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ABR for TRU transmutation with Breed & Burn Blanket for Improved Economics and Resource Utilization

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ABSTRACT

Background: (1) Fast sodium-cooled critical reactors (SFR), such as the Advanced Burner Reactor (ABR), are a major candidate in the US for the transmutation of the TRU generated in LWR. The ABR is designed to have a low conversion ratio (typically CR=0.5 tor 0.75) by designing the core to have a relatively small fuel volume fraction and enhanced neutron leakage probability; typically, on the order of 20% of the fission neutrons leak out. In presently designed ABR these neutrons do not have any constructive usage. The relatively high neutron leakage probability helps designing the core to have an acceptable coolant voiding reactivity effect. (2) A recent study at UC Berkeley found that critical breed-and burn (B&B) cores cannot be designed using pure thorium as the feed fuel. This is so because, in the SFR spectrum, (a) ・(233U) < ・(239Pu) and (b) the fast fission probability of 232Th is significantly smaller than that of 238U.

The objective of the proposed study is to assess the feasibility of using the large number of neutrons that leak out from the ABR (SFR, in general) core without penalizing the ABR transmutation-ability: Instead of designing the ABR core to be of a pancake shape with the dominant neutron leakage being in the axial direction, it is proposed to design the ABR core to be of a cigar shape with the majority of the neutron leakage in the radial direction and to make use of the leaking neutrons to “drive” a B&B thorium blanket that radially surrounds the core. The primary design objective is to maximize the fraction of the total power generated by the thorium B&B blanket. The larger this fraction is, the lower the fuel cycle cost is likely to be, as the recycled TRU fuel is expected to be significantly more expensive than the cost of a once-through fertile fuel. Simultaneously with extra power generation per TRU consumed, the thorium blanket produces 233U; i.e., the proposed core concept also converts TRU to 233U. This conversion is relevant if there is an interest in deployment of a thorium-based nuclear energy system for which significant inventories of 233U will be required.

An additional objective is to assess the feasibility of facilitating the development and early introduction of depleted uranium fed B&B reactors by driving subcritical depleted uranium fueled B&B blankets with the excess neutrons that leak out from a cigar-shape core. Whereas for critical B&B cores to be able to sustain the breed-and-burn mode of operation the cladding must be able to sustain a neutron induced radiation damage of 500 dpa, the first generation of depleted uranium B&B subcritical blankets could be designed to meet the presently acceptable radiation damage constraint that is only 200 dpa. The blanket burnup could be progressively increased as cladding materials that are licensable to higher dpa level become available; up until, hopefully, reaching the burnup level (>30% peak BU) enabling sustaining the B&B mode of operation in a critical reactor. The higher the blanket burnup is, the larger will be the fractional energy generated by the blanket and the more economical the driver-blanket SFR will be.