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Sensitivity Calculations for Shielding of KN-12 Spent Nuclear Fuel Transportation Cask using MAVRIC and SAMPLER

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1. Introduction

A spent nuclear fuel transport cask should be demonstrated by performing critical, shielding, thermal, and structural analyzes to ensure safe transport of nuclear fuel. The purpose of this study is to investigate the results of the external radiation dose rates for a transport cask. MAVRIC [1] in SCALE 6.2 code package was used for the shielding analyses of KN-12 transportation cask. [2] Sensitivity evaluations for the shielding of the cask were also performed using SAMPLER [3] in SCALE 6.2.

Two kinds of sensitivity models using SAMPLER and MAVRIC were made for the cask with 12 WEC PWR spent fuel assemblies. First, the neutron and gamma dose-rates were calculated using region tally and point detectors methods for the cask surfaces. Next, another neutron and gamma dose-rates were also calculated along with the cask heights using region tally only.

The purposes of this study are to investigate the applicability of region tally to calculate the dose rate of the cask surface and to simulate the trends of dose rates of the cask surfaces according to the positions from bottom to top of the cask.

2. Shielding Evaluations

WEC fuel assemblies with 5.0wt% concentration were selected and cask body, neutron absorber and fuel baskets were used as described in its safety analysis report. The criteria for the shielding evaluation are described in NUREG-1617. [4] ANSI standard (1977) incorporated in MAVRIC was used for flux-to-dose-rate factors and the latest ENDF/B-VII.1 'v7-200n47g' was used for the cross section library.

When calculating dose rates it is normal to use point detector options. But the point detector method does not pass all of the convergence tests and is designed to be far from scattering material - which is why they are required to be in a void. When calculating the dose at the surface instead of point detector MAVRIC provides region tally options. So one should define a small region near the surface using a region tally. It is necessary to change the adjoint source to match with region tallies. Region tallies do average the flux over the given region and will be better than a point detector right next to a surface. For the doses at two meters away, point detectors will work better.

2.1 Dose rates calculations using MAVRIC

MAVRIC sequence in SCALE6.2 uses multi-group or continuous energy Monte Carlo code MONACO [5] and calculates the adjoint flux as a function of position and energy, and combines the results of an adjoint calculation from the 3-D deterministic code TORT with MONACO which is a new 3-D Monte Carlo code being developed within SCALE package for shielding calculations.

SCALE 6.2 uses a new version of DENOVO that has a better first collision estimate for point sources. In adjoint calculation, the point detectors sit on mesh planes, so DENOVO divides them into several on each side of the dividing plane(s). So SCALE 6.2 take way longer for this case. Changing the problem to region tallies, DENOVO in SCALE 6.2 is faster than SCALE 6.1 for both the forward and adjoint calculation.

The MAVRIC modeling of the cask which includes the fuel assemblies is shown in Fig. 1. Shielding of the K-12 transportation cask is provided by the thick-walled cask body and the lid. For neutron shielding, polyethylene material surrounds the vessel wall and stainless steel is placed below the cask bottom and above the cask lid.

Table 1 and 2 summarizes the total surface dose rates of the cask for region tally and point detector each. The dose rate limits for a normal condition are 2mSv/hr at any point on the outer surface of the cask including top and under-side(bottom) of the cask and 0.1mSv/hr at any point 2meters from the outer lateral surface of the cask excluding the top and underside of the cask.

The dose rates calculated are very close to both region tally and point detector and meet the criteria.

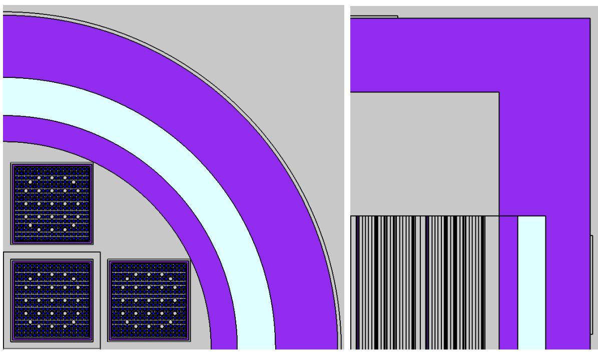

Fig. 1. MAVRIC Modeling of KN-12 for Region Tally

Table 1. Total Dose Rates (Region Tally)

	Total Dose Rate	
	mSv/h	Rel. uncert
Top	2.89677E-01	0.01423
Side	5.34488E-02	0.04506
Bottom	5.78145E-01	0.05875

Table 2. Total Dose Rates (Point Detector)

	Total Dose Rate	
	mSv/h	Rel. uncert
Top	2.96406E-01	0.02189
Side	6.25881E-02	0.02818
Bottom	6.09388E-01	0.13178
2 meter (side)	1.52620E-02	0.00158

The total dose rates are the sum of neutron and gamma dose rates. 100 batches and 10e+6 particles & 10e+7 particles per batch for neutron and gamma each were used for dose calculations.

2.2 Sensitivity calculations using SAMPLER

The SAMPLER sequence within SCALE 6.2 allows random sampling and perturbation of a wide range of parameters and nuclear data within virtually any sequence currently in the SCALE code package. The user input varies considerably based on the type of perturbation being applied. SAMPLER generates a specified number of perturbed inputs for each case. Identical perturbed values are used in each realization of each case, as specified. Different values are used for cases that are not specified to use the same values.

SAMPLER uses a three-step process for executing the required calculations. The first step is the generation of the perturbed inputs. The second step is to execute all the generated SCALE calculations. After all calculations are complete, SAMPLER is run in a post-processing mode to extract requested information from the generated output.

Sensitivity analyses were performed by changing the heights of the cask. SAMPLER calculation provides the expected values of the data and repeats the perturbation for a specified number of samples (set by the user) to obtain the results distribution with its standard deviation and its correlation coefficients. The SAMPLER module has been used coupled with MAVRIC in this sensitivity calculations.

The neutron and gamma dose-rates were calculated on every 100 surfaces bottom (-213cm) to top (263cm) of the KN-12 transportation cask using SAMPLER. Fig.2 shows the neutron, gamma and total dose rates according to the positions of the cask height.

The peaks of neutron response on top came from the absent of neutron shield as shown in Fig 1.

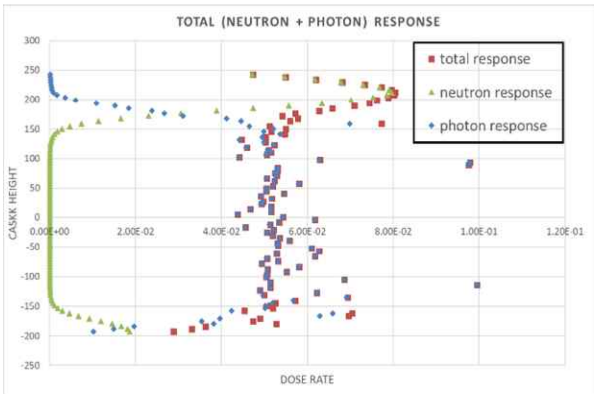

Fig. 2. Neutron, Gamma and Total Dose Rates

And the drop of the gamma response on the top might be stemmed from the reason that there is a space between a cask lid and spent fuel assemblies in the cask. The dose rates calculated every 100 positions are investigated and also meet the criteria.

Using SAMPLER, one can simulate the sensitivity analysis of dose rate calculations for many kinds of purposes.

3. Conclusion

The shielding evaluations of KN-12 cask for spent fuel transportation were carried out using point detector and region tally methods of MAVRIC. As the results are very close to each other, it is recommended that one use the region tally for the calculation of surface dose rates of a cask instead of point detector options. The dose rates according to the positions of the cask height were also investigated using SAMPLER.

Using the results and methods of this study, an optimum shielding analysis to determine the design specifications of the neutron and gamma shields for a future storage and transport cask design can be established.

REFERENCES

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