Shielding Evaluations of Fuel Failure Scenarios Using MAVRIC

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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. However, Spent fuels with high burnup values of 60 to 80 GWd/MTU increase the potential to fail due to the degradation of fuel and cladding materials [1].

The purpose of this study is to investigate the results of potential fuel failures on the external radiation dose rates for a transport cask. The dose rates may be changed by fuel failures which are considered very improbable.

Shielding evaluations for fuel failure scenarios in which the geometric structure or conditions of spent fuel assemblies and fuel rods are changed due to beyond design basis accidents are evaluated for KN-18 transport cask. MAVRIC was used to evaluate the dose rates for the conditions of the cask [2].

2. Shielding Evaluations

KN-18 is a transport cask for 16×16 CE type fuels. In this study, Plus7 fuel assemblies with 5wt% concentration were selected and KN-18 cask body, neutron absorber and fuel baskets were used as described in its safety analysis report. The criteria for the shielding evaluation are different from the dose rate limits described in table 5-1 of NUREG-1617. [3]

The source term evaluation was carried out by ORIGEN-ARP to evaluate the neutron and gamma source of the cask. The total neutron and gamma ray intensity per cask is calculated as 3.17e+09 n/s and 7.64e+16 p/s.

For the calculations of the dose rate, ANSI standard (1977) incorporated in MAVRIC was used for flux-to-dose-rate factors [4] and the latest ENDF/B-VII.0 'v7-200n47g' was used for the cross section library.

2.1 Evaluations for normal condition

The MAVRIC modeling of the cask which includes the fuel assemblies is shown in Fig. 1. Shielding for the K-18 is provided by the thick-walled cask body and the lid. For neutron shielding, resin material surrounds the vessel wall and resin material is placed below the cask bottom and above the cask lid. Additional shielding is provided by the basket structure and support disks [5]. Table 1 summarizes the surface dose rates of the cask. 100 batches and 100,000 particles per batch were used for both neutron and gamma dose calculations.

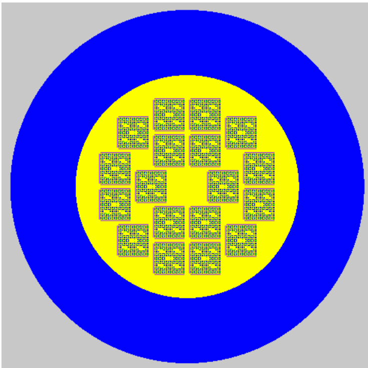


Fig. 1. MAVRIC Modeling of KN-18 Cask.

Table 1. Surface Dose Rates of KN-18 Cask

helium	Neutron (mSv/h)	Gamma (mSv/h)
Side	1.14674E-02	9.09986E-04
Bottom	3.81165E-01	2.75457E-02
Top	1.46653E-05	1.09467E-03

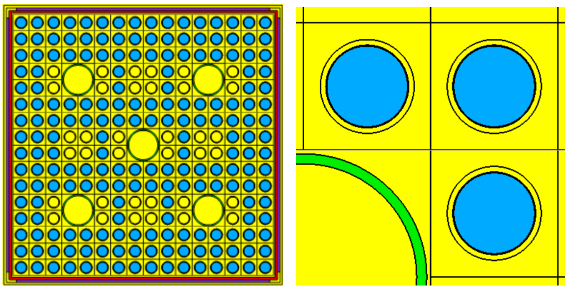
2.2 Evaluations for fuel failure scenarios

It has been grown particular concerns when high burnup spent fuels had been analyzed under hypothetical accident conditions. For shielding evaluations under those circumstances, several assumptions were made as internal and external structures within the cask, the basket structures with neutron absorbers, especially nuclear fuel assemblies, are maintained as their original states. In addition, fuel failure scenarios are assumed to be within the scope of severe accidents.

The axial burnup distribution is assumed to be uniform. In general, the uniform axial distribution is more conservative in the shielding evaluation. The shape change due to the fuel damage plays a very important role in the shielding evaluation, and thus a large change in the uncertainty is expected.

For the fuel failure scenarios, the following two cases which are unlikely to occur are considered as shown in Fig. 2.

○ Loss of multiple fuel rods (5%, 10%, 20%)
○ Loss of rod cladding



(Loss of fuel rods) (Loss of cladding)
Fig. 2. MAVRIC modeling of fuel failures.

These scenarios investigate the effect of loss of rods and claddings by considering the reduction in source terms and fuel region density as well which would tend to reduce or increase dose rates. To model these scenarios, various numbers of rods and claddings were simply assumed to be absent from the duel assembly model.

Table 2 and 3 summarize the dose rates according to the conditions of the loss of fuel rods and rod claddings. For every case, the results of the dose rate evaluations at 1m from the accessible surface of the cask were also added.

Table 2. Surface Dose Rates for Loss of Rods

		Neutron(mSv/h)	Gamma(mSv/h)
5% loss	Side	1.15541E-02	1.22902E-02
	Bottom	3.64869E-01	2.81504E-02
	Top	1.47807E-05	1.95238E-03
	Side(1m)	3.87871E-03	2.12198E-04
10% loss	Side	1.16270E-02	1.31744E-03
	Bottom	3.33898E-01	3.17590E-02
	Top	1.36663E-05	2.89536E-03
	Side(1m)	3.96452E-03	4.80720E-04
20% loss	Side	1.21776E-02	1.28801E-02
	Bottom	3.31592E-01	2.89582E-02
	Top	1.37205E-05	3.69868E-03
	Side (1m)	1.45155E-03	2.28862E-04

Table 3. Surface Dose Rates for Loss of Cladding

	Neutron (mSv/h)	Gamma (mSv/h)
Side	1.14616E-02	1.33337E-02
Bottom	3.60088E-01	3.84408E-02
Top	1.42856E-05	2.21159E-03
Side(1m)	3.69469E-03	2.56909E-04

The absent of fuel rods and claddings reduces the external dose rates. The total dose rates are the sum of neutron and gamma dose rates. The results show that most calculated dose rates meet the criteria; 2mSv/hr for cask surface of normal condition and 10mSv/hr for 1m from the surface of accident condition. This means that the fuel failures like the loss of rods and rod cladding would not affect the shielding criteria of the SAR.

3. Conclusion

In this study, the shielding evaluations of KN-18 cask for spent fuel transportation were carried out for normal conditions and various fuel failure scenarios. It is expected that the shielding evaluations using MAVRIC for normal and these fuel failure scenarios can be used for the development of a new cask for future transportation or storage purposes. Moreover it is necessary to consider the detailed specifications of the transport cask to evaluate sufficiently reliable results.

REFERENCES

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[5] “KN-18 Spent Nuclear Fuel Transport Cask Safety Analysis Report (Rev.01),” KHNP, November 2013.