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Analysis on Fission Product Inventory with the Consideration of Axial Power Distribution

Hae Sun Jeong* and Kwang Soon Ha
Korea Atomic Energy Research Institute, Daejeon, Korea
**Corresponding Author: haesunin@kaeri.re.kr*

1. Introduction

The fission product inventory in a core and possible release into the containment should be evaluated to obtain a construction permit or operating license of a nuclear reactor. This inventory evaluation should be based on the regulatory guides (e.g., TID-14844 [1] and NUREG-1465 [2]) and determined using the appropriate depletion codes such as the ORIGEN 2.0 or the ORIGEN-ARP. Most of the regulatory guides have proposed taking the assumptions that can lead to more severe results than those that are realistically expected. In the case of a Loss of Coolant Accident (LOCA), the fission product inventory in the core is generally estimated based on the average burnup of a fuel assembly, regardless of the accident occurrence time and degree of fuel meltdown.

However, the actual fuel burnup is non-uniform along the core height with axial power distributions, and fluctuated with fuel cycles as shown in **Figure 1** [3]. In this study, the variation of fission product inventory in the core is analyzed by considering the degree of fuel meltdown at the Beginning of Cycle (BOC), the Middle of Cycle (MOC), and the End of Cycle (EOC). For this study, the ORIGEN-ARP in the SCALE 6.1 package code system [4] and the axial power distributions of the Ulchin (Hanul) unit 6 were used for the depletion calculation.

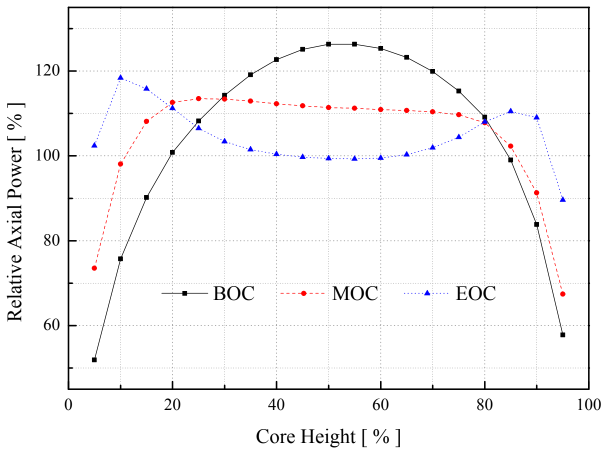

Fig. 1 Relative Axial Power Distributions along the Core Height of Ulchin (Hanul) Unit 6 at BOC, MOC, and EOC

2. Materials and Methods

To evaluate the fission product inventory released during a LOCA event, one fuel assembly was assumed to be melted. The fuel assembly of Ulchin unit 6 consists of a 16×16 array of 236 fuel rods, with enrichment of 4.51 wt% for 184 rods and 4.00 wt% for 52 rods, and 5 guide tubes, and is closed at the top and bottom by end fittings. The burnup cross section library of this assembly model was generated using the TRITON module of the SCALE6.1 code system (see **Figure 2**). A series of depletion calculations were performed using the ORIGEN-ARP with the generated burnup cross section library.

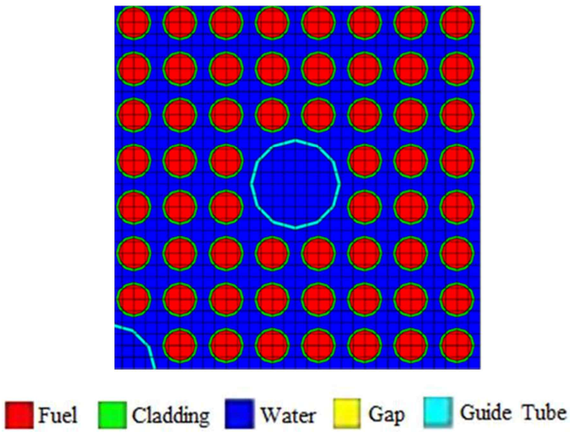

Fig. 2 A 1/4 Fuel Assembly Model of TRITON Calculation

Two types of calculations were performed in this study as follows; CASE (1) - a meltdown applied with the conservative assumption provided by the regulatory guides and CASE (2) - various cases of meltdown considering the accident occurrence points. The fuel meltdown by the LOCA event proceeds from the top to the bottom of the fuel, as the coolant level decreases. The fission products released on the meltdown procedure are, therefore, influenced by the burnup varied with the non-uniform axial power of the fuel. The nuclear design report [3] for this model provides the relative axial power at various points of the fuel height and the average burnup classified by fuel assembly type at each cycle. The relative axial burnup can be obtained by applying the ratio of the relative axial power to the average burnup. As the meltdown from the top of the fuel follows the relative axial burnup along the fuel height, the burnup values from the degree of meltdown were determined to take an average the burnups from the top of the fuel down to the meltdown point. **Table 1** presents the average burnup of the cycle applied to CASE (1) and those of CASE (2) which set considering the degree of fuel meltdown at BOC, MOC, and EOC.

Table 1 Summary of Fuel Burnup Condition [MWD/MTU]

			BOC	MOC	EOC
CASE (1)	Average Burnup		17,413	27,309	37,154
CASE (2)	Meltdown [%]	10	12,328	21,670	36,894
		30	16,975	26,804	38,603
		50	18,911	28,213	37,968
		70	19,493	28,938	37,868
		90	18,788	29,066	38,781

3. Results and Discussions

For the case of EOC on CASE (1), **Figure 3** shows the activity change of total and major fission products released into the containment as a function of the effective full power day. Major fission products include krypton, xenon, iodine, and other significant nuclides. The total activity is gradually increased as a function of the irradiation time in the core, while the other is exponentially decreased as most of them have very short half-lives.

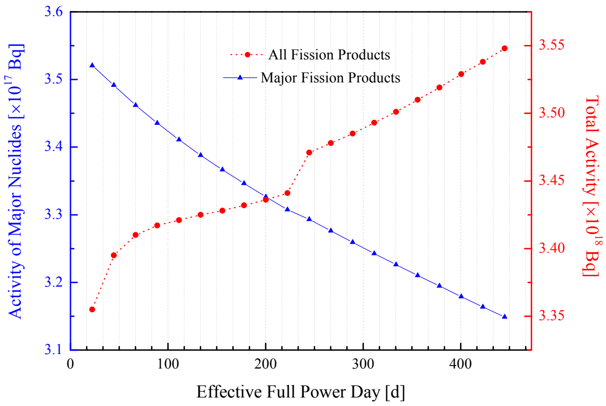

Fig. 3. Activity Change along the Effective Full Power Day (100% Meltdown with Average Burnup)

Considering the major fission products only, the results of CASE (2) were compared with those of CASE (1) at each cycle. **Figure 4** shows the percentage change between two cases which CASE (1) is subtracted by CASE (2) and then divided by CASE (1). For a degree of meltdown below approximately 30%, the calculation results applied with the conservative assumption represent higher activity than those considered with the axial burnup distributions. However, the calculation with the assumptions recommended by the regulatory guidelines does not produce results more conservative than for over about 30% meltdown. The difference in absolute activity quantity for the major fission products between CASE (1) and CASE (2) is tabulated in **Table 2**. From these results, it was found that the fission products released into the containment should be evaluated regarding the accident occurrence time and the degree of fuel meltdown.

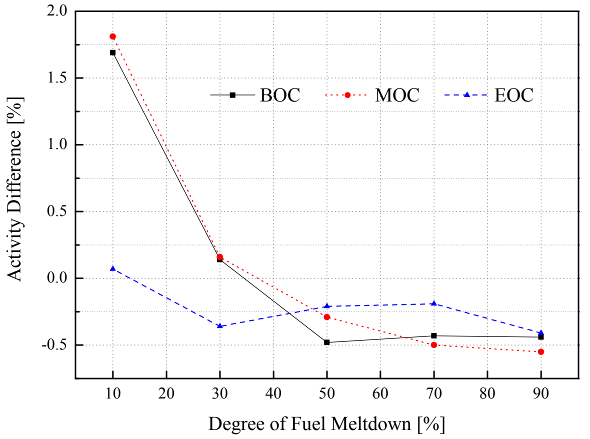

Fig. 4 Activity Difference of Major Fission Products between CASE (1) and CASE (2)

Table 2 Difference of Absolute Quantity for Major Fission Products [Bq]

Meltdown [%]	BOC	MOC	EOC
10	5.60E+14	5.83E+14	2.28E+13
30	1.37E+14	1.52E+14	-3.42E+14
50	-7.96E+14	-4.61E+14	-3.35E+14
70	-9.89E+14	-1.13E+15	-4.15E+14
90	-1.33E+15	-1.59E+15	-1.16E+15

3. Conclusions

The variation of fission product inventory in the core was analyzed based upon the degree of fuel meltdown, which reflects the axial power distribution of the fuel at BOC, MOC, and EOC. When considering some major fission products released into the containment, the calculation with the assumptions recommended by regulatory guides does not lead to results more conservative than for over approximately a 30% meltdown. Therefore, the fission products released into the containment need to be evaluated with a consideration of the accident occurrence point and the degree of fuel meltdown.

Acknowledgements

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