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Radiation Activity of Safety-Related Fission Products of DUPIC Fuel

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INTRODUCTION

It is important to estimate the radiation activity of the nuclear fuel which is a source term of the loss of coolant accident. The purpose of this study is to identify the most important parameters of the source term calculation based on three fuel types: typical natural uranium CANDU fuel, slightly enriched uranium and DUPIC fuel. The characteristics of the radiation source term were analyzed through sensitivity calculations of the linear power, fuel burnup, and the power shape.

RESULTS

For the analysis of the radiation source term, the fission products gap inventory and total inventory were calculated based on ANS5.4 fission gas release model employed in the ELESTRES performance evaluation code. Fractional release of isotopes with half lives greater than 1 year was calculated. The total inventory estimated by the ELESTRES code was then compared to the results obtained by the ORIGEN-2 code as shown in Table 1. It can be seen that the radiation activity prediction by the ELESTRES code is similar to that by the ORIGEN-2 code except for a few isotopes, which can be attributed to the difference of the detailed burnup chains implemented in these two codes.

The radiation activity of the DUPIC fuel was also calculated by the ORIGEN-2 code and compared to the results of slightly enriched uranium oxide fuel. As shown in Table 2, both fuels show similar results as far as the total radiation inventory is concerned. The result indicates that the total fission products inventory is strongly dependent on the linear power and fuel burnup.

In order to get the fission products release to the fuel gap, the ELESTRES code should be used. In the ELESTRES code, the material properties such as thermal conductivity and thermal expansion of the DUPIC fuel were already included on the experimental data. The results of fission products gap inventory are summarized in Table 3 and Table 4. It can be seen that the gap inventory increases as the fuel burnup increases while the total inventory of major isotopes is saturated at the early burnup. It was also found that the gap inventory increased at a higher linear power condition for natural UO_2 fuel due to the enhanced diffusion of fission gas elements at higher centerline temperature. For the DUPIC fuel, the gap inventory was higher due to the higher centerline temperature caused by the lower thermal conductivity.

CONCLUSIONS

Fuel performance analysis was carried out to investigate the most important parameters that determine the magnitude of the fission products source term. It can be concluded that the linear power determines the source term regardless of the initial fission products inventory and fuel burnup. The gap inventory is mostly determined by the fission gas release associated with higher centerline temperature.

Table 1. Comparison of Total Inventory Activity from the Calculation Results of ELESTRES Code and ORIGEN-2 Code for Natural UO_2 Fuel. (unit : Ci/ton)

Burnup	150MWh/kgU		
Isotope	ELESTRES	ORIGEN-2	ratio
I-131	1.08.E+06	1.44E+06	0.75
I-132	1.66.E+06	2.09E+06	0.79
I-133	2.60.E+06	2.88E+06	0.90
I-135	2.44.E+06	2.67E+06	0.91
I-137	1.29.E+06	1.13E+06	1.14
KR-85M	4.92.E+05	3.91E+05	1.26
KR-87	9.56.E+05	7.49E+05	1.28
KR-88	1.35.E+06	1.06E+06	1.28
KR-89	1.75.E+06	1.29E+06	1.36
SR-89	1.47.E+06	1.08E+06	1.36
TE-131	9.87.E+05	1.26E+06	0.78
TE-132	1.65.E+06	2.06E+06	0.80
TE-133M	1.13.E+06	1.05E+06	1.07
TE-133	1.51.E+06	1.61E+06	0.94
TE-135	1.31.E+06	1.09E+06	1.20
XE-133	2.40.E+06	2.75E+06	0.87
XE-135M	4.18.E+05	5.98E+05	0.70
XE-137	2.37.E+06	2.49E+06	0.95
XE-138	2.39.E+06	2.29E+06	1.04

Table 2. Comparison of Total Inventory Activity between DUPIC fuel and SEU fuel(1.638wt%) from the Calculation Results of ORIGEN-2 Code. (unit : Ci/ton)

Burnup	150MWh/kgU		
Isotope	DUPIC	SEU	ratio
I-131	1.37.E+06	1.30E+06	1.05
I-132	1.96.E+06	1.91E+06	1.03
I-133	2.78.E+06	2.83E+06	0.98
I-135	2.60.E+06	2.63E+06	0.99
I-137	1.16.E+06	1.26E+06	0.92
KR-85M	3.54.E+05	4.55E+05	0.78
KR-87	6.81.E+05	9.01E+05	0.76
KR-88	9.56.E+05	1.27E+06	0.75
KR-89	1.17.E+06	1.59E+06	0.73
SR-89	1.09.E+06	1.51E+06	0.73
TE-131	1.19.E+06	1.15E+06	1.03
TE-132	1.93.E+06	1.88E+06	1.02
TE-133M	1.04.E+06	1.16E+06	0.90
TE-133	1.59.E+06	1.60E+06	0.99
TE-135	1.15.E+06	1.24E+06	0.92
XE-133	2.70.E+06	2.74E+06	0.99
XE-135M	5.51.E+05	5.22E+05	1.06
XE-137	2.43.E+06	2.48E+06	0.98
XE-138	2.29.E+06	2.46E+06	0.93

Table 3. Comparison of Total and Gap Inventory Activity Summation from the Calculation of ELESTRES Code for Natural UO_2 Fuel at a linear power of 44 kW/m and 55 kW/m. (unit : Ci)

Linear Power	Burnup (MWh/kgU)	50	100	150	200
44 kW/m	Total Inventory	14634.93	14883.83	15015.4	15090.11
	Gap Inventory	48.274	75.315	107.302	137.152
55 kW/m	Total Inventory	18186.02	18506.22	18682.17	18792.26
	Gap Inventory	681.067	1212.911	1783.966	2131.832

Table 3. Comparison of Total and Gap Inventory Activity Summation from the Calculation Results of ELESTRES Code for SEU(1.638%) and DUPIC Fuel at a Burnup of 150MWh/kgU. (unit : Ci)

Fuel	SEU			DUPIC Fuel		
Inventory	Total Inventory	Gap Inventory	% Release	Total Inventory	Gap Inventory	% Release
Activity Summation	13832.42	37.097	0.268189	13827.68	536.774	3.881881