PACKAGE DESIGN FOR SPENT FUEL USED FOR REACTIVITY MEASUREMENT

Hee Young Kang, Jong Oh Kim, Young Gil Lee
Hong Ryul Cha, Ho Dong Kim and Jong Sook Hong

Korea Atomic Energy Research Institute
150 Dukjin-dong, Yusong-gu, Taejon 305-353, Korea

SUMMARY

The multipurpose RM-1 package has been developed to transport spent fuel rod-cuts and to measure the fissile contents and radioactive poisons of spent fuel rods. The package has been designed to handle a small amount of decay heat and to shield intensive neutron and gamma-rays. Thermal analysis of the RM-1 package was carried out under normal heat conditions. The shielding analysis was done to minimize the RM-1 package weight while maintaining an overall shielding effectiveness.

The maximum temperatures on the surface of the fuel rod-cuts is approximately 50 ℃. A calculation of gamma-ray and neutron dose rates on the package surface and 2 m from the surface has been carried out. It is revealed that the total dose rates under normal conditions meet the design limits specified by the domestic and IAEA package standards[IAEA, 1985].

INTRODUCTION

The RM-1 package has been designed to transport the PWR spent fuel rod-cuts and to measure the fissile contents and radioactive poisons of spent fuel rods. The package is designed to measure neutrons from spent fuels by neutron counter. The reactivity measurement method to determine the contents and characteristics of spent fuel material has been studied. It is a new technology to measure the reactivity and fissile content of highly radioactive materials by using a NDA neutron counting method. The package should be designed to protect from neutron and gamma-rays. The external radiation level of the package should be limited to meet the standards specified by the domestic and IAEA transport regulations. The temperature of the fuel rods and shield layers should be determined under certain conditions. The inner cavity containing the fuel rods is filled with air as a natural cooling.

The radiation source term of the spent fuel is defined for the multigroup shielding analysis. For the typical PWR in equilibrium, fresh fuel at 3.2% U-235 enrichment is considered. The ORIGEN2 code used to calculate the buildup of the fission products, activation products and actinides during the irradiation. The neutron sources are from either (α, n) and spontaneous fission of heavy metals. The (α, n) neutron source is almost entirely due to the Pu-238, Cm-242 and Cm-244. Likewise the spontaneous fission neutron source is almost entirely due to Cm-242, Cm-244 and Cm-246.

Thermal analyses are used by the HEATING7.2 code[Childes, 1993] for decay heat of spent fuel rods. The decay heat is generated from spent fuel rods and is dependent on the burnup and cooling time. The heat transfer in dry fuel rods consists of radiation, conduction and natural convection. The package body is a multi-layer that contains the polyethylene(poly), aluminium, lead, stainless steel material layer. The shielding analyses for package are performed by the MCNP code for neutrons and the QAD-CG code for gamma-ray.

ANALYSIS FOR PACKAGE DESIGN

The RM-1 package for 8 fuel rod-cuts has been designed for two kinds of structural material. One is the lead for gamma-rays. The other is the high density polyethylene materials for neutron sources. These major materials used in the package design have to be selected and arranged to minimize the package weight and to measure the neutrons by a neutron counter. Fig. 1 shows the conceptually designed model of the RM-1 package for thermal and shielding analysis. The size of the package is 90 cm in height and 55 cm in diameter.

Thermal analysis is carried out using the HEATING7.2 code. Decay heat from the irradiated PWR fuel rod-cuts with 10 cm lengths is considered as a heat source. The decay heat rate from spent fuel is calculated by the ORIGEN2 code. The decay heat for 8 fuel rod-cuts based on 8 yrs cooling time is very low around 1.2 w. The inner cavity of the package is considered to be filled with air. A simplified 2-D model for thermal analysis is used. Temperatures in the fuel rod will be evaluated to maintain the thermal integrity of the package.

To select the optimal shield layers which minimize the package weight, a number of shielding calculations are performed. The QAD-CG and MCNP code are used to perform the gamma-ray and neutron calculations. In order to determine the proper lead shield thickness, shielding calculations are carried out.

RESULTS AND DISCUSSIONS

The temperatures for the RM-1 package were obtained by thermal analysis. It appears that the maximum temperature of the fuel rod-cuts is approximately 50 ℃, as shown in Fig. 2. The temperature difference between the fuel rod surface and package surface was 10℃. Temperatures of the fuel rod surface is low enough to maintain the thermal integrity of the package under normal condition.

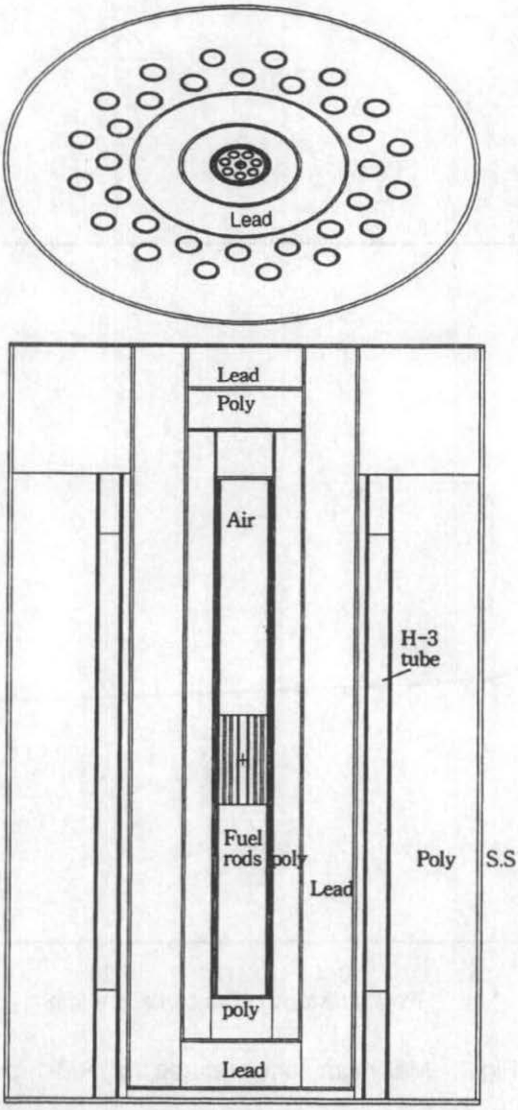

Fig. 1 MCNP Model for reactivity measurement of spent fuel

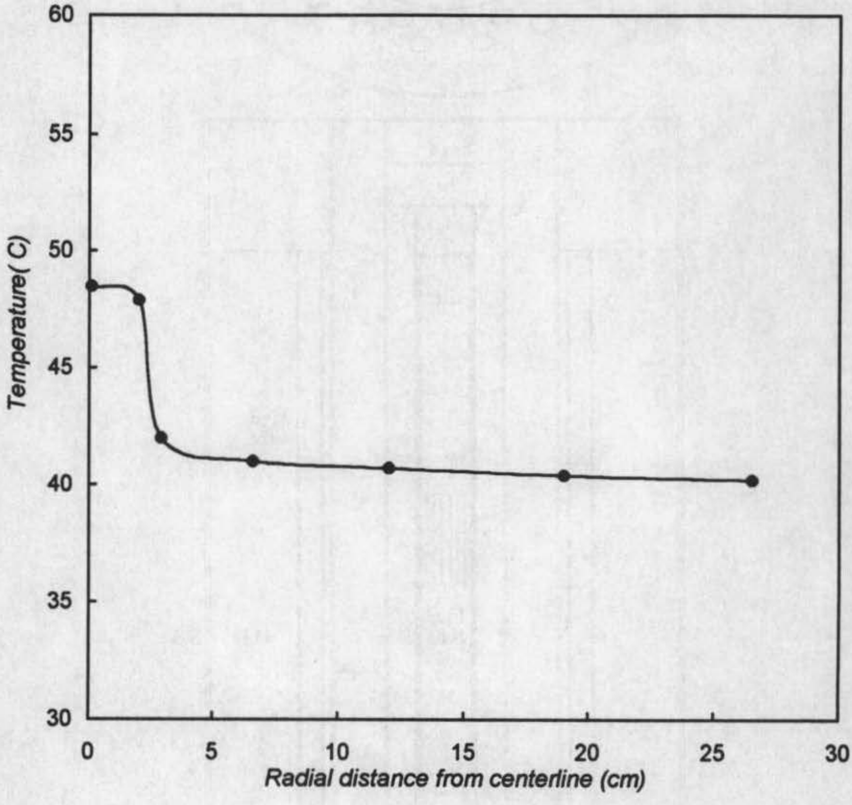

Fig. 2 Maximum temperatures for RM-1 package

In compliance with the regulations specified in the packaging standards of radioactive materials, the pertinent radiation levels under normal conditions are 200 mRem/hr at any point on the external surface. The dose rates calculated by MCNP and QAD-CG code under normal transport conditions were obtained using the package model. The dose rates profile versus the lead thickness was given in Fig. 3 to determine the proper lead thickness. A summary of the maximum dose rates for the RM-1 package is tabulated in Table 1. The total dose rates of the package were 184.7 mRem/hr at the external side surface and 2.8 mRem/hr at 2 m from the surface. These values are less than those of the design limit specified by packaging standards.

CONCLUSION

Thermal and shielding analyses were performed to design the RM-1 package under normal conditions. All the calculated results do not exceed the limits specified in the standards. It is revealed that the RM-1 package keeps its thermal integrity and shield effectiveness from the spent PWR rod-cuts. This study provides also a basis for the further development of a new package design.

REFERENCES

IAEA, "IAEA Regulations for the safe transport of Radioactive Materials," IAEA Safety Series No.6, 1985

A. G. Croff, "A User's Manual for the ORIGEN2 Computer Code," ORNL/TM-7175, 1980

K. W. Childs, "HEATING 7.2 User's Manual," ORNL/TM-12262(1993)

V. R. Cain, "QAD-CG, The Combinational Geometry Version of The QAD-P5A Point Kernel Shielding Code," Bechtel Computer Code-NE007(1997)

J. F. Briesmeister, Ed., "MCNP- A General Monte Carlo N-Particle Transport Code Version 4A," LA-12625-M(1993)

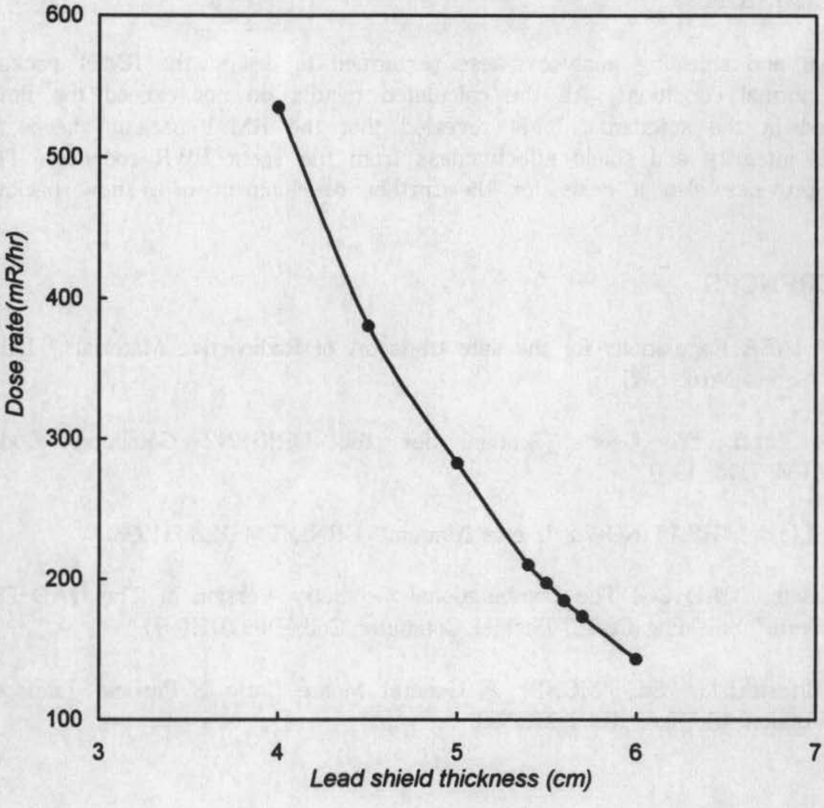

Fig. 3 Maximum dose rates on the surface for RM-1 package versus lead thickness

Table 1 Summary of the maximum dose rates for RM-1 package

Detector location	Dose rate (mRem/hr)		Remark
	QAD-CG	MCNP-4B	
1. Gamma-ray			
Side surface	184.4	151.0	
1 m from surface	8.9	6.2	
2 m from surface	2.8	1.4	
Top surface	35.7		
2 m from surface	1.6		
Bottom surface	68.2		
2 m from surface	1.8		
2. Neutron			
Side surface		0.3	
1 m from surface		0.011	
2 m from surface		0.003	
Top surface		0.11	
Bottom surface		0.37	
Total dose rate			*Design limit
Side surface	184.7		200.0
1 m	8.91		
2 m	2.803		10.0
Top surface	35.81		200.0
2 m	1.6		10.0
Bottom surface	68.57		200.0
2 m	1.8		10.0