# Safety-Related Performance Analysis of Dry Process Fuel by ELESTRES

Ho Jin Ryu, Chang Je Park, Hangbok Choi, and Kee Chan Song
*Korea Atomic Energy Research Institute, hjryu@kaeri.re.kr*

## 1. Introduction

A dry re-fabrication process of spent fuel was developed in order to reuse fissile elements in the spent fuels of pressurized light water reactors(LWR) without the aqueous extraction of sensitive nuclear materials[1]. The dry re-fabrication technology is called DUPIC(Direct Use of spent PWR fuel in CANDU reactors). In the OREOX process of the DUPIC fuel, spent fuel pellets separated from the claddings of spent LWR fuel are oxidized from $UO_2$ to $U_3O_8$ at 450-500°C in an oxidizing atmosphere and reduced into $UO_2$ at 650-700°C in a reducing atmosphere[2]. Using the spent fuel powder prepared from the OREOX process, fresh DUPIC fuels for CANDU reactors are fabricated after compaction and sintering processes in a shielded hot cell. Fission gas species and volatile fission products are removed during the OREOX and sintering process[3]. The DUPIC fuel has a different chemical composition due to the solid fission products and material properties vary from those of the fresh $UO_2$ fuel[4]. The DUPIC fuel also differs from the high burnup oxide fuel because it does not contain fission gas elements or volatile fission products.

Therefore, it is necessary to analyze various performance aspects due to the changed material properties such as thermal conductivity. In this study, radiation activity of the DUPIC fuel was estimated to identify the most influencing parameters on the fission gas related performance using ELESTRES code[5,6]. Total inventory and gap inventory of DUPIC fuel were compared to $UO_2$ fuel with varying burnup and linear power.

## 2. Results

The total inventory for natural $UO_2$ fuel in a CANDU reactor estimated by the ELESTRES code with varying burnup was compared to the results obtained by the ORIGEN-2 code as shown in Figure 1 and Figure 2. The radiation activity prediction for total inventory by the ELESTRES code is similar to that by the ORIGEN-2 code except for a few isotopes. The radiation activity of the DUPIC fuel was also calculated by the ORIGEN-2 and compared to the results of slightly enriched uranium oxide fuel and 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 fuel burnup regardless of the initial fission products inventory. In order to get the fission products release to the fuel gap, the ELESTRES code was used as shown in Figure 3. 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.

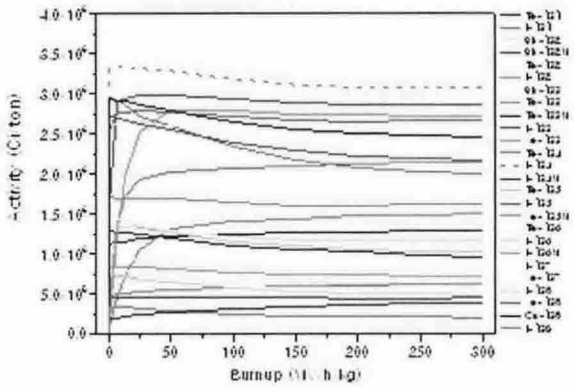


*Figure 1. Total inventory variation of natural $UO_2$ fuel calculated by ORIGEN-2.*

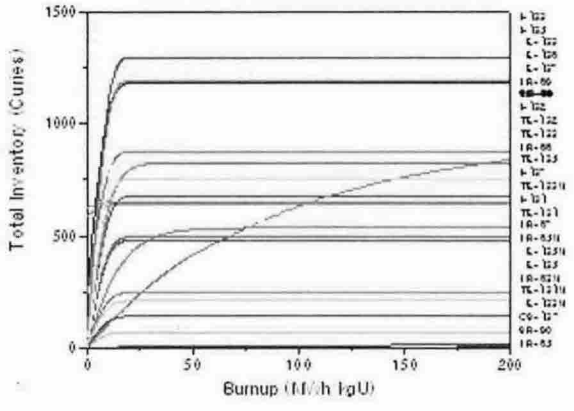


*Figure 2. Total inventory variation with burnup for natural $UO_2$ fuel calculated by ELESTRES.*

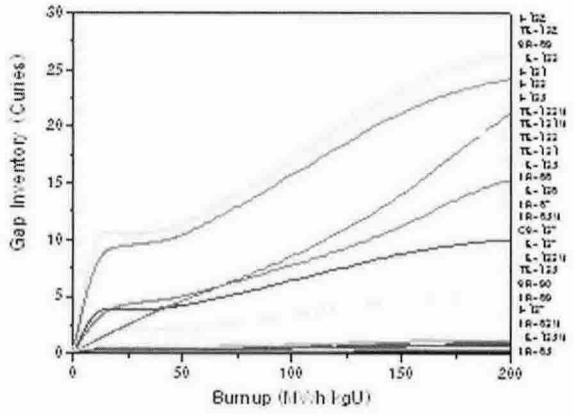


*Figure 3. Gap inventory variation with burnup for natural $UO_2$ fuel calculated by ELESTRES.*

It was also found that the gap inventory increased at a higher linear power condition for $UO_2$ fuel due to the enhanced diffusion of fission gas elements at higher centerline temperature as shown in Figure 4. Figure 5 shows the gap inventory of DUPIC fuel was higher than that of $UO_2$ fuel with the same enrichment when a nominal design power envelop was applied to each fuel.

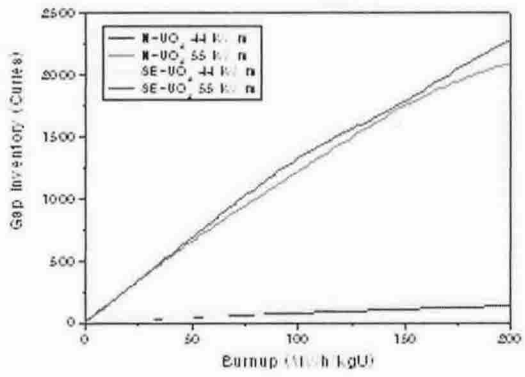


*Figure 4. Comparison of gap inventory between natural $UO_2$ and slightly enriched $UO_2$ at linear element rates of 44 kW/m and 55 kW/m.*

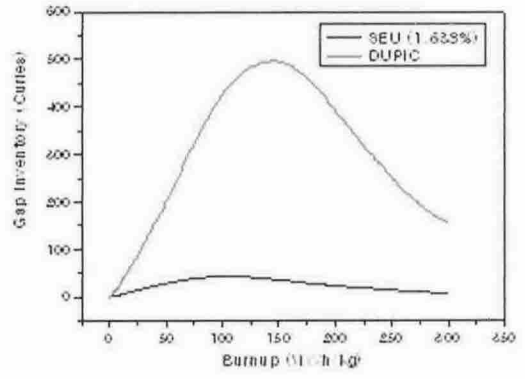


*Figure 5. Comparison of gap inventory between SEU and DUPIC fuel operated by nominal design power envelop.*

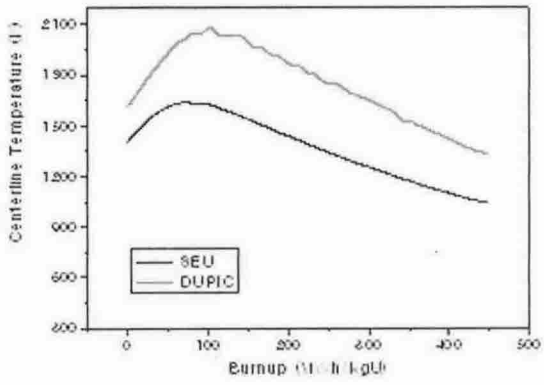


*Figure 6. Comparison of centerline temperature between SEU and DUPIC fuel operated by nominal design power envelop.*

The higher gap inventory or higher fission product release to the gap is originated from the enhanced chemical diffusion at higher centerline temperature of DUPIC fuel at the same linear power as shown in Figure 6. The higher centerline temperature is caused by the lower thermal conductivity of DUPIC fuel.

## 3. Conclusions

Material property of the DUPIC fuel were employed in the modified performance evaluation code to estimate the gap inventory of fission products. The linear power determined predominantly the amount of gap inventories regardless of the initial fission products inventory and fuel burnup. The gap inventory was mostly determined by the release of fission gas and volatile elements associated with higher centerline temperature. The thermal properties of the DUPIC fuel were evaluated as the most important parameters that determine the gap inventories.

## Acknowledgements

This study was sponsored by Ministry of Science and Technology (MOST) through the National Nuclear R&D Program.

## REFERENCES

[1] W.I. Ko, H.D. Kim, M.S. Yang, Nuclear Technology, 138 (2002) 123.
[2] K.W. Song, Y.H. Kim, B.G. Kim, J.W. Lee, H.S. Kim, M.S. Yang, H.S. Park, J. Kor. Nuc. Soc. 28 (1996) 366.
[3] H.J. Ryu, K.C. Song, G.I. Park, J.W. Lee, M.S. Yang, International IUPAC conference on the High Temperature Materials Chemistry XI, Tokyo, Japan, 19-23, May (2003).
[4] K.H. Kang, K.K. Bae, H.S. Park, K.C. Song, J.S. Moon, J. Kor. Powder. Metall. Inst., 7 (2000) 123.
[5] H.C. Suk et al. ELESTRES.M11K Program Users' Manual and Description, KAERI/TR-320/92 (1992).
[6] M. Tayal, ELESTRES Code Description, Atomic Energy of Canada Ltd. Report, AECL-9331, (1987).