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Tritium Mitigation/Control for Advanced Reactor Systems

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ABSTRACT:

The Fluoride salt-cooled High-temperature Reactor (FHR) is a reactor concept that combines advantages of the Sodium Fast Reactor (SFR) and the High-Temperature Gas-cooled Reactor (HTGR). The primary coolant is FLiBe (a mixture of LiF and BeF_2) with a melting point of 459ºC and a boiling point of 1,433ºC. FLiBe has a heat capacity of 2.34 kJ/kg-ºC and a thermal conductivity of 0.56 W/m-ºC at 0.156 MPa. Due to the low operating pressure and advantageous primary coolant characteristics (high density and good thermal characteristics), a significant reduction in size and cost can be realized with respect to gas-cooled reactors and water-cooled reactors.

However, due to the neutron activation of the FLiBe coolant, a considerable amount of tritium is produced. This has been estimated to be 5,000 Ci/day at startup in an FHR with a power rating of 2400 MWth. Tritium formation rates (as HT or T_2) from $_7$Li in molten salt reactors can be compared to the rates in CANDU reactors. The tritium produced in the primary loop, if left to accumulate, has a very high permeation rate through the intermediate heat exchangers (IHXs). As a result, three-loop systems are currently being considered for FHRs in order to diminish tritium permeation. The extra loop obviously offsets the above-mentioned benefits of the FHRs.

In high-temperature components such as an IHX, tritium permeates readily in metals. The anticipated difficulty in containing tritium justifies special care in system design. A sound understanding of tritium’s generation pathways, as well as its properties and possible ways to prevent it from escaping are an integral part of containment plan for FHRs.

In this study, eliminating the intermediate loop, we propose a two-loop FHR with a tritium removal facility, which was developed for tritium recovery in fusion reactor. Using this approach, an economic benefit according to no intermediate loop can be obtained, while the safety concern of tritium permeation is mitigated. Additionally, an IHX that has a similar permeation rate to tritium production rate of 1.9 Ci/day in a 1000 MWe PWR will be designed to prevent the residual tritium that is not captured in the tritium removal system from passing into the power cycle. The main focus of this proposed work is to aid in the mitigation of tritium permeation issue from the primary side such that concentration of tritium in the secondary side and the process side could be significantly reduced.