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|  | Radioactive Waste Management Associates |

Memo

To: Bob Halstead

From: Marvin Resnikoff

Date: 3/25/2016

Re: NUREG/CR-7209 Review

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General Comments

NUREG/CR-7209, “A Compendium of Spent Fuel Transportation Package Response Analyses to Severe Fire Accident Scenarios”, reviews in some detail four severe road and rail accidents, and the potential impact on licensed transportation casks likely to be used in transporting nuclear fuel from reactors to a proposed waste repository. The compendium responds to many of the criticisms the State of Nevada raised in its review of NUREG-2125. In general, it examines the thermal environment for four accidents including the Baltimore Tunnel fire, Caldicott Tunnel and the MacArthur Maze fire and ramp collapse. It calculates the response of four casks to these thermal environments and the potential release of radioactive materials. For the four accidents considered, we do not consider the assumptions conservative. For the potential accidents considered, the contractor, Pacific Northwest Laboratories, calculates a radionuclide release of 21 to 24.5 Ci to the external environment, which is approximately 0.01% of the Cs-137 inventory of the GA4 cask.

NUREG/CR-7209 does not consider the Lac-Mégantic, Quebec rail accident that took place on July 6, 2013. [Lac-Mégantic](https://en.wikipedia.org/wiki/Lac-M%C3%A9gantic), is located in the [Eastern Townships](https://en.wikipedia.org/wiki/Eastern_Townships) of the [Canadian](https://en.wikipedia.org/wiki/Canada) province of [Quebec](https://en.wikipedia.org/wiki/Quebec). An unattended 74-car [freight train](https://en.wikipedia.org/wiki/Freight_train) carrying [Bakken Formation](https://en.wikipedia.org/wiki/Bakken_Formation) (North Dakota) [crude oil](https://en.wikipedia.org/wiki/Crude_oil) rolled down a 1.2% grade hill from [Nantes](https://en.wikipedia.org/wiki/Nantes,_Quebec) and [derailed](https://en.wikipedia.org/wiki/Derailment) downtown, resulting in the fire and explosion of multiple [tank cars](https://en.wikipedia.org/wiki/Tank_car). Forty-two people died and half the town was destroyed. After 20 hours, the centre of the fire was still inaccessible to firefighters. It is not obvious why this rail accident was not included. Since NUREG/CR-7209 also includes references from 2015, it had the time to discuss this rail accident. As a result of this accident, shipments from North Dakota have been rerouted along rail lines in the USA. Many of these rail lines are potential shipping routes from nuclear reactors to Yucca Mountain.

NUREG/CR-7209 also does not consider the 1984 Summit Tunnel rail accident in Great Britain. This accident involved a tunnel fire with temperatures that reached 1530 oC, far hotter than the three fire accidents mentioned above.

Specific Comments

In the specific comments below, we critique specific points raised by PNL.

**Section 2. History of cask standards.** The cask standards were first developed in 1961 and adopted by IAEA in 1964. At the time, it was stated that severe transport fires “seldom last more than half an hour.”

An average temperature of 1850°F or 1010°C was proposed, the temperature of hydrocarbon fires. According to Sandia, hydrocarbon fuels burn at T between 1500 oF (800) and 2400 oF, (1300) with average 1850oF (1000). But this was rejected by regulators at the time because “such peak temperatures are reached only very locally by metallic material involved in a fire.”

Both of these assumptions do not apply in the present day. The standards developed for conditions in the 1960’s are still used in the 21st century. Severe accidents have involved fires that have burned much longer than ½ hour, at much hotter temperatures than 800 oC. NUREG/CR-7209 attempts to show that casks developed according to 1960’s standards are satisfactory under present day conditions.

The present standards consist of a 1) Free drop, 2) Crush, 3) Puncture, 4) Thermal, and 5) Immersion, to be carried out sequentially. Under certain accident conditions, the sequence is not the above. The MacArthur Maze accident consisted of a fire first, followed by crush.

**Section 3. Accident History**

As shown by DOT data, while the probability of rail accidents has been declining, the accident rate for rail fires has been increasing. This is due to the fact that more oil has been moving by rail, primarily due to the North Dakota oil field. As seen in Figs. 1 and 2, while the total train accident rate is declining between the years 2004 and 2013, the fire accident rate (which includes all fires, not just petroleum fires) is actually increasing. These graphs which include a trendline are for the U.S. as a whole and do not include Canada. For the U.S. as a whole, the fire accident rate in the year 2013, is over twice as great as calculated by Sprung in CR6672, and the FEIS.

NUREG/CR-7209 also argues that long duration fires in a tunnel are unlikely because of poor ventilation and in the open environment, long duration fires are not possible because many railroad tracks are elevated above grade and are constructed on porous substrate. That is, pooling of spilled flammable liquid is less likely in an open environment when compared with a tunnel environment, where the rail bed surface is often rock, concrete, or pavement. “Historically many of the fires resulting from rail accidents have involved the leakage of flammable gas (such as propane), rather than a liquid.

These arguments In NUREG/CR-7209 are not compelling and contrary to the facts. With train loads of oil tanker cars, in an open environment, fire often follows a derailment. As at Lac-Megantic, rail cars are jumbled, one on top of the other. A fire overpressurizes nearby cars and a major conflagration ensues. With trains hauling 100 oil tankers, we are no longer talking about “pooling” of oil from one car. That is an outdated concept. Further, with a major fire, firefighters and emergency personnel cannot get close to the fire, for fear of additional cars exploding.

The Baltimore Tunnel fire, due to one tripropylene tanker, was oxygen-starved, but temperatures did rise to 1700 oF; it burned for almost 3 hours until a water pipe burst. The NRC calculations to determine the potential impact on a nuclear fuel cask assumed the fire occurred at a distance of 20 meters, assuming the presence of a buffer car. The Howard Street tunnel is single track, so the NRC model makes some sense. However, the tunnel does have a slight grade and liquid petroleum can move the length of a rail car. Tunnels differ from open environments in one important sense – the tunnel walls can heat up; the tunnel then becomes similar to an oven, maintaining higher temperatures even after the flames are extinguished.





While the accident history in the USA downplays the impact of a fire in a tunnel or open air environment, it fails to discuss an issue that contributes to accidents – corporate culture. The Lac-Megantic fire was in one sense predictable because the CEO of the Wisconsin Central railroad, involving the derailment of a freight train, in Weyauwega, Wisconsin, March 4, 1996, was the same CEO of the train company involved in the Lac-Megantic. To cut costs, the number of engineers was reduced from two to one. It is likely with two engineers, the oversight of allowing an unbraked, uncoupled from the engine, 74-car oil tanker train to roll down the hill, would have been noticed.

**Section 4. Design Requirements.**

This section details the design of the four cask considered – rail casks: TN-68 and Holtec Hi-Star, and highway casks: GA-4 and NAC-LWT. Each of these casks has gamma attenuation material, such as lead or several metal cylinder, and neutron-absorbing material, such as boronated water or plastic. One common feature that is not discussed in detail are the metal bars that connect the various shells. For example, as shown in the diagram, the TN-68 cask has metal bars that connect the exterior shell to the inner shell. The thermal analysis for all 4 casks is considered proprietary, and is redacted, so we cannot determine whether a conduction path from a fire has been included in the thermal analysis. We do know that such a thermal path has not been included in calculations for the Holtec Hi-Star cask and we suspect for none of the other casks as well. The standard conservative assumption is to assume the neutron-absorbing material is present during a fire, and the space is emptied during the cool-down period after the fire, an air blanket retaining the inner heat. But the metal bars connecting the outer cylinders to the inner cylinders is customarily ignored.

**Section 5. Accident Scenarios**

For the accident scenarios, NUREG/CR-7209 considers three highway accidents and one rail tunnel accident, the Howard Street tunnel fire in Baltimore. The Howard Street tunnel fire was due to one rail tanker containing 28,600 gallons (108,263 liters) of liquid tripropylene. This material has about the same combustion heat as propane and gasoline. NUREG/CR-7209 examines the temperatures 20m from tanker assuming a buffer car separates the tank car from the nuclear cask. But this assumes triprop does not move and flames are localized to tank car area. At the 2011 Waste Management Conference, I asked the NRC engineer Chris Bajwa why he assumed that liquid triprop did not move. His response was that if triprop moved, it would be absorbed in the ground. The Howard Street tunnel report does not document this assumption. In other tunnel situations, with two tracks, the hazmat could be on an adjacent track. Other than DOT intent, no regulation requires hazmat not be present when nuclear fuel is within a tunnel.

The Caldecott Tunnel fire near Oakland, California occurred shortly after midnight on April 7, 1982. The tunnel consists of two lane roads in each direction, separated by a wall. In the accident, the tank trailer overturned and the entire vehicle (tanker and trailer) came to rest approximately 1650 ft (503 m) from the west portal of the tunnel. The tanker contained 8,800 gal. (33,310 liters) of gasoline. The overall duration of the fire is estimated at approximately 2.7 hours, but the intensely hot gasoline-fueled portion of the fire is estimated to have lasted about 40 minutes. The maximum temperature at the ceiling, 935°C, about 80 meters downwind, was reached after only 10 minutes into the fire. NUREG/CR-7209 does not discuss the deformation of thick metal grates in the tunnel.

The MacArthur Maze fire, an overturned tanker truck caught fire, weakened the girder holding the highway above, which subsequently collapsed on the tanker truck below. Thus here one must model the fire and crush forces if a nuclear fuel cask were also involved. On April 29, 2007 at approximately 3:37 a.m., a tanker truck and trailer carrying 8,600 gallons (32,554 liters) of gasoline overturned and caught fire on the Interstate 880 (I-880) connector of the MacArthur Maze interchange located in Oakland, California. The intense heat from the fire weakened the steel girders of the Interstate 580 (I-580) roadway above, collapsing two adjacent sections. The package is on the lower I-880 roadway, fully engulfed in fire for 37 minutes, exposed to a flame temperature of 2012°F (1100°C). A video shows the first I-580 roadway span above the I-880 roadway beginning to sag about 5 10 minutes into the fire and collapsing completely at approximately 17 minutes. In all, the fire continued to burn intensely until for about 102 minutes.

**Section 6.0 Analyses of Fire Accident Scenarios**

In this section, each of the casks were evaluated in the fire accident scenarios of Section 5. The NAC-LWT was also assumed to be carried on a flat bed in the Baltimore Tunnel. The seals of the NAC-LWT, partially composed of Teflon, were expected to degrade. The MacArthur Maze fire is the harshest environment for the NAC-LWT cask. The peak clad temperature exceeds burst rupture conditions. While the seals in the TN-68 cask are expected to degrade in a tunnel fire, the peak clad temperatures, 845°F (452°C) in the TN-68 package and 930°F (499°C) in the HI-STAR 100 package, are well below the regulatory limit of 1058°F (570°C) for zircaloy. Thus, the cladding is not expected to burst. However, this is a limited view of an accident scenario. With high burnup fuel and thinned cladding, the impact may shatter the cladding, which is not much thicker than a metal turkey roasting pan. Thus, if the seals degrade, it is possible for radioactive material to be released.[[1]](#footnote-1)

**Section 7.0 Consequences of Fire Accident Scenarios**

For the TN-68 cask in a tunnel fire, like the Baltimore Tunnel fire, the seals may degrade, but only slight amounts of crud, primarily Co-60, could be released, according to NUREG/CR-7209. No burst rupture of the cladding is expected. However, if the impact is severe and the fuel is high burnup, it is possible the thin cladding could shatter, releasing semi-volatile Cs-137. NUREG/CR-7209 does not take this into account.

According to NUREG/CR-7209, the MacArthur Maze fire accident would raise the internal temperature of the lighter highway casks so that burst rupture of fuel cladding is expected. NUREG/CR-7209 then calculates the release of fission products, but only from a single location in the fuel cladding. Cs-137 is not expected to be released from the entire length of a fuel rod. As a result, NUREG/CR-7209 calculates the release of 21 to 24.5 Ci to the external environment. This is approximately 0.01% of the total Cs-137 inventory of the cask. There is no support for this assumption.

1. Though I have the reference, I haven’t had the time to examine the crush forces on a hot NAC-LWT cask. [↑](#footnote-ref-1)