Analysis of Radiation Exposure to Spent Fuel Container Truck Drivers

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1. Introduction

In the nuclear energy sector, the safe transportation and storage of spent fuel is a top priority. For this reason, accidents involving spent fuel containers have been an important issue, with most of the focus on drops. Spent nuclear fuel (SNF) transportation is one such job with a high radiation risk. SNF contains high radiation activity, and there is the potential for radiation leakage during the transportation process. Therefore, truck drivers who transport SNF need to be trained about radiation safety.

Occupations that have the potential for exposure to radiation require a high level of understanding about radiation safety and precautions. In addition, the risk of prolonged exposure to repetitive low-level radiation should not be overlooked for drivers who transport spent nuclear fuel, regardless of accident. Therefore, in this study, the radiation effects on the driver have been evaluated while the spent fuel cask was in good condition.

2. Methodology

Source definition

Based on the research conducted on domestic light water reactor fuels, with burnup of 55 GWD/MTU, enrichment of 4.51 wt%, and cooling period of 5 years, the source term for assemblies has been derived with an assumption of a uniform distribution of source intensity. The results are shown in Figure 1. [1]

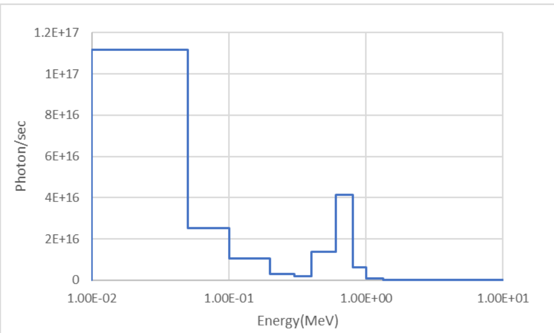

Figure 1. Gamma spectrum of assembly

Cask model

The reference model for the SNF is KN-18, and the spent fuel assembly is CE 16x16. The cross-sectional view of the spent fuel cask is as follows.

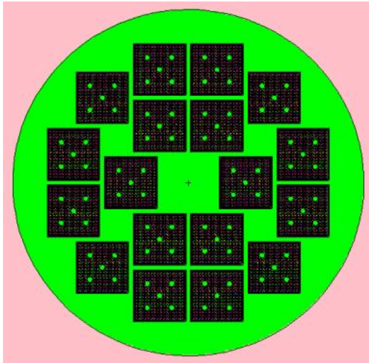

Figure 2. Cross-section of KN-18 cask [2].

Dose assessment

The Monte Carlo N-Particle Transport Code (MCNP) version 6.2 was used in the simulation tests, with separate calculations for neutrons and gamma rays. The dose conversion factors were calculated using the International Commission on Radiological Protection (ICRP) Publication 21 [3, 4].

For dosimetry, a human head with a diameter of 10 cm was simulated using an F4 tally located 1 m away from the center of the lid of the container, and PNNL-15870 was referenced for material information of the brain. [5]

To assess driver exposure dose, the MCNP code is used to model as shown in Figure 3 and the results as shown in Figure 4.

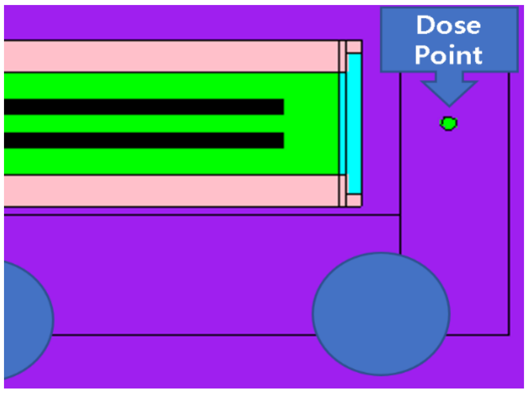

Figure 3. Dose point for dose assessment.

Variance reduction technique

The container is made of thick SS-304 material, and it is not easy for the radiation particles to tally the dose point. Therefore, the mesh + weight window, which is one of the typical variance reduction techniques, has applied to reduce the relative error.

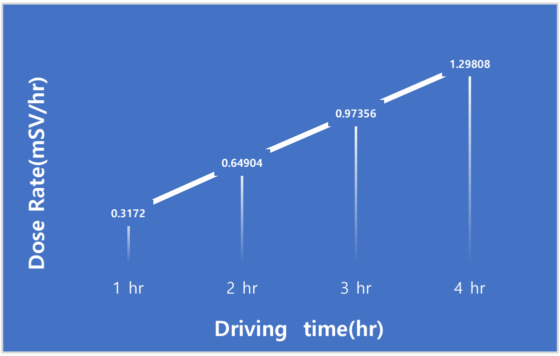

Figure 4. Dose point for dose assessment.

Normal annual exposure dose

To calculate the dose rate which driver receives in a year on the job, we used the following equation.

$$ED = dose\ rate\ \times d\ \times\ w$$

ED: exposure dose(mSv/hr)
d: One-way driving time(hour)
w: workday per year

Since the site of the high-level disposal site is undecided, the driving time is assumed to be 1 to 4 hours.

Abnormal exposure dose

Even in the absence of an accident, the bolts that hold the container and lid together can become loose and create a small gap between the container and lid during transportation. In the case of an accident, it can be recognized and avoided, but in this case, unless there is a separate alarm device, it cannot be recognized, resulting in unnecessary exposure. This study has evaluated the doses to truck driver during unrecognized abnormal situations. The dose has applied to dose rate with a driving time of 1 to 4 hours. The behavior of radiation under abnormal condition is shown in Figure 5.

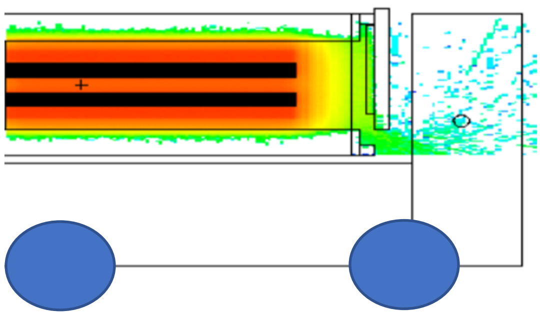

Figure 5. Behavior of radiation under abnormal conditions

3. Results and Discussion

The dose rate at the measurement point was calculated to be 1.22E-3 mSv/hr. Assuming 4 hours of one-way driving time and 260 working days per year, the driver's exposure dose is 1.27 mSv in year. The driver's exposure dose according to driving time is shown in Figure 4

In an abnormal situation, the dose rate was measured at 9.22E-01 mSv/hr and assuming 4 hours of driving time, the driver would receive 3.69 mSv. This value is about three times the annual dose limit that we can normally receive, which is 1 mSv. Therefore, it represents a very high risk of exposure, and this fact should be noted.

According to the Korean Nuclear Safety Act, the dose limit for radiation workers is less than 100 mSv for 5 years and 50 mSv per year. For the public, the annual dose limit is 1 mSv or less. Obviously, this is a low dose for a radiation worker, but this is assuming the container is sound.[6]

4. Conclusion

An assessment of the dose a driver would receive in a year if the container were sound. Even in the absence of an accident, the bolts that hold the container and lid together can become loose and create a small gap between the container and lid during transportation. In the case of an accident, it can be recognized and avoided, but in this case, unless there is a separate alarm device, it cannot be recognized, resulting in unnecessary exposure. In addition, inert gases or volatile particles may leak through the gap if the exposure material is poor. In this case, the risk of internal exposure through breathing may be greater than external exposure. In the future, we will perform dose assessments assuming the scenarios.

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