Performance Characteristics of Actinide-Burning Fusion Power Plants*

E.T. Cheng

TSI Research, Inc., Rancho Santa Fe, CA 92067-2754

Burning actinides with fusion neutrons appears to be a promising option to destroy large quantity of actinides associated with spent fuel actinides and excess plutonium, and to utilize fertile fuel such as natural uranium to provide unlimited nuclear energy for mankind. To determine feasibility of transmutation with fusion neutrons, studies have been performed using a near-term fusion device as a neutron source. The actinides in the spent fuel are mainly Pu isotopes, although some minor actinides (MA), namely isotopes of Np, Am and Cm are also present. The excess plutonium material is mainly Pu239. Sub-criticality, reduction of high level waste (HLW) volume, and reduction of long-term risk of disposed HLW are among the major advantages offered by transmutation. The disadvantages of transmutation comparing to the once-through cycle scenario are concerns for plutonium proliferation and safety in handling enhanced radioactivity due to that associated with minor actinides, mainly Am and Cm isotopes, which may accumulate in large quantities during transmutation. Large fraction of minor actinides in the transmutation system appears also to be an important factor to reduce the performance and efficiency. Similar conclusions could be drawn for the fertile-burning nuclear energy generation fusion power plants.

Molten salt, which is a mixture of lithium fluoride and beryllium fluoride, is one of the transmutation blanket concepts studied recently. Molten salt can dissolve a small quantity of actinide salt in it and a fusion power plant based on the molten salt can become very attractive because of the possibility to minimize the actinide inventory in the transmutation plant. Furthermore, on-line removal of fission products and replenishing of destroyed actinides can be, in principle, operated in a molten salt fusion power plant.

In this paper, the focus of the presentation will be on two molten salt based fusion power plants. One of them is to burn spent fuel actinides, the other is to burn U238. Both power plants produce output energy larger than a fusion power plant would normally produce without including actinides. The spent fuel actinide burning power plant has two blanket options. One is a beryllium blanket to enhance the neutron multiplication and provide soft neutron spectrum for better fission burning of the actinides. The initial energy multiplication performance of this power plant can be as high as 180 when the criticality factor, k-eff, is 0.952. But after destruction of 3 actinide inventories in the blanket, the performance drops significantly, to an energy multiplication of 13 (k-eff 0.616). The other is a blanket without external beryllium. Due to a relatively harder neutron spectrum, modest performance is thus expected. But the performance is more stable along the burning time. The U238 burning fusion plant has much lower performance than in a spent fuel burning plant, because the replenishing material does not have a fissile component. Detailed performance of the various blanket concepts, its degradation during burn-up and the attendant evolution of isotopic concentrations of all actinides were obtained and will be discussed.

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