U.S. Department of Energy

Project Title

Self-sustaining thorium boiling water reactors

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Program: ARC-1

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ABSTRACT

Over the years there has been recurring interest in compact-lattice LWR for achieving higher conversion ratio than possible with conventionally designed PWR and BWR cores. One of the most complete recent designs is the innovative Resource-Renewable BWR (RBWR) developed by Hitachi. Hitachi has developed several variants of core designs for the RBWR including the fuel-self-sustaining RBWR-AC core (conversion ratio CR~1.0) and the RBWR-TB2 core that is designed to be a TRU burner (CR ~0.5). Similar to Sodium Fast Reactors (SFR), both RBWR core designs are capable of multiple recycling of TRU. Both RBWR core designs can fit within the pressure vessel of the well proven ABWR and deliver the same total power. Relative to the ABWR, the RBWR core design features a tighter fuel lattice, a shorter core, a smaller coolant mass flow-rate and pressure drop and a higher core void fraction.

However, the achievement of negative void reactivity coefficients in the RBWR is very challenging because of the large increase in the η values of most of the TRU as well as of the ^{238}U with spectrum hardening caused by coolant voiding. To counteract that effect the coolant voiding has to substantially enhance the neutron leakage probability. The need for a large leakage-probability drove Hitachi to design a pancake shape small height core, to "lump" the fissile fuel into two axial zones, each approximately 20 cm in length, with depleted U blanket zone on both sides of each fissile zone, and to add B_4C to the bottom and top reflectors. The resulting axial power distribution is quite sensitive to the TRU loading in the two axial fissile zones, to the Pu buildup in the three blanket zones surrounding the two fissile zones, to the axial void distribution and to the control rods insertion pattern.

The objective of the proposed study is to perform a conceptual design of cores and control systems for an alternative RBWR-AC, to be referred to as a Hard Spectrum BWR for BReeding (HSBWR-BR), and of an alternative RBWR-TB2, to be referred to as Hard Spectrum BWR for Transmutation (HSBWR-TR) that could be installed in an ABWR using thorium instead of depleted uranium for the primary fertile fuel. The approach proposed for this study is similar to that used by Hitachi for the design of the RBWR with a few exceptions: use of thorium instead of depleted U, possibly elimination of internal blanket and elimination of B_4C or other parasitic absorbers from the axial reflectors. As ^{232}Th has a significantly smaller fast fission cross section than ^{238}U and as the $\eta(^{233}U)$ increase with neutron energy is significantly smaller than that of ^{239}Pu and most other TRU in the relevant high energy range, it is possible to design a Th-based high void fraction water cooled core to have negative void reactivity coefficients without having to resort to small length high-leakage axial fissile zones, internal blankets and parasitic absorbers in the axial reflectors. Our preliminary exploratory analysis indicates that it is possible to achieve fuel-sufficiency in the proposed Th-based cores and that the attainment of adequate shutdown reactivity margin of the control system may be a challenge.