Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 7-8, 2015

Effect of Fuel Structure on Performance of Unified Spent fuel Attribute Tester

Kihyun Kim[a*], Byung Marn Kho[a], Seong Youn Jo[a], Siwan Noh[b]
[a]*Korea Institute of Nuclear Nonproliferation and Control, 1534 Yusungdae-ro, Yusung-gu, Daejeon 305-348, Korea*
[b]*Department of Nuclear Engr., Hanyang Univ., 222 Wangsimni-ro, Seongdong-gu, Seoul 133-791, Korea*
[*]*Corresponding author: khkim@kinac.re.kr*

1. Introduction

The Unified Spent fuel Attribute Tester (USAT) has been developed to enhance the effectiveness and efficiency of national inspection about accounting and control of nuclear material since 2011. USAT is a verification device for the spent fuel assemblies and non fuel items in the LWR spent fuel pond. USAT started from the concept of combinations of two devices. One is the Spent Fuel Attribute Tester(SFAT) for spent fuel assembly verification. The other is the IRradiated fuel Attribute Tester(IRAT) for non fuel item verification. Both of them have the same theoretical concept in respect of using a gamma spectroscopy, which can analyze the specific spectrum of the gamma ray from the target. The conceptual design of USAT was prepared in 2011 using Monte Carlo N-Particle(MCNP) modeling and measurement simulation and design data of SAFT and IRAT. From the following year, the prototype USAT was manufactured and modified through the in-situ test. Currently, the structural difference of top parts of fuel assembly between Westinghouse(WH) type spent fuel and Korean-Standard(KSNP) type fuel has been recognized with serious concern because of malfunction id6entified at in-situ test about KSNP type fuel.

In this study, the modeling of the two different types of fuel assemblies and USAT measurement simulation based on the modeling results was conducted by using MCNP code.

2. Methods and Results

MCNP code was used to prepare the spent fuel assembly modeling and USAT measurement simulation. The source term of spent fuel assembly was conducted by ORIGEN code calculation. The code analysis work was delegated by Hanyang Univ. upon request from KINAC. The USAT device includes preamplifier built in CZT detector, tungsten shielding assembly, cable, multi channel analyzer, and commercial analysis software.

2.1 In-situ USAT function test

USAT function that verifies the distinction of Cs-137 gamma peak of radiations from spent fuel was tested at Kori, Hanbit and Hanul nuclear power plants. Fig. 1 shows that the test at Kori-3 unit which uses WH type fuel was successful. However, other tests were not able to distinguish the 662keV Cs-137 gamma peak from the spectrum. According to the test results, the structural difference of top parts of the fuel assembly may affect the gamma absorption rate.

Fig. 1. Test result of WH type spent fuel assembly

2.2 Modeling of KSNP spent fuel assembly top parts

The top plate has two kinds of thickness because of the protruded part along with the radial direction on the flange of guide tube. The support pillar and 4 hold-down springs were assembled on the top plate. The center pillar and hold down springs on the plate were neglected from the modeling because the end surface of air pipe could not be located on those 5 positions. Single fuel rod was considered as a universe because the size of guide tubes was different from the size of fuel rod. Fig. 2 illustrates the modeling of top plate of KSNP type fuel assembly.

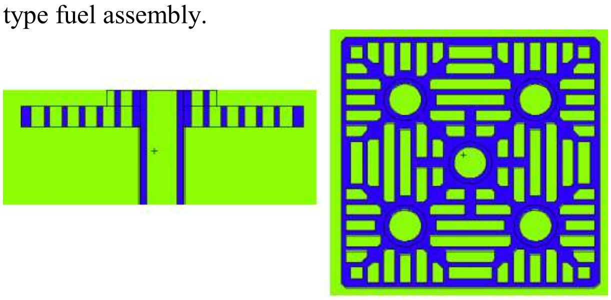

Fig. 2. Modeling of top plate of KSNP type fuel assembly

2.3 Modeling of WH spent fuel assembly top parts

The 2.4 cm thickness of top plate has 4 hold-down springs on the plate and 25 holes for guide tubes which connect to the bottom of the assemblies. The hold-down springs were neglected from the modeling. The oval shaped holes which let the water flow were considered polygonal shape in modeling. Fuel assembly has 25 guide tubes and 264 fuel rods including poison rods. Repeated structure method was deployed for modeling of guide tubes, poison rods, and fuel rods respectively. The modeling inside of fuel rod consists of top end plug, bottom end plug, plenum with spring, gab, cladding, and pellet. Partial or whole modeling of the fuel rod was applied upon purposes.

2.4 Measurement simulation

ORIGEN-ARP code was used to acquire the distribution of gamma energy emitted from the spent fuel assembly. Every conditions for the measurement simulation, the uranium oxide fuel, 4.5 % of initial enrichment of U-235, 50,000 MWD/MTU of burn-up, 41.67 MW/MTU of linear power density, three times burned, 50 days of outage period, and 15 years of cooling time, was identical except for the fuel rods array, one was 17x17 and the other was 16x16, and described on the input text. The difference of source term between two types of spent fuels was negligible according to the calculation. The radiation emission was assumed that the angle is within 3 degree and the direction is only upward. It was also assumed that the radiation generated from fuel rods resided in the surface of air pipe end tip is able to come to the CZT detector. The energy of radiation was limited over 0.1 MeV.

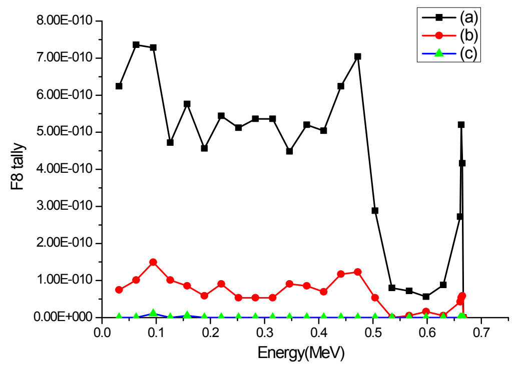

Fig. 3. F8 tally result according to the source location

The degree of contribution to the tally result as the location of source and air pipe was analyzed based on the fuel modeling. The source term out of cross section of air pipe was neglected. According to the simulation results, the counts of radiation obliquely entered into the CZT detector were 40. It is negligible comparing to the 2.1 billion source counts. The radiation entered into the detector was dramatically increased when the source was located inside of the cross section of air pipe.

According to the simulation result, the relative error of F8 tally was below 10%. The absorption of radiation passing through air pipe and collimator was hardly possible because the relative counts of obliquely entered radiations from neighboring fuel rods were less than nano-order.

3. Conclusions

The linearity between CZT detector and source was one of the crucial considerations. The structural difference between WH type and KSNP type fuel assemblies possibly produce the oblique of radiation path and it may affect the counts of radiations from spent fuel passing through 1 m length air pipe and tungsten collimator. In order to optimize the design of USAT, not only maintaining alignment between fuel zone and radiation collimation zone but also positioning air pipe on top plate of fuel assembly should be re-determined to maximize the entering radiation counts.

REFERENCES

[1] Pelowitz DB. MCNPX user's manual, Version 2.6.0. LA-CP-07-1473. 2008.

[2] Glenn F. Knoll, Radiation Detection and Measurement, Willey, 2003

[3] Ham, Y. S., et al. "In-Situ Safeguards Verification of Low Burn-up Pressurized Water Reactor Spent Fuel Assemblies." 8th International Conference on Facilities Operations-Safeguards Interface. 2008.