Prospects of Using Reprocessed Uranium in CANDU Reactors, in the US GNEP Program

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INTRODUCTION

Current Global Nuclear Energy Partnership (GNEP) plans envision reprocessing spent fuel (SF) with view to minimizing high-level waste (HLW) repository use and recovering actinides (U, Np, Pu, Am, and Cm) for transmutation in reactors as fuel and targets. The reprocessed uranium (RU), however, is to be disposed of. This paper presents a limited-scope analysis of possible reuse of RU in CANDU (Canada Deuterium Uranium) Reactors, within the context of the US GNEP program. Other papers on this topic submitted to this conference discuss the possibility of RU reuse in light-water reactors (LWRs) (with enrichment) and offer an independent economic analysis of RU reuse [1-4].

A representative RU uranium "vector", from reprocessed spent LWR fuel, comprises 98.538 wt% ^{238}U, 0.46 wt% ^{236}U, 0.986 wt% ^{235}U, and 0.006 wt% ^{234}U. After multiple recyclings, the concentration of ^{234}U can approach 0.02 wt%. The presence of ^{234}U and ^{236}U in RU reduces the reactivity and fuel lifetime (exit burnup), which is particularly an issue in LWRs [5].

DESCRIPTION OF THE ACTUAL WORK

Representative CANDU usage of RU in CANFLEX [6] fuel assemblies (43 fuel pins) was assessed with respect to the available reactivity and the expected fuel discharge burnup levels. Cases were run with the WIMS [7-10] code for uniformly-fueled RU-derived fuel pins, with a constant target value of integral k_{inf}.

The presence of ^{236}U in the RU-derived fuel shortens the fuel lifetime. One means of compensating this effect is to enrich the fuel to a higher ^{235}U assay. Reactor neutronics calculations were performed to determine the additional ^{235}U required to offset the initial ^{236}U content in the fuel. Furthermore, the effects of the ^{234}U and ^{236}U on the initial reactivity and discharge burnup were assessed for a range of concentrations.

RESULTS

Fig.1 presents the variations of initial k_{inf} for fresh RU-derived fuel as a function of the weight fraction of the ^{235}U concentration in the RU, for two nominal values of the ^{236}U concentration. Fig.2 similarly plots the expected exit (discharge) burnup of the RU-fueled CANFLEX assemblies as a function of the initial ^{235}U concentration.

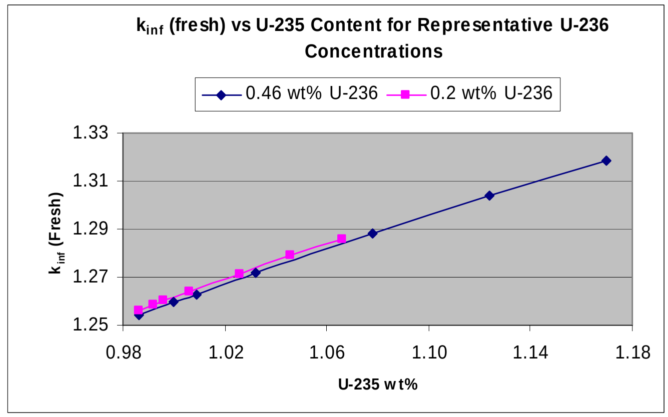

Fig.1. k_{inf} (fresh) vs ^{235}U in RU in CANDU

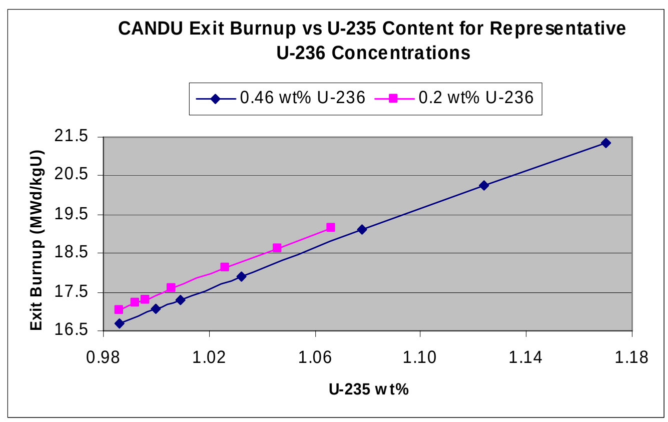

Fig.2. Exit burnup vs ^{235}U content in RU in CANDU CANFLEX

Detailed analysis of the results has quantified the effects of variations in isotopic compositions of ^{235}U, ^{236}U, and ^{234}U on initial k_{inf} and on the exit burnup of the fuel assemblies. Table I shows the relative (normalized per wt%) influence of the concentrations of these isotopes on the behavior of RU-derived fuel assemblies in CANDU reactors for small variations in the RU composition. The tabulated effects are per wt% for the isotopes averaged over the ranges of 0 to 0.46 wt% for ^{236}U, 0 to 0.02 wt% for ^{234}U, and 0.986 to 1.009 wt% for ^{235}U. The thermal and resonance energy neutron absorption cross sections for ^{234}U are considerably larger than those for ^{236}U, but

^{234}U also converts to ^{235}U during the fuel assembly irradiation.

Table I. Effects (normalized to wt%) of variations in RU isotopic composition in CANDU CANFLEX

Uranium isotope	Effect on fresh k_{inf} (%Δk/k/Δwt%)	Effect on exit burn-up (ΔMWd/kgU/Δwt%)
^{235}U	+24.5	+26.8
^{234}U	-9.1	-2.51
^{236}U	-0.61	-1.46

The net effects of ^{234}U on k_{inf} and exit burnup are much less than the net effects of ^{236}U, because the wt% of ^{234}U in the RU-derived fuel is considerably less than that of ^{236}U. The ratio of ^{236}U to ^{234}U is typically about 80 for RU from spent LWR fuel, but this ratio drops as the ^{234}U component of RU increases after multiple recycling. The ^{234}U concentrations up to 0.02 wt% and ratios of ^{234}U to ^{236}U as small as 10 were assessed in this work.

To offset the effect of the ^{236}U in RU-derived CANDU CANFLEX fuel assemblies and achieve the same exit burnup as if there was no initial ^{236}U in the fuel, additional ^{235}U (amounting to approximately 5% of the ^{236}U concentration) would need to be added. This is only one-fifth of the required increase in ^{235}U fuel enrichment in comparison to that required for pressurized water reactors (refs 2 and 5). It has been reported [11] that the reactivity effects due to variations (±50%) in the concentration levels of ^{234}U and ^{236}U would be negligible to the operation of the CANDU 6 reactors in Korea.

SUMMARY AND CONCLUSIONS

While in PWR analyses, the burnup penalty caused by the concentration of ^{236}U in RU needs to be offset by additional ^{235}U enrichment in the amount of ~25% to 30% of the weight percentage of the ^{236}U; however, the effect in CANDU is much smaller.

Furthermore, since the ^{235}U content in RU exceeds that of natural uranium, CANDU offers the advantageous option of uranium recycling without re-enrichment. The exit burnup of CANDU RU-derived fuel is considerably larger than that for natural uranium-fueled scenario, despite the presence of ^{234}U and ^{236}U.

ACKNOWLEDGEMENT

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