Thorium-Based Mixed-Oxide Fuel for the Consumption of Transuranic Elements in Pressurized Water Reactors

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1. Objective

The goal of this fuel cycle is to reduce both the time and size requirements on nuclear waste storage facilities while increasing proliferation resistance by burning reactor grade plutonium and other long lived radioisotopes taken from spent nuclear fuel. The plutonium-thorium-uranium fuel is designed for existing Westinghouse pressurized water reactors to ensure economic feasibility and short term implementation.

2. Assembly Design

Each assembly design is similar to the figures below with only slight enrichment and pin position modifications. Integral fuel burnable absorber (IFBA) coatings were placed on some pins to even the power level throughout the cycle length. The design is a heterogeneous 17x17 array.

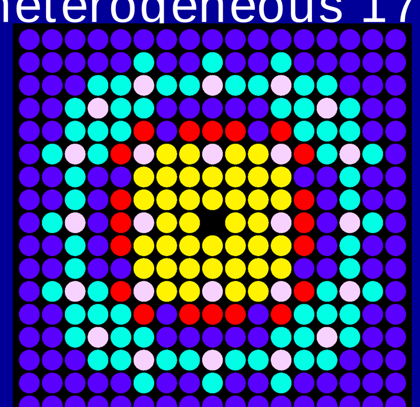


Figure 1: Map for assemblies 1, 2 and 4.

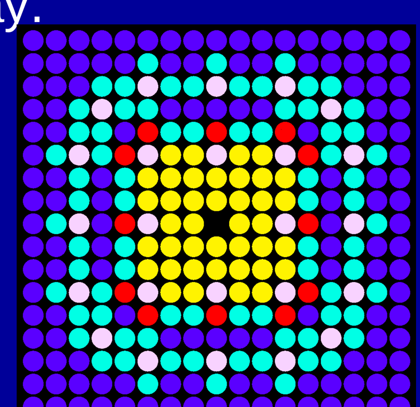


Figure 2: Map for assemblies 6 and 7.

- (^{235}U, ^{238}U, Th)O_2 pins with low enriched ^{235}U.
- (Th, Pu)O_2 pins with low enriched reactor grade Pu.
- (Th, Pu)O_2 pins with moderate enriched reactor grade Pu.
- Minor actinide oxide pin
- Guide tubes

3. Core Layout

The core loading pattern for the proliferation resistant advanced transuranic transmuting design (PRATT) was optimized to obtain an even power distribution which increases the cycle length and improves safety.

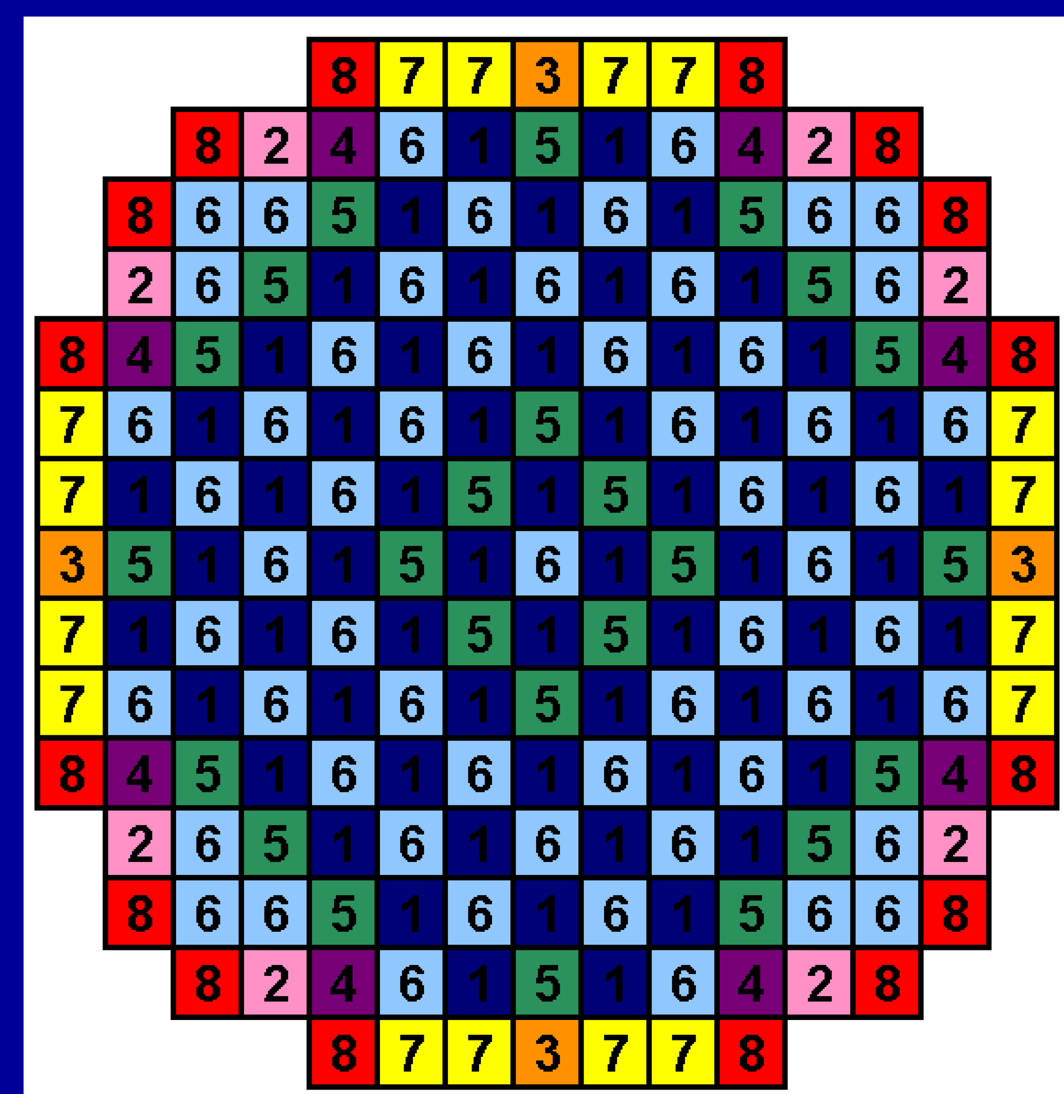


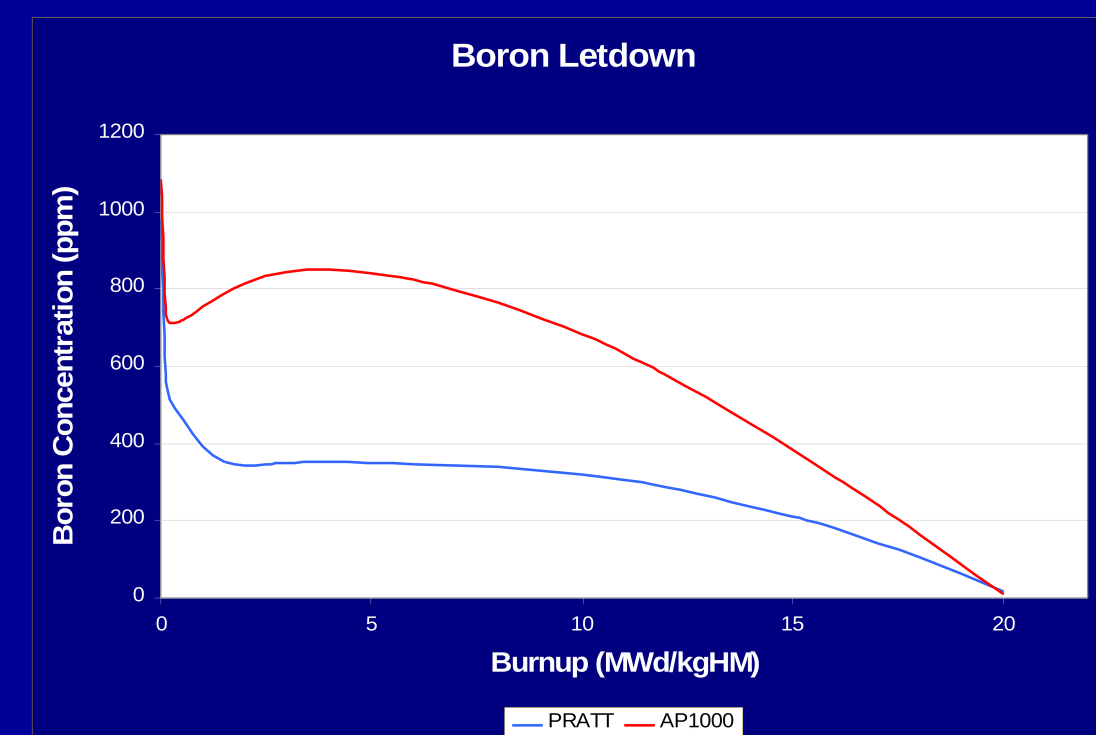
Figure 3: Core loading pattern.

The periphery of the core is loaded with the highest enriched assemblies while the inner region is composed primarily of two different assemblies, both with lower enrichments in a modified checker board pattern.

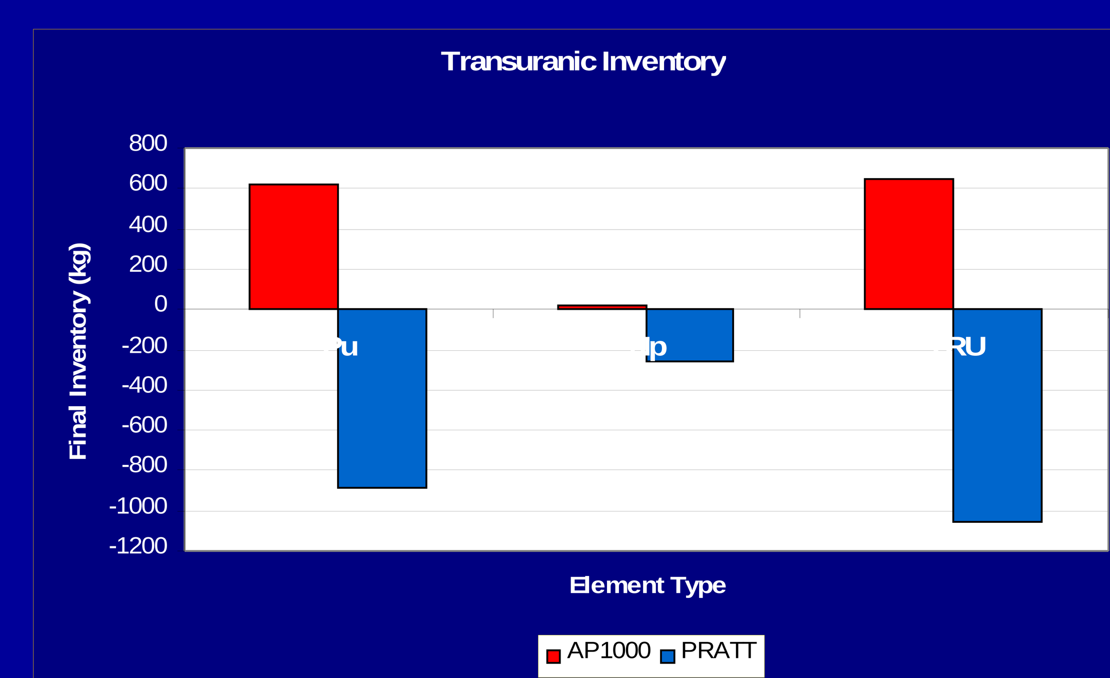
Assembly Number	Assemblies per Core	Pu wt% Pin 1	Pu wt% Pin 2	^{235}U wt% Pin 3
1	60	12.0	9.0	10.0
2	8	18.0	12.0	15.0
3	4	18.0	15.0	13.0
4	8	12.0	12.0	13.0
5	24	12.0	9.0	10.0
6	57	12.0	8.0	10.0
7	16	18.0	12.0	15.0
8	16	18.0	15.0	13.0

4. Cycle Length and Inventory Change

Soluble boron is added to control excess reactivity and ensures a multiplication factor of 1. The maximum cycle length is determined by zero boron concentration. Minimizing the boron concentration increases operational safety. The PRATT design is compared below with the current Westinghouse reactor the AP1000.

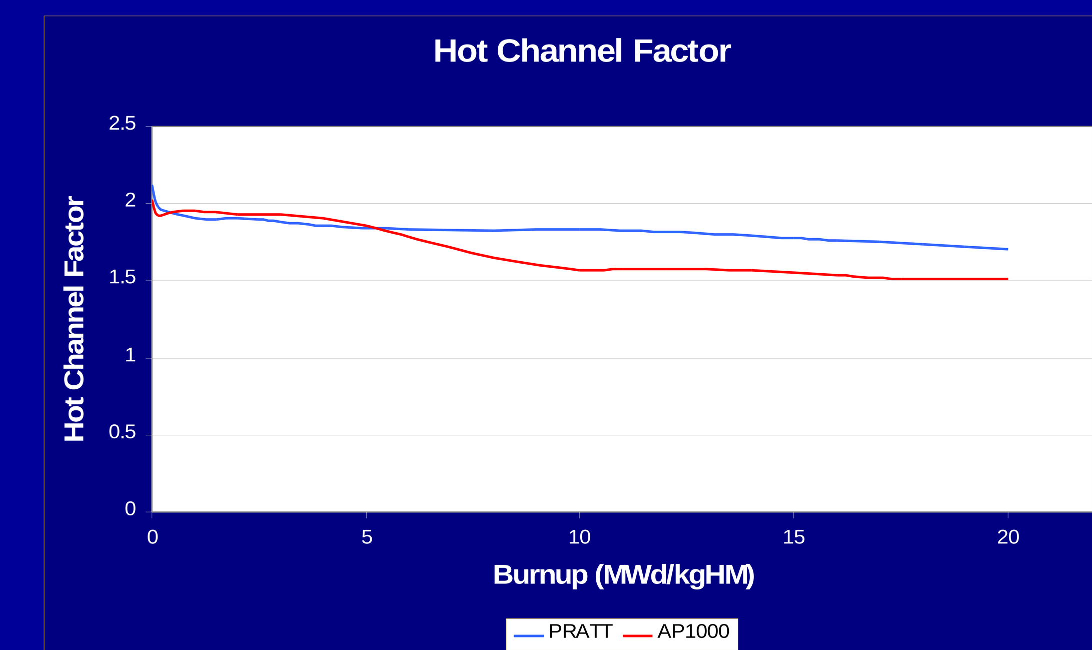


Comparison of the isotopic inventory change in units of kilograms over one cycle length, 20 MWd/kgHM, shows the PRATT design accomplishes its goals of a net consumption of transuranics, Pu and Np specifically.

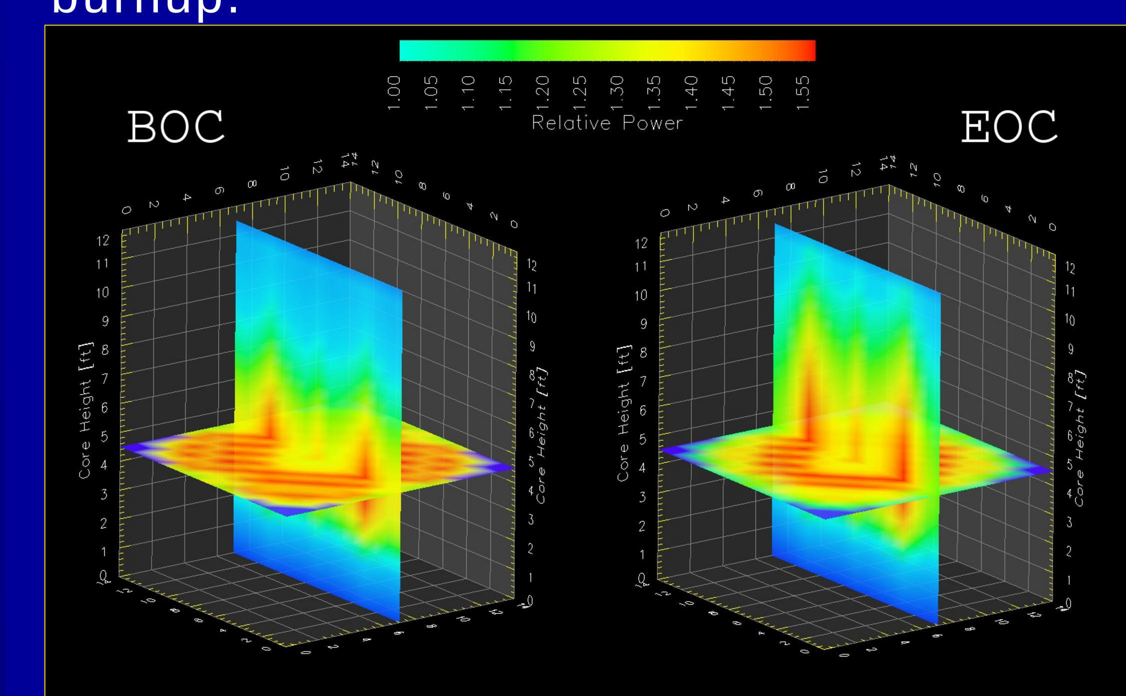


5. Relative Power

The hot channel factor is defined as the ratio of the maximum to average heat flux in the core. Regulations state that this ratio needs to be less than 2.5.



The overall relative power, shown below, depicts the movement of radial and axial power throughout the cycle length. The radial power distribution is nearly uniform at the beginning of the fuel cycle and moves inward while the axial power rises with burnup.



6. Conclusions

- Net reduction of long-lived radioisotopes.
  - 885 kg of Pu destroyed per cycle.
  - 256 kg of ^{237}Np destroyed per cycle.
- Operational safety increase by a low boron concentration and low hot channel factors.