is an unattractive option because, by separating plutonium, a proliferation risk is created. In addition, the costs of the reprocessing option are higher than those of storage and disposal.

The transportation of spent fuel is an important factor in these considerations. If it is accepted that the transportation of spent fuel can be achieved at very low levels of risk, there will be more flexibility over how spent fuel should be handled. It means, for example, that the best location, based on geological and other technical and social factors, could be selected for the disposal of spent fuel even if it is some distance from the nuclear reactor sites themselves.

Yucca Mountain Consultations

Nevertheless, the experience in the United States suggests that extensive consultations with the public should be a part of the overall evaluation process for managing spent nuclear fuel. Some of the variables in existing technical papers on spent fuel transportation (age of the spent fuel, types of cask, route scenarios, etc.) prepared by experts for the IAEA, United States and European countries may need to be modified and re-examined to take account of the actual circumstances found in Canada.

The process in the United States for managing spent fuel in a centralized repository has been underway for over twenty years. The Nuclear Waste Policy Act of 1982 and its amendments require or authorize the U.S. Department of Energy (US DOE) to locate, build and operate a deep, mined geologic repository and a storage facility and develop a transportation system that safely links them with U.S. nuclear power plants. In July 2002, the U.S. Senate approved the construction of the repository at Yucca Mountain, Nevada. Yucca Mountain is located 100 miles northwest of Las Vegas and the repository is planned to operate from 2010.

In 1999, the US DOE issued a draft Environmental Impact Statement (EIS), followed by a supplemental EIS in 2001, to provide decision-makers and the public with the opportunity to consider and better understand the environmental impacts of the proposed repository. It addressed the public comments received and issued a Final EIS along with the site recommendation in 2002. This reports that radiation exposures to the public will be well below both U.S. Environmental Protection Agency limits and natural background radiation levels and that the environmental impacts of transportation are small.

As is already the case with spent fuel transportation in the United States, the packages used for moving spent fuel to Yucca mountain will have to be licensed by the U.S. Nuclear Regulatory Commission (NRC) and meet IAEA standards. Spent fuel will be shipped along specified highway routes and/ or rail lines.

At the end of 2003, the US DOE announced that its preferred rail option is to construct a 320-mile branch line through the Caliente corridor, approaching Yucca Mountain from the north. This would cost around $1 billion to construct. Under the "mostly rail" transportation option, around 175 shipments would take place annually for 24 years.

The US DOE is also considering a "mostly truck" option. Highway shippers would require NRC approval for routes that would have to conform to U.S. Department of Transportation (US DOT) regulations, take the most direct interstate path and avoid large cities when a bypass or beltway is available. Law enforcement, emergency response capability and secure facilities for emergency stops would also be checked. US DOT regulations also require that the shipper notify the governor of each state on the transportation route seven days before a shipment takes place.

Public Information

In relative terms, materials that are more hazardous and more vulnerable to terrorist attack are transported much more frequently, and with less effective precautions, than spent fuel. Yet more news articles are written about the dangers of nuclear transportation than about any other hazardous cargo and more "public" protest is directed at it than at the transportation of toxic chemicals, petroleum products and gases.

There is no requirement for nuclear transporters to communicate widely to the public when they are shipping spent fuel, or to engage in "public relations". On the contrary, shippers are more likely not to wish to communicate any information for two reasons. First, IAEA security guidelines recommend restricting information about shipments to reduce the opportunity of an act of sabotage or attempted theft. Second, the release of information about routes and timings can aid protesters who may be able to prevent or slow a movement of spent fuel if they know when it is leaving a reactor site and how it will be transported. This causes logistical difficulties for transporters and may increase operating costs.

In the opinion of this author, spent fuel transportation is the focus of greater critical media reporting and protests for two main reasons. First, regional and local authorities in the area where the spent fuel is to be transported may object to the overall disposal plan.

For example, Nevada State opposes the use of Yucca Mountain as the site for the United States repository and, as part of a campaign to prevent its operation, criticizes the plans for transportation. The rationale appears to be that if the shipments can't take place, the repository will be unable to operate. Regional/ local authority opposition may be a response to negative local public opinion about spent fuel disposal plans. From the perspective of managing objections to spent fuel management, this observation suggests that there is considerable value in undertaking a genuine and detailed consultation with stakeholders during the entire process of deciding how to deal with spent fuel and during the operation of a repository.

Second, there are many Non-Governmental Organizations (NGOs) that campaign to close the nuclear power industry as a whole, usually as one of several core objectives. If nuclear materials cannot be transported, the nuclear industry will be unable to operate. Historically, those NGO campaigners and advocacy groups that have argued that spent fuel shipments are unsafe have shown little interest in public safety beyond the nuclear industry. As has been detailed in this paper, the transportation of spent fuel internationally has an excellent safety record compared to that of other hazardous cargo. These groups largely ignore the transportation risks of other materials and display little knowledge or interest in them, claiming to be "experts" in only nuclear transportation. They usually refer to the possibility of a "catastrophic" accident, which naturally concerns people and attracts newspaper headlines. There is no well-known international NGO that campaigns to reduce all risks in hazardous material transport irrespective of the nature of the cargo. The motives of these anti-nuclear groups has to be considered when evaluating their arguments.

Because of their common interests, regional authorities sometimes work with anti-nuclear advocacy groups against the transportation of nuclear materials in a symbiotic relationship that gives local officials and politicians the extra resources and campaign experience of the NGOs, while giving the groups the power and legitimacy that comes with working with government institutions. This can create a powerful alliance of opposition encompassing legal activity, public relations and politics. The regional authorities and advocacy groups have the incentive to oppose nuclear transportation whatever transport methods are used in order to achieve their aims, i.e. while they often campaign on safety grounds, there may be no level of safety that would satisfy them.

Concluding Remarks

Experience overseas over the last forty years shows that the transportation of spent fuel can be managed safely. Spent fuel is shipped against a background of strict regulations and careful planning. There are a number of extensive technical papers that support the conclusion that spent fuel transport is a low risk activity.

The process is already underway in Canada to manage a range of technical and practical issues concerning the long-term management of spent fuel. Officials may wish to consider some additional questions before spent fuel is transported as part of a spent fuel management system: Should dedicated trains be used? Should fuel be transported in canistered form to reduce worker exposures and provide an extra layer of containment? Should dual-purpose casks be preferred over storage-only and transport-only options? What are the acceptable levels of incident free risk, i.e. risks to members of the public from the normal transportation of spent nuclear fuel, as opposed to the question of accidents? The question of communications and public relations for nuclear transportation should also be addressed. These and other questions will need to be carefully considered by Canadian officials in the future.

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