Feasibility Study: Impact Analysis through MCNPX simulation for various spent fuel loss scenarios

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1. Introduction

The IAEA is performing radiation profiling on "spent fuel dry storage casks" in order to verify the contents of the casks according to the operator's declaration, because there are no direct methods which can verify the spent fuel state.

Although the principle of this method (radiation profiling – fingerprinting) is very simple, there is the possibility of causing many errors. The errors can generally be caused by the long periods for the verification (about 1 year from one verification to the next) and alteration of the verification condition such as changes in the equipment used and operators. Finally, many errors can occur by previous causes, when verifying the spent fuel storage.

It is recognized that "the research supporting the previous weakness has to be performed". So, impact analysis was done "to interpret spent fuel loss cases" and "to support the interpretation of the radiation profiles in the absence of baseline measurements", as a feasibility study to support these problems.

2. Simulation Model

2.1 Wolseong Canisters Geometry

The canister blueprints were offered by the KHNP (Korea Hydro & Nuclear Power) in order to apply the correct information to the canister simulations. Based on these blueprints, the canister geometry was made out. When constructing the MCNPX geometry, the low effective parts for the simulation were excluded in order to reduce the simulation efficiency.

• <u>Canister body:</u> The height and diameter of the canister is about 6.4m and about 3.0m, respectively. The sub-structures in the canister include reverification tubes, baskets, rebar and canister liners, etc.

• <u>Reverification tubes:</u> The height of the important part for the dose detection is about 489.50 in the canister. The diameter of the concrete hole is about 5.168cm. The inner diameter and the thickness of reverification tube is about 4.768cm and about 0.2cm, respectively.

• <u>Basket:</u> The diameter of the basket is about 1.07m as these are stored into the canister.

• <u>Rebar:</u> These are located between baskets and reverification tubes.

• <u>Spent fuel:</u> In case of spent fuel simulation, considering all the rods of the spent fuel can cause simulation time to increase. So in this study, one spent fuel bundle was assumed as single cylinder.

2.2. Wolseong Canisters Materials

• <u>Canister body:</u> Most parts of the canister except sub-structures are composed of concreted. The principal composition material is oxygen, silicon calcium, etc.

• <u>Basket, canister liner, and reverification tube:</u> The principal composition material is stainless steel.

• <u>Rebar:</u> The principal composition material is steel

• <u>Spent Fuel:</u> The Spent fuel is the most important radiation source. It is composed of uranium, plutonium, etc.

2.3 Detector Geometry and Material (CdZnTe, He-3)

The height of the detectors is generally specified according to the detector type. But the detector's height was not important in this simulation because a segmentation tally was used. When using a segmentation tally, the geometry of the reverification tube was assumed as one cylinder. The segmentation height was assumed to be 3cm (for photons) or 5cm (for neutrons). The principal composition material is Cadnium, Zinc, Teluride, He-3, lead, aluminum.

2.4 Source term and Tally

To simulate a canister, source term was evaluated by using Origen-ARP. Information used in source term evaluation includes "cooling time" and "burn-up" of the spent fuel. Also, Activation products such as Plutonium were considered.

As previously mentioned, the segmentation tally was used to evaluate the photon/neutron dose in this study. In evaluating the photon dose, the F6 tally was used and the total accumulated energy per unit mass was evaluated. In evaluating the neutron dose, the F4 tally was used and neutron counts were evaluated.

2.5 Spent fuel retrieval loss scenario

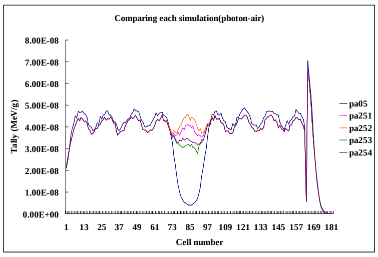
To do an impact analysis for a spent fuel loss scenario, a specific basket was assumed as a dummy basket, and some bundles of the 60 bundles were selectively assumed as dummies. The number of spent fuel loss scenario was 5. Each scenario was 0.5SQ loss, 0.25SQ loss (4 cases). In each scenario, air or stainless steel was used as dummy material. And dummy basket is place on a 5th shelf from the bottom.

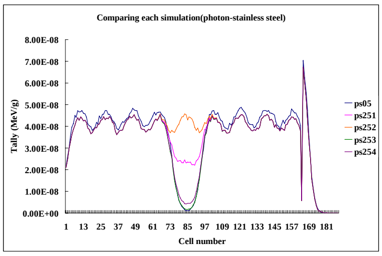
3. Simulation results and Analysis

3.1 Simulation Results

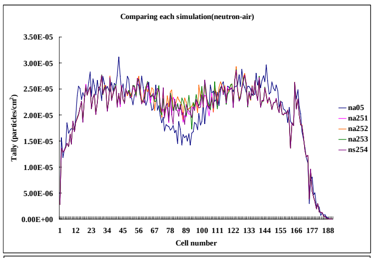
Simulations for the 5 cases were performed. Each simulation result for each spent fuel loss scenario is following.

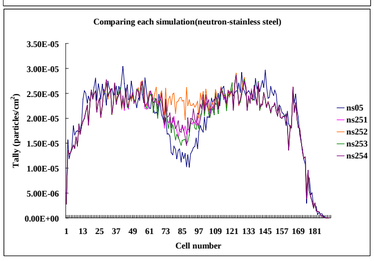
• Photon simulation Results (air and stainless)





• Neutron simulation Results (air and stainless)





As previously mentioned, dummy basket is place on a 5th shelf from the bottom. So, the peak of the dose profile could be distinguished at the neighborhood of the center of the graph (see Figures) for all cases. But the dose profile shape of two different particles (photon and neutron) was very different. This is because of attenuation characteristics of each particle.

3.2. Statistical Analysis

To guarantee the reliability of the simulation, the results of precision and accuracy test was confirmed.

In case of precision test, the 10 statistical test offered by MCNPX code was checked. In all simulations, the 10 statistical tests were passed.

In this study, a physical accuracy test could not be performed, because the real properties of the spent fuel in a specific canister could not be known. In all simulations, most principal factor is the source term. To calculate the source term, information from each spent fuel such as bun-up, cooling time must be known. Generally, all information about each spent fuel can be known. But one basket is composed of bundles which have various properties (example: burn-up, cooling time of each bundle). So, when calculating the source term to reflect the real storage situation, all various properties could not be considered.

3. Conclusions

In most simulations, the dose peak in the neighborhood of the 5th basket could be formed by an influence of the dummy. In case of photon simulation, peak shape was definitely distinguished very well. But in case of neutron, peak shape was lumped because of the penetration characteristics of the neutron. Based upon the previously analysis, the dose profile characteristics of each particle can be summed up below.

Particle	Photon	Neutron
9 Peak distinction	Available	Unavailable
Dose Sensitivity by geometry	Large	Small
The weak point	large geometry dependency	low peak resolution
The advantage	Distinguishabl e peak.	Low geometry dependency

In conclusion, when verifying and re-verifying the completeness of the inventory of spent fuel stored in dry storage in case of a containment/surveillance failure, to use the two particles' dose profile would be advantageous to get a more reliable verification results.

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