Practical Combinations of Light-Water Reactors and Fast Reactors for Future Actinide Transmutation

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INTRODUCTION

Earlier systems analysis studies compared full actinide partitioning-transmutation (P-T) requirements for realistic closed fuel cycles during the multicycle approach to equilibrium. Performance characteristics were evaluated for several scenarios including those using (1) all-thermal-spectrum irradiations, (2) all-fast-spectrum irradiations, and (3) optimum "hybrid" combinations of thermal-spectrum and fast-spectrum irradiations.

RESULTS

The results showed that optimum performance (actinide burnup) can be obtained by irradiating plutonium (or plutonium-neptunium) in fast-spectrum reactors and americium-curium targets in thermal-spectrum reactors (Table I). However, the approach to equilibrium during multicycle P-T operations was not significantly different for the three scenarios evaluated (Fig. 1).

TABLE I. Comparison of Hybrid-Case Burnup[a] Percentages (Values in Parenthesis Are Percentages for Net Production)

	FR/0.50 CR[b]	FR/0.25 CR	LWR	Hybrid Pu-Np in FR/0.25 CR Am-Cm in LWR
^{239}Pu	27	41	73	38
^{240}Pu	3	5	15	2
^{241}Pu	12	12	(193)	2
^{242}Pu	1	2	(106)	(14)
^{243}Am	(7)	(8)	(126)	(2)
^{244}Cm	(243)	(280)	(1950)	(755)
^{237}Np	35	41	60	33
^{241}Am	39	44	80	83
^{238}Pu	(141)	(147)	(420)	(337)
Total TRUs[c]	18.5	28.0	36.2	25.4
Sum ^{241}Pu + ^{241}Am	32.6	36.5	15.9	63.8

[a] Burnup = (amount in feed – discharge amount)/amount in feed. Feed composition in all cases was light-water-reactor (LWR) low-enriched-uranium spent fuel irradiated to 45 GWd/MT and cooled 30 years.
[b]FR = fast reactor; CR = conversion ratio.
[c]TRUs = transuranics.

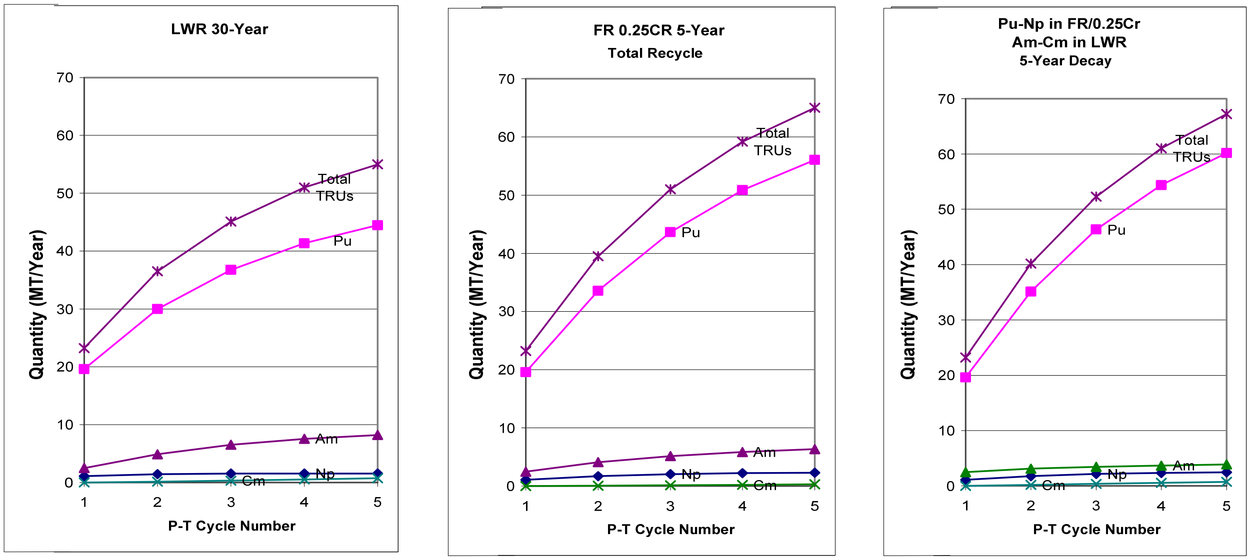

Fig. 1. Comparison of total TRU and element inventories in the total recycle from each cycle during multiple P-T cycles.

Moreover, the results showed that, because the design of Advanced Burner Reactors (ABRs) has been optimized at ~840 MW(t), a large number of ABRs (33–90) would be required to transmute the ~23 MT/year of TRU actinides currently produced in ~2000 MT/year of low-enriched-uranium spent fuel; in comparison, 10–24 existing (or new) 3400-MW(t) LWRs would be sufficient (Fig. 2).

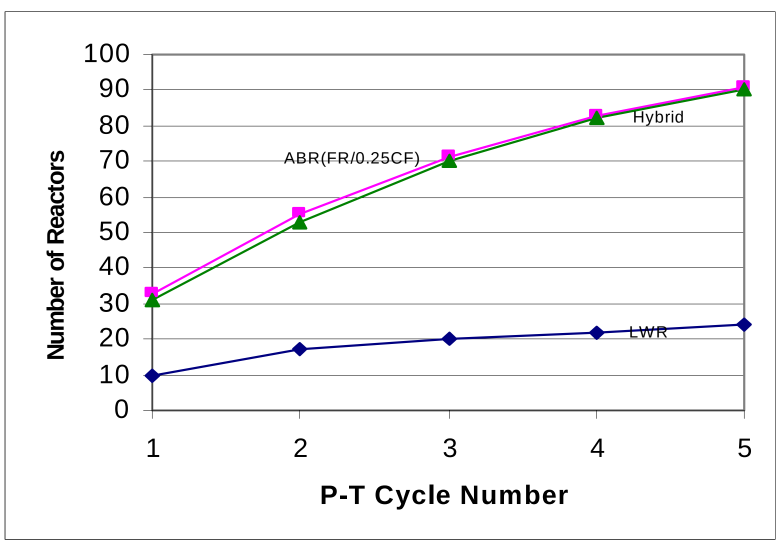

Fig. 2. Number of reactors required to transmute TRU actinides produced in 2000 MT/year of LWR UO_2 spent fuel (~100 LWRs).

CONCLUSIONS AND EXTENDED STUDIES

Based on the previous study results, full near-term implementation of P-T using only ABRs will be difficult. Initial use of existing LWRs could provide an early start to full actinide P-T and stop the continuing growth of the spent fuel inventory. Subsequent addition of larger fast-spectrum reactors will be more practical. Extended studies of this concept are in progress to evaluate an approach using, initially, one 35- to 40-year P-T cycle in which existing and new LWRs are utilized for the entire transmutation irradiation, followed by succeeding P-T cycles using ABRs for transmutation of the plutonium-neptunium and LWRs for americium-curium. The use of ABRs with conversion ratios of 0.25 and 1.0 will be compared.

REFERENCES

1. E. D. COLLINS, J. P. RENIER, "Quantitative Comparisons of Actinide Partitioning-Transmutation in Light Water Reactors and Fast Reactors," *Proceedings of the Organization of Economic Cooperation and Development, Nuclear Energy Agency, 9th Information Exchange Meeting*, Nimes, France (September 2006).