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Transportation Risk Assessment – An Early Look at the Canadian Program

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ABSTRACT

This assessment takes a preliminary look at the risk posed by the Canadian used fuel transportation program through the examination of hypothetical accidents along potential transport routes. As the location of Canada's eventual repository site is unknown, an all-road transportation program involving the transportation of used nuclear fuel is assumed.

Road transportation has been chosen as the preferred transport mode for calculating transportation risk. This is due to the fact that members of the public and transportation workers in the road transport realm are, on average, in closer proximity to road based used fuel shipments for longer periods of time than during rail transport.

An exhaustive list of hypothetical accident scenarios was created based on Ontario-centric transportation data and infrastructure to identify all potential accident scenarios. This list was reduced to a set of bounding accidents which are examined with respect to probability of occurrence and radiological consequences.

Radiological risk due to used fuel transportation is assessed to be very low. This is largely due to the robust international model regulatory framework.

INTRODUCTION

The Canadian used fuel transportation program is decades away from the start of operations. The first used fuel shipments are not expected to commence until the mid-2040s. As a result, the Canadian used fuel transportation program is still in the early planning stages. Detailed development of the transportation program is largely dependent on the location of the eventual repository site; a decision expected to be made within the next four to five years. Currently, five potential host communities (blue circles in Figure 1) remain in the Canadian siting program. All are located in the Province of Ontario. Implementing a well thought-out, methodical approach to transportation planning, even at this early stage, is critical in the development of a robust and safe used fuel transportation program.

Canada's Used Fuel Inventory

The vast majority of Canada's used fuel inventory originates from commercial electricity generating sites with a very small percentage from research reactors. The used fuel from electricity generating sites consists solely of CANDU type fuel of natural uranium origin. CANDU type fuel bundles are much smaller than light-water reactor fuel. They are about the size of a fireplace log and weigh about 24 kg each. At this time, there are approximately 2.8 million used fuel bundles in interim storage at seven reactor sites (purple squares in Figure 1) spread over four Canadian provinces. This fuel inventory is projected to reach approximately 5.3 million used fuel bundles when Canada's current electricity generating reactor fleet reaches its end-of-life in the mid-2060s [1]. About 92% of all of Canada's used fuel inventory is projected to originate at three nuclear sites: Bruce (52%), Pickering (16%) and Darlington (24%).

Figure 1 – Interim Used Fuel Storage Sites and Siting Communities in Canada

Used Fuel Transportation Distances and Modes

The distance between the repository sites in southwestern Ontario and the one in northwestern Ontario is approximately 1600 km. Additionally, the distance between the eastern-most interim used fuel storage site (purple square 7 in Figure 1) and the western-most potential repository site (blue circle 1 in figure 1) is approximately 2900 km. While selection of the eventual mode or modes of transport for Canada's used fuel inventory remains undecided, both road and rail transport options between origin sites and the potential repository host sites are being studied and assessed.

Interim Storage Configurations

To assess the transport options, interim used fuel storage must be understood. At the three large Ontario nuclear generating sites where the vast majority (projected to be 92%) of the used fuel is stored, used fuel is stored in rectilinear modules each holding 96 used fuel bundles (Figure 2). At the remaining Canadian nuclear sites, used fuel is stored on-end in cylindrical baskets holding up to 60 used fuel bundles.

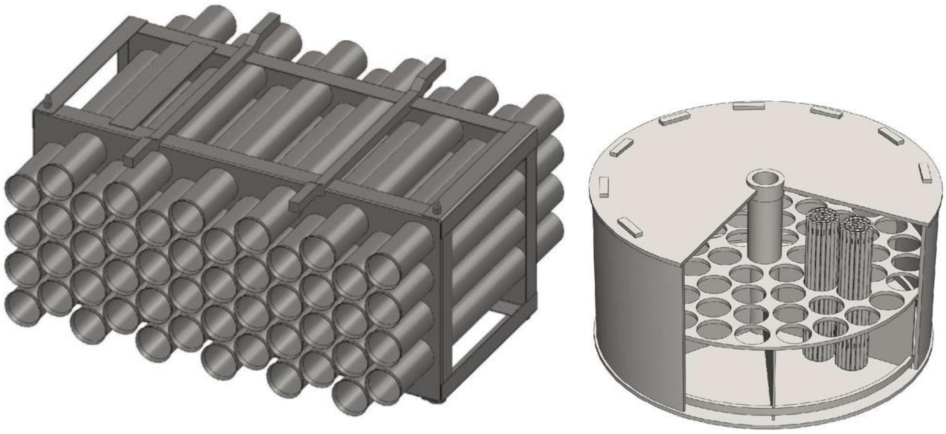

Figure 2 Canadian used fuel storage structures

TRANSPORTATION PACKAGE DESIGNS

Two certified Type B(U) transportation package designs exist for the transport of used fuel in modules. The Used Fuel Transportation Package (UFTP) is designed to transport two modules containing 192 used fuel bundles. A fully loaded UFTP weighs approximately 35 tonnes and was designed for permit-free road transport. The Dry Storage Container Transportation Package (DSC-TP) is designed to transport one Dry Storage Container (DSC) which holds four modules containing 384 used fuel bundles. A fully loaded DSC-TP weighs approximately 100 tonnes and was designed for rail transport. Road transport of the DSC-TP over short distances is possible, however the gross vehicle weight (GVW) of a tractor-trailer combination carrying a single DSC-TP exceeds normal GVW limits and must be classified as a superload. Superloads have specific transport requirements set by the Ontario Ministry of Transportation. One certified Type B(U) transportation package, the HI-STAR 63, is available to transport two baskets containing up to a total of 120 used fuel bundles. The HI-STAR 63 package was designed by Holtec International for the CANDU reactors in South Korea and is not currently certified for use in Canada. The transportation packages are illustrated in Figure 3.

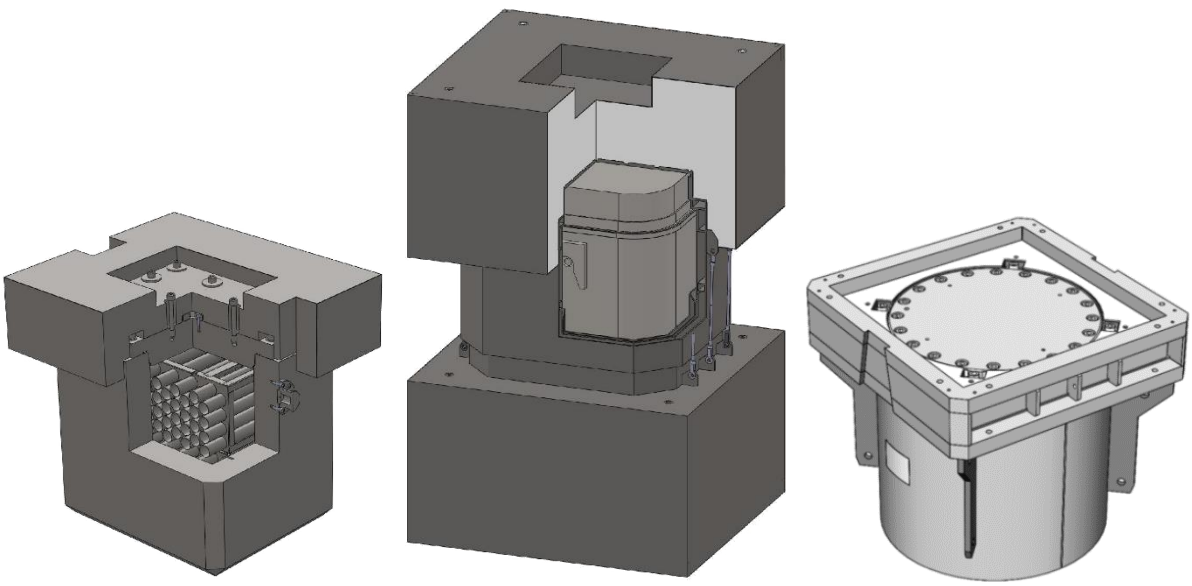

Figure 3. UFTP, DSC-TP and HI-STAR 63 Transportation Packages

RISK ASSESSMENT

The first step in any risk assessment is to define what is meant by risk. A commonly used definition used in assessments is that risk is the product of probability – the likelihood of an event occurring; and consequence – the outcome of that event. Hence the highest risk activity is one with an almost certain likelihood of occurrence with a catastrophic consequence. Likewise, the lowest risk activity is one with a remote chance of occurrence and little to no consequence. Risk can be minimized by decreasing the probability of an events occurrence and/or by reducing the consequence of that event.

The second step is to quantify risk. When the probability of an event occurring and the consequence of that event are known, the risk associated with that event can be quantified. Once quantified, the risks associated with a given activity can be categorized into risk levels. This allows the mechanisms that contribute to risk to be understood.

Finally, where required, measures can be implemented to mitigate risk.

Accident Probability

As previously mentioned, probability is the likelihood of an event occurring. Although it is difficult to predict the future, looking at the frequency of past events can provide a basis of what might happen in the future.

Transport accident frequencies in Ontario involving trucks of all kinds have been relatively stable over the past few decades. This indicates that the probability of a transport accident occurring can be predicted by looking at accident frequencies of past events. The overall accident rate is approximately 1.5 accidents per million km travelled [3]. Looking briefly at accident consequence at a high-level, the data indicates that about 17% of all accidents involving trucks involve some form of personal injury. In Ontario, this figure has also been stable over the past few decades. This data provides a good indicator of what can be expected in the future and also suggests that the overall accident probability, regardless of cargo being transported, is likely to remain stable.

Using this data, accident frequencies for the Canadian used fuel transportation program can be estimated. The Canadian used fuel repository is being designed to process and store 120,000 used fuel bundles per year. For the projected 5.3 million fuel bundle inventory, this equates to an operational campaign of about 45 years. An all-road transportation program is anticipated to require approximately 28,500 road shipments. Each road shipment is assumed to consist of a tractor-trailer unit carrying a transportation package accompanied by a separate escort vehicle. Transport to the repository sites in southwestern Ontario would involve a total transport distance of about 34 million km, and a total transport distance of about 212 million km to the site in northwestern Ontario.

Applying Ontario road transport accident frequency statistics on the Canadian used fuel transportation program suggests that an all-road transport campaign to a repository site located in northwestern Ontario could involve about 316 accidents, about 54 of these could involve some kind of personal injury. This data represents all truck transport in Ontario. It is not specific to transports involving dangerous goods, or even Class 7 Radioactive Materials transports. Hence these numbers suggest the number of accidents that would occur for any transportation campaign of similar size.

Although using historical accident frequencies to predict future events is valid, the probability of an accident occurring is a function of many factors, some controllable and some not. While factors such as the actions of other users of the roads are impossible to control, many factors can be controlled to minimize accident probability. These factors include things such as: driver distraction, fatigue, vehicle maintenance, observing weather and road conditions, driving hours, driver training, driver compensation, etc. Some of these factors are already part of many RAM transport programs. For example, requirements for drivers responsible for dangerous goods transports, and Class 7 Radioactive Materials in particular, require training over and above the training required for the transport of other commercial goods. This required regular awareness and safety training for drivers does reduce accident rates.

It is important to note that transport, regardless of cargo, inherently involves risk and that it may be impossible to eliminate accidents completely. Safe RAM transport is managed through robust transport regulations which require development and use of packages where safety is inherent through strong design, testing, manufacturing and quality control practices.

Accident Types

To evaluate the consequence of an accident, it is not sufficient to know that an accident will occur. Knowing the accident type is required to assess its consequence. Further, to evaluate the risk associated to that accident, the probability of occurrence of that accident needs to be determined. One significant challenge in determining the probability of a transport accident occurring is that the list of possible transportation accidents seems endless. Fortunately, the vast majority of all accidents that occur can be bounded by a small set of extreme accident scenarios. This is accomplished using an approach termed an event tree analysis [4]. An event tree begins with an initiating event and traces branches of all possible subsequent events. Once all branches on the tree have been identified, probabilities of the outcomes can be determined.

This approach was used to take a preliminary look at transport risks associated with the Canadian used fuel program. This methodology identified an exhaustive list of several hundred thousand unique road accident scenarios. To connect the list of potential accidents with real-world situations, the accident assumptions were based on physical data specific to transport in Ontario (e.g. maximum vehicle speeds were based on Ontario transport speed limits, infrastructure features such as bridge heights were based on maximums along potential routes, topographic features such as rock-cuts along the routes and waterbody depths were considered, etc.). By grouping similar events and selecting those with the most significant potential consequence, this extensive list of accidents was reduced. For example, a vehicle striking the concrete pillar of a bridge was considered to be more severe in consequence and hence would provide a bounding scenario over a vehicle striking a utility pole or tree. This way, the exhaustive list of accident scenarios was reduced to ten bounding accident scenarios considered to be of the highest severity.

Consequence

The consequence of a RAM transport accident has two components. The first is the conventional component – the consequence of that given accident if it did not involve RAM. This component is independent of the RAM cargo. Consequence for conventional accidents is touched on earlier in this paper. Based on statistics from accidents involving trucks in Ontario, 17% of accidents involve some form of personal injury. Mitigation of the conventional component is outside the scope of this work.

The second component is the radiological one. The consequence of each identified bounding accident scenario was assessed against the regulatory requirements for Type B transportation packages. One scenario involving a greater than 9 m drop from a bridge onto a bedrock surface required additional analysis to determine consequence. This preliminary assessment based on use of the UFTP determined that the regulatory test requirements encompassed all of the bounding accident scenarios. This analysis underscores the robustness of the international regulatory RAM framework.

Fortunately, through the IAEA, the radioactive materials transport industry has developed and implemented robust international model regulations [5] to mitigate the radiological consequence of RAM transport accidents. This fact is recognized in the Emergency Response Guidebook [6] used by emergency response personnel across North America. The guidebook states that "because of design, evaluation and testing of packages, [radiological releases] would be expected only for accidents of utmost severity." And more importantly that "priorities for rescue, life-saving, first aid, fire control and other hazards are higher than the priority for measuring radiation levels."

Conclusions

The simple act of physically transporting material from one location to another involves risk. Through prudent planning, however, the risks can be assessed and minimized. Conventional transport risk is similar to that of any large scale transport campaign. Radiological risk due to RAM transport is low and does not affect the overall risk due to transportation. The robust Type B package requirements are sufficient to ensure containment of radioactive materials during potential severe accidents. The total number of potential accidents will vary with repository location and transport risk will need to be reassessed once a repository site and transport mode are selected, i.e., the further distance travelled, the probability for more accidents is expected. However, measures can be put in place to mitigate risk.

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