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|  | Radioactive Waste Management Associates |

Memo

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| To: | Bob Halstead, Joe Strolin,  |
| From: | Marvin Resnikoff |
| Date: | July 25, 2017 |
| Re: | NEV-NEPA-Halstead - #9 |
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# **Summary**

The State of Nevada has introduced contention NEV-NEPA #9 which considers transportations of spent nuclear fuel versus at-reactor storage. The contention asserts that the FSEIS does not consider the no action alternative in that it fails to consider reasonably foreseeable sabotage at one or more of the 76 identified commercial reactor or DOE storage sites. “Without equally considering reasonably foreseeable sabotage scenarios under both the proposed action and the no action alternative there is no adequate disclosure of alternatives under NEPA.” In this memo I want to consider reasonably foreseeable sabotage scenarios at reactor storage sites and also want to bring up to date our previous calculations on sabotage that may occur when transporting spent nuclear fuel. This update will look at higher burnup fuel, higher burnup than is considered in the FSEIS.

**At-Reactor Storage**

Spent nuclear fuel is stored at reactor sites in fuel pools and several different dry storage casks. There are three dry storage casks presently in use: the Castor cask, the NUHOMS cask and the HOLTEC cask.

**Castor Cask.** The CASTOR cask has forged iron walls 15 inches thick, but it is susceptible to an armor piercing missile. On June 25, 1998 the U.S. Army conducted a weapons test at the Aberdeen proving grounds in Maryland. Video of the tests shows a TOW antitank missile perforating the cask wall. The hole was approximately grapefruit sized. The Castor casks is widely used in Europe, but only at the Surry reactors in Virginia.

The most widely used casks in the United States are the HOLTEC and NUHOMS. The NUHOMS casks are sealed canisters holding nuclear fuel that fit into a horizontal concrete box. The nuclear fuel assemblies fit within a lattice work inside the stainless steel cylinder which is welded shut. The canister holds 24 PWR fuel assemblies.

The Holtec cask is a concrete upright cylinder into which sits a sealed canister holding 24 PWR fuel assemblies or as many as 68 BWR fuel assemblies.

The HOLTEC cask is a concrete cylinder that's 2 1/2 to 3 feet thick. One sabotage event would be the use of TNT or PETN to blast a hole in the side of the concrete cylinder. I looked into the amount of TNT required to make a hole in a 3 foot concrete cylinder. My calculations show that if TNT is located immediately adjacent to the concrete cylinder, it would require 78 pounds of TNT or a smaller amount PETN. Probably a smaller amount of a shaped charge would be as effective. It would also require less TNT weight if the concrete cylinder were 2 1/2 feet thick. An additional small amount of explosive material would be required to make a hole in the stainless steel canister since the stainless steel canister is only one half inch thick.

The amount of TNT needed would be increased if the charge were located some distance from the cask. The weight of TNT goes essentially as the cube of the distance between the charge and the cylinder. The formula is the following:

P = R3KC

Where R is the distance to the object

 K is a material factor, a function of the strength, mass and thickness of the target

 C is the tamping factor, a function of the placement of the explosive. E.g., if the explosive were placed in the air intake of the Holtec cask, which would effectively simultaneously destroy the concrete and the canister.

For reinforced concrete and the explosive placed outside the Holtec cylinder, the amount of explosive required, is shown in Table 1.

**Table 1. Lbs of Explosive to Shatter Reinforced Concrete[[1]](#footnote-1)**

|  |  |  |  |
| --- | --- | --- | --- |
| **Thickness (ft)** | **Lbs TNT** | **Lbs PETN** | **M2 Block** |
| 2.5 | 54 | 68.4 | 65 |
| 3 | 78 | 47.4 | 45 |

In addition to TNT shaped charges, the above ground Holtec storage system is also vulnerable to other types of explosions. For example, a car loaded with explosives could be driven onto the storage facility pad and be exploded next to the HOLTEC cask. I have not estimated that scenario either. The shock waves would also be important in determining whether the fuel rod cladding would remain intact. This would be particularly important for high burnup fuel where fuel rods within each assembly have thinner walls and are more brittle. None of these issues are discussed in the FSEIS.

The Holtec system consists of vertical cylinders, generally placed above-ground, but they can also be located below ground. My concern here is that a fuel truck holding 8000 gallons of gasoline could be unloaded into this underground storage facility and set on fire. I have not done the calculations that estimate the impact of such a scenario. These at-reactor sabotage scenarios need to be compared in the FSEIS to the transportation sabotage scenarios.

We have not considered the effect here of an anti-tank missile. Clearly it would be easier to protect a fixed facility than a moving cask since an anti-tank missile could be fired from any location along the route. The FSEIS should make this comparison between at-reactor and moving targets. All storage facilities and train carriers could be ringed with a screen or building so that explosives would be detonated at some distance from the storage systems, but there are no regulatory requirements to do so.

**Release of Radionuclides in Sabotage Event**

**Update to previous calculations by RWMA**

We previously analyzed the FSEIS regarding its calculations of a successful sabotage attack[[2]](#footnote-2). The FSEIS calculations are based on a report by Luna[[3]](#footnote-3). In a later report we investigated more closely his assumptions concerning blowdown effects, that is to say the equalization of pressure inside and outside the cask after a sabotage event[[4]](#footnote-4). In Luna’s calculations the potential release of cesium is higher from a truck cask than a rail cask even though the inventory in a rail cask is six times greater. We want to repeat the assumptions made by Luna which allowed him to come to this conclusion and then discuss why they are incorrect. After that we will discuss the calculations involving a sabotage event that has an entry and exit holes, not just an entrance hole to a cask and update our previous results for higher Burnup fuel.

Luna correctly assumes that the fuel rods are pressurized. In a potential sabotage event, the assembly rods are perforated and the pressure within the cask increases. Since the rail cask has much greater free volume than the truck cask, the pressure within the truck cask is higher after a sabotage event then in a rail cask and that accounts for his calculation that less radioactive material was released in a rail cask.

However Luna makes two errors in his calculation which lead to his incorrect conclusion. First, he assumes the cask is not pressurized initially and that is an incorrect assumption since the Holtec cask is pressurized in order to facilitate the cooling of the contents. In our 2010 calculations we correct that mistake. Comparison of our calculations with his appear in table 2 below.

The second error in his calculation is his assumption concerning the release of cesium- 137. While he assumes that the entire pressure within the fuel rod is reduced accounting for the increased pressure within the cask, he does not similarly assume that all the available cesium is released. By “available” we mean cesium in the gap between the fuel and the cladding. We corrected that error in our 2008 paper. Since all the pressure within the fuel rod is reduced, this implies the buildup of krypton, iodine and helium is released. But he does not assume that the available cesium in the fuel rod gap would similarly be released. The comparison between our cesium release and his also appears in Table 2 below.

**Table 2. Cs Release Fractions**

|  |  |  |
| --- | --- | --- |
|  | **Truck** | **Rail** |
| RWMA[[5]](#footnote-5) | 2.13E-3 | 2.29E-4 |
| Luna[[6]](#footnote-6) | 5.33E-4 | 7.15E-6 |

The Cs inventory in truck and rail casks containing 24 PWR high burnup fuel (80 MWD/MTU) are shown in Tables 3a and 3b for both 1-hole and 2-hole sabotage events.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **fraction inventory released** | **Inventory 45 MWd/MTU** | **Inventory 80 MWd/MTU** | **Cs released pressurized cask 45 MWd/MTU** | **Cs released pressurized cask 80 MWd/MTU** |
| truck | 2.13E-03 | 1.60E+05 | 4.20E+05 | 3.41E+02 | 8.95E+02 |
| rail | 2.29E-04 | 9.60E+05 | 2.52E+06 | 2.20E+02 | 5.77E+02 |

**Table 3a. Cs Release from 2010 Report 1-hole Pressurized 24 PWR**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **fraction inventory released** | **Inventory 45 MWd/MTU** | **Inventory 80 MWd/MTU** | **Cs released pressurized cask 45 MWd/MTU** | **Cs released pressurized cask 80 MWd/MTU** |
| truck | 2.89E-02 | 1.60E+05 | 4.20E+05 | 4.62E+03 | 1.21E+04 |
| rail | 5.13E-03 | 9.60E+05 | 2.52E+06 | 4.92E+03 | 1.29E+04 |

**Table 3b. Cs Release from 2010 Report 2-hole Pressurized 24 PWR**

Note: the calculated releases includes the results of the 1994 GRS experiment[[7]](#footnote-7)

1. Department of the Army, “Explosives and Demolitions,” FM 5-25, February 1971 [↑](#footnote-ref-1)
2. Resnikoff, and Traverse, J, “Potential consequences of a successful sabotage attack on the spent fuel shipping container,” RWMA, November 2008. [↑](#footnote-ref-2)
3. Luna, R.E., *Et a*l., “Projected source terms for potential sabotage events related to spent fuel shipments,” Sandia National Laboratories, Sand 99 – 0963, June 1999. [↑](#footnote-ref-3)
4. Resnikoff M, and Traverse J, “Luna blowdown calculations,” RWMA, February 2010. [↑](#footnote-ref-4)
5. (RWMA, 2010) [↑](#footnote-ref-5)
6. Luna, RE, “Release fractions from Multi-element Spent fuel casks resulting from HEDD attack,” WM’06 Conference, 2006. [↑](#footnote-ref-6)
7. Pretzsch, G and Lange, F., “Experimental Determination of the Release of UO2 from a Transport Container for Spent Fuel Elements after Shaped Charge Bombardment,” Gessellshaft fur Anlagen-und Reaktorsicherheit, Report GRS A-2157, May 1994. [↑](#footnote-ref-7)