Verification of MCNP simulation according to various widths of shielding using by CZT semiconductor detectors

JOO SORIN[a], PARK GYEONGSEOK[a], KIM HYEONDAE[a],
KANG HWA YOON[b], LEE BYOUNG-IL[b], KIM JEONG-IN[b], KANG SEO KON[b*]
[a] Energy And Environment Systems Co., Ltd(ENESYS)
[b] Korea Hydro & Nuclear Power Co., Ltd(KHNP), Radiation Health Research Institute(RHRI)
[*]*Corresponding author seogoni@khnp.co.kr*

1. Introduction

There are several methods to measure source terms at a Nuclear Power Plant (NPP), however it is not easy to use due to difficulty of measure and analysis considering on-site conditions. Monitoring source terms is necessary at a NPP for aggressive ALARA activities and evaluation of exposure of workers, For that reason, EDF (Electricite de France) has been conducting the "Source Term Reduction" Program since 2003[1]-[2], [4]-[7]. The program has EMECC (Ensemble de Mesure et d'Etude de la Contamination des Circuits)[3][6] and CZT (Cadmium Zinc Telluride)[6][7] campaign which are tools to analyze nuclides at a NPP. AEP (American Electric Power) also introduced another type CZT detector to perform source term monitoring and they had announced the results through the ISOE (Information System on Occupational Exposure)[8].

Energy And Environment Systems Co., Ltd(ENESYS) and Korea Hydro & Nuclear Power Co., Ltd(KHNP), Radiation Health Research Institute(RHRI) are developing the CZT Monitoring System to measure source terms, such as CRUDs(Chalk River Unidentified Deposits) in the Primary Coolant System using by CZT semiconductor. A CZT semiconductor detector is good to monitor source terms at a NPP in that it is possible to make a portable type because it does not need any cooling system at room temperature and it has good energy resolution. The CZT Monitoring System can measure activity of CRUDs with analysis of detected gamma spectrum but it is must considered detector efficiency, spatial distribution of radiation source, geometry of materials between detector and radiation source. Because they affect gamma spectrum shape.

This study is conducted to know geometric effect of shielding by comparing counting rate between MCNPX simulation and experiment results according to shielding.

2. Methods and Results

2.1 Methods

We are developing the CZT Monitoring System (see Fig 1. Left) of use 3 type CZT semiconductor detectors, CZT1500, CZT500 and SDP313 (Ritec co., Ltd, Riga, Latvia) and Multi-Channel Analyzer, MCA527L (GBS Elektronik GmbH, Radeberg, Germany). The geometric effect test was conducted at the Gamma Irradiation Facility (KHNP, CRI (Central Research Institute), see Fig 1 Right), which has various amount of Cs-137 source.

Figure 1 **The CZT Monitoring System (Left) and Experiment (Right).**

For Monte Carlo(MC) Simulation, we use MCNPX. The source is Cs-137 and it is in cylindrical stainless steel case, diameter 0.7 cm. Distance from center of source to surface CZT Crystal is 50 cm and 100 cm. the CZT crystal size is 17mm(W)*17mm(H)*5mm(D) (CZT1500), 10mm(W)*10mm(H)*5mm(D)(CZT500), 2mm(W)*2mm(H)*4mm(D)(SDP313). The shielding is iron and it width is 0 mm(no shielding), 6 mm, 12 mm, 18mm(see Fig 2 Configuration of MCNPX and Table 2)

Distance (d)	Shielding Width (W)	Detectors
50cm	0 mm	CZT1500 CZT500 SDP313
	6 mm	
	12 mm	
	18 mm	
100cm	0 mm	CZT1500 CZT500 SDP313
	6 mm	
	12 mm	
	18 mm	

Table **1 Condition of MCNPX and Experiment**

D(cm)	W_i	CZT1500			CZT500			SDP313		
		MCNPX	Measure	$\frac{W^{MCNPX}}{W^{Measure}}$	MCNPX	Measure	$\frac{W^{MCNPX}}{W^{Measure}}$	MCNPX	Measure	$\frac{W^{MCNPX}}{W^{Measure}}$
50	W_6	0.712	0.718	0.992	0.712	0.69	1.032	0.712	0.702	1.014
	W_{12}	0.507	0.530	0.957	0.507	0.505	1.004	0.507	0.505	1.004
	W_{18}	0.361	0.373	0.968	0.361	0.361	1	0.361	0.35	1.031
100	W_6	0.712	0.724	0.983	0.712	0.67	1.063	0.712	0.707	1.008
	W_{12}	0.507	0.518	0.979	0.507	0.501	1.013	0.507	0.538	0.942
	W_{18}	0.361	0.346	1.043	0.361	0.332	1.089	0.361	0.368	0.981

Table 2. Geometric effect of shielding at 662 keV(Cs-137). Where $W_i = \frac{\text{Count of } i}{\text{Count of no shielding}}$, $i = 6, 12, 18$(width of shielding)

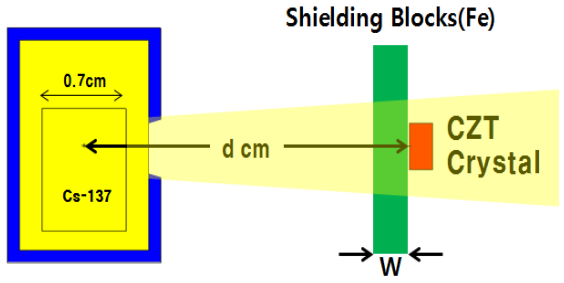

Figure 2 **Configuration of MCNPX**

2.2 Results

To calculate activity of source, we must consider detector efficiency, spatial distribution of source, information of material such as density, components, shape. We compare geometric effect of MCNPX result and Measurement to confirm MC simulation. The shielding effect is given ratio $W_i = \frac{\text{Count of } i}{\text{Count of no shielding}}$, $i = 6, 12, 18$(width of shielding) at 662 keV(Cs-137). To check MC result, we calculate the ratio of W^{MCNPX} to $W^{Measure}$ $\frac{W^{MCNPX}}{W^{Measure}}$. Almost all results are less than $\pm 5\%$. As we expected, both results are independent from distance(or dose rate) and detector size (see Table 2).

3. Conclusions

This study conducted to calculate activity of source terms such as CRUD in pipe or steam generator at a NPP with in-vivo method. To known how it is in pipe of primary coolant system, as we mentioned, three factors are very important. We checked one of them, geometric effect, of use MC simulation and Measurement. The shielding effect result between MC and Measurement are almost all same with $\pm 5\%$ error. As we expect the results are independent from dose rate (or distance) and a kind of detector size.

REFERENCES

[1] L. Guinard et al., 2008, Review of the evolution of international collective radiation exposure and associated good practices, with special focus on Source Term Reduction strategies for EDF PWRs, ISOE European ALARA Symposium, Turku (Finland)
[2] G. Ranchoux et al., 2009, Source Term Reduction Strategies for EDF PWRs, ISOE International ALARA Symposium, Vienna (Austria)
[3] R. Eimecke et al. 1988, Ensemble de Mesures et d'Etudes de la Contamination des Circuits, International Conference on Radiation Shielding, Bournemouth (UK)
[4] A. Rocher et al., 2009, New CZT measurement device – Comparison with EMECC measurements in EDF PWRs, ISOE European ALARA Symposium, Vienna (Austria).
[5] Yves GARCIER, 2008, Radiation protection challenges at EDF, ISOE(International Symposium on Occupational Exposure), Tsuruga (Japan)
[6] A. Rocher and al., 2009, New CZT measurement device – Comparison with EMECC measurements in EDF PWRs, ISOE(International Symposium on Occupational Exposure), Vienna (Austria)
[7] J. Bonnefon, et al., 2012, CZT technology applicaion at EDF, ISOE(International Symposium on Occupational Exposure), Prague(Czech Republic)
[8] David W. Miller and Zhong He, 2012, Field Application of CZT Detector for Evaluation of Radiation Source Term, 2012 Asian ISOE ALARA Symposium, Tokyo(Japan)