Evaluation of Reuse of Reprocessed Uranium in the Context of the U.S. Global Nuclear Energy Partnership Program

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INTRODUCTION

Current Global Nuclear Energy Partnership (GNEP) plans envision reprocessing spent fuel (SF) with a view to minimizing high-level waste (HLW) repository use and recovering plutonium for use in mixed oxide (MOX) fuel. The reprocessed uranium (RU), however, is to be disposed. This paper presents a limited scope analysis of reuse of RU in light-water reactors (LWRs) in the context of the U.S. GNEP program.

An idealized system model of the U.S. nuclear fuel cycle was formulated as it would operate under the GNEP no-RU-reuse scenario and under alternate U-reuse scenarios. We treat in detail only those steps in the fuel cycle which would differ between these alternate strategies. Ultimately, cost differences between the strategies are estimated which lead to the general conclusion that RU reuse appears economically preferable to disposal.

This paper covers part of a larger effort. Other papers submitted to this conference cover detailed discussion of the LWR neutronics calculations used in this paper, RU reuse in HWRs and an independent economic analysis of RU reuse.[1-4]

DESCRIPTION OF THE ACTUAL WORK

A system model of the baseline GNEP LWR fuel cycle would include natural-U production, conversion, enrichment, fuel fabrication, fuel burnup in reactors, SF cooling, reprocessing, recycle of plutonium into MOX fuel, disposal of RU, and disposal of fission products (FPs), cladding, etc. If we alter this to reuse rather than discard RU, most of these steps arguably will not change significantly in character or magnitude. Ones that will change are:

(a) Reactor neutronics
(b) RU disposal
(c) RU conversion to fluoride
(d) Natural U production
(e) Enrichment tails disposal
(f) Separative work (SWU)

In this analysis, we evaluate only these steps.

The presence of ^{236}U in RU-derived fuel modifies the fuel's behavior in the reactor. Reactivity is reduced, a problem more at the end of the fuel's life than the beginning. One means of compensating is to enrich the fuel to a higher ^{235}U assay. Reactor neutronics calculations were performed to determine the additional ^{235}U required to compensate for initial ^{236}U in the fuel, as well as to define the RU composition for following reactor passes [2]. With this compensation, there is no fuel lifetime penalty – the cost penalty for RU-reuse will appear as a SWU-requirement increase.

In RU reuse scenarios, no RU disposal is required. In effect, the bulk of the RU becomes enrichment tails.

The remainder of the steps listed above are related to enrichment. In RU-reuse scenarios, RU must be converted to UF_6 for enrichment. The RU displaces a portion (10–15%) of the natural-U feed. In all reuse scenarios evaluated, there was a slight reduction in tails produced. SWU requirements could be higher or lower in re-use scenarios: RU typically has a higher-than-natural ^{235}U assay (requiring fewer SWU), but additional ^{235}U is required to compensate for ^{236}U (requiring more SWU).

To quantify the total and isotopic mass balance in the enrichment step, a model of uranium enrichment was adapted from DeLaGarza [5]. Originally designed to follow only ^{236}U during RU enrichment, we extended it to track all minor U isotopes.

The enrichment model and the neutronics model were integrated to allow tracking of masses and isotopic compositions through several sequential fuel cycle passes. All scenarios assumed an annual steady state in which 3000 MTU of fuel was prepared, burned in PWRs, cooled, then reprocessed. Enriched fuel is produced from either all-natural feed or from natural feed plus the RU from the previous pass. Enrichment product assays differ by scenario; tails were taken as 0.20 wt % enrichment. U-236 and other minor isotope concentrations derive from the neutronics calculation of the discharged SF from the previous reactor pass, suitably aged.

For each RU-reuse scenario, an equivalent no-reuse scenario was run in parallel, and the

differences in quantities (e.g., of natural U feed; SWU) determined.

RESULTS

Numerous RU-reuse scenarios were run, varying in age of SF (3y, 5y, 50y, the last representing fuel in the current US inventory), the original (effective) fuel enrichment (3% and 4.5%, and fuel burnup (33 or 55 GWd/MTU), and number of consecutive reactor passes.

In all RU-reuse scenarios, RU displaces a large quantity of natural feed (~3000 MTU) and this dominates the scenario cost differential. SWU needs are generally slightly higher for the reuse scenarios (80-400 MT-SWU), but enrichment tails generation was always less (140-270 MTU). Finally, of course, the re-use scenarios avoided disposal of RU (~2800 MTU).

Scenario cost differences were determined using two price sets, a "high" case using recent record high UF_6, conversion, and SWU prices ($233/kgU, $12/kgU and $140/kg-SWU, respectively) and an "average" case using earlier values more representative of historical median costs ($50/kgU, $7/kgU, and $116/kg-SWU). Considering only these costs, the RU-reuse scenarios were always less expensive than the no-reuse scenarios (by $600M-700M/y for the "high" cost set and $80M-$130M/y for the "average" cost set. Costs for tails or RU disposal are probably significant, but are very uncertain, and are not included in these figures. Whatever they may prove to be, they would further favor the RU-reuse case.

In summary, this analysis supports the case that RU reuse would be economically advantageous relative to the baseline GNEP scenario of disposal of RU.

REFERENCES

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