# Neutronics Design Studies of KALIMER-600 for TRU Transmutation

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One of the Gen IV reactor development goals is the management of high-level radioactive wastes from the LWR spent fuels because the radiotoxicity of the long-lived nuclides (e.g., Pu, Np, Am, Cm, $^{129}$I, $^{99}$Tc) contained in LWR spent fuels lasts for a very long time period. Fast spectrum reactors have several desirable neutronics characteristics for the nuclear transmutation of the long-lived nuclides[1,2]. In this paper, core design study results for a 600 MWe sodium-cooled fast reactor for the effective transmutation of the TRU nuclides are given. Two types of TRU transmutation cores are analyzed in this study; the first type is the reference core that is based on the KALIMER-600 breakeven core[3] and the second type is an annular type core where void duct assemblies and a central island region of non-fuel assemblies are introduced to improve the core neutronics characteristics.

In the reference core, $B_4C$ absorber rods, dummy rods and moderator rods are used to make it possible to use a single enrichment fuel, to reduce the degradation of fuel Doppler coefficient, and to reduce sodium void reactivity worth. In comparison with the KALIMER-600 breakeven core, the fuel rod outer diameter is reduced from 0.85cm to 0.75cm and the active core height from 100cm to 90cm in order to reduce the breeding ratio. All the fuel assemblies have 234 fuel rods, 6 moderator rods ($ZrH_{1.8}$), and 25 dummy rods. The fuel assemblies in the inner and middle core regions have 6 $B_4C$ rods while these 6 $B_4C$ rods in the outer core region fuel assemblies are replaced with dummy rods that have the same cladding as $B_4C$ rods but the internal region is voided.

For the power flattening under a single enrichment fuel, the boron enrichments for the inner and middle core regions are adjusted to be 60wt%$B^{10}$ and 25wt%$B^{10}$, respectively. Figure 1 shows the core configuration. The fuel form used in this study is the metal fuel of U-TRU-10Zr.

For the transmutation core having void duct assemblies[4], the increase in the transmutation rate is achieved by reducing the fuel rod outer diameter and core height, and using the void duct assemblies. In particular, void duct assemblies are also used to reduce the sodium void reactivity and to achieve the power flattening in a core loaded with fuels of a single enrichment.

Figure 2 shows the configuration of the core with void duct assemblies. The active core height is 90cm. The fuel rod dimensions are the same as those of the reference core. A fuel assembly consists of 265 fuel rods and 6 moderator rods. To further increase the neutron loss, two cases are considered for a 30 cm region below fuel; $B_4C$ (50wt%$B^{10}$) for the first case and void for the second case.

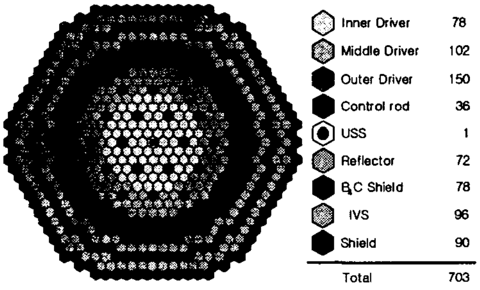

Figure 1. Configuration of the reference core

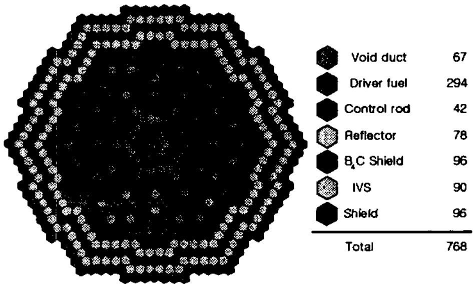

Figure 2 Configuration of the core having void duct assemblies

As shown in Figure 2, the core has a central island region consisting of non-fuel assemblies that are devised to increase neutron leakage and to reduce power peaking[4].

The cycle length is 332EFPD and the refueling interval is 13 months with a capacity factor of 85% for all the cores. The six and four batch fuel management schemes are used for the reference core and the cores having the void duct assemblies, respectively.

Table 1 shows the summary of the core performance analysis results of the reference core and two cores having void duct assemblies. Of these three cores, the reference core has the largest burnup reactivity swing, the highest TRU weight percent at BOEC, and the largest positive value of the sodium void reactivity. This core can transmute 307.1kg/cycle of TRU that corresponds to the TRU amount produced from about two LWRs of the same power and cycle length. The core having void duct assemblies and using a $B_4C$ region below fuel has the smallest value of sodium void reactivity (~994pcm at BOEC) but the least negative value of Doppler coefficient. On the other hand, the core having void duct assemblies and a void region below fuel has larger positive value of sodium void reactivity by ~400pcm than the core having void duct assemblies and a $B_4C$ region.

Table 1. Core performances comparison between the reference core and the cores having void duct assemblies

| Parameter | Reference core | $B_4C$ below fuel | Void below fuel |
|---|---|---|---|
| Active core height (cm, cold) | 90 | 90 | 90 |
| Cycle length (EFPD) | 332 | 332 | 332 |
| Average conversion ratio | 0.6493 | 0.6588 | 0.7190 |
| Burnup reactivity swing (pcm) | 3127 | 2879 | 2634 |
| Average discharge burnup (MWD/kg) | 116.3 | 121.7 | 121.0 |
| Average TRU wt% in HM (BOEC) | 40.6 | 34.4 | 31.3 |
| TRU consumption rate (kg/cycle) | 307.1 | 279.5 | 239.8 |
| TRU support ratio | 2.18 | 1.98 | 1.70 |
| Uranium consumption rate (kg/cycle) | 216.8 | 247.6 | 284.2 |
| Average power density (W/cc) | 207.9 | 223.6 | 223.1 |
| Peak linear power (W/cm, BOEC/EOEC) | 298.5/290.7 | 307.0/301.1 | 292.6/287.2 |
| Fast neutron fluence ($n/cm^2$, E>0.1MeV) | $2.945\times10^{23}$ | $3.835\times10^{23}$ | $3.777\times10^{23}$ |
| Doppler coefficient (BOEC, dρ/dT) | $-0.00272T^{-0.98}$ | $-0.00321T^{-1.01}$ | $-0.00391T^{-1.0}$ |
| Sodium void reactivity (pcm, BOEC/EOEC) | 2145/2199 | 994/1070 | 1432/1514 |

## References

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[4] S. G. Hong et al., "Use of Void Duct Assemblies for TRU Transmutation Core Design," Proceedings of the KNS Autumn Meeting, Pusan, Korea, Oct. 27-28, 2005.