TRITIUM PERCOLATION, CONVECTION, AND PERMEATION IN FUSION
SOLID BREEDER BLANKETS*

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Lithium-bearing ceramics have been proposed for tritium-breeding blankets in D-T fusion reactors. The conceptual designs for these blankets utilize a solid breeder (e.g., LiAlO_2 or Li_2O), a helium purge stream for tritium recovery, a coolant (e.g., H_2O or He), and a structural material (e.g., HT-9 ferritic steel or a titanium modified stainless steel) to separate the coolant from the breeder. Tritium breeding, release rate from the breeder, inventory, and leakage to the primary coolant have been identified as areas of concern in these blanket designs.

In this work, models are developed to describe the percolation of released tritium through the breeder interconnected porosity to the purge stream, convection of tritium by the helium purge stream, and leakage or permeation of tritium through the structural material to the primary coolant system. Important parameters in the models are tritium generation rate, breeder microstructure, tritium species in the gas phase, temperatures, tritium diffusivities and permeabilities, and effectiveness of oxide barriers.

Tritium desorbs from the solid breeder in molecular form as either T_2 , HT, T_2O , HTO, or some combination of these species. The form depends to a large extent on the chemistry of the purge stream and the amount of oxygen which diffuses from the breeder to the pore-solid surface area. A pure helium purge stream favors T_2 and/or T_2O , while addition of enough hydrogen (i.e., protium) to the helium purge to enhance the surface desorption process favors the release of HT and/or HTO. The results of in-reactor and out-of-reactor studies are reviewed to identify the forms of released tritium as a function of purge and breeder chemistry.

While the gas phase transport of tritium due to a number of mechanisms is discussed, diffusion is identified as the rate controlling mechanism in the percolation of the tritium species from the pore/solid surfaces to the purge flow. Models are developed for ordinary diffusion, transition diffusion, and Knudsen diffusion. Once the tritium species reach the helium purge streams, convection is shown to be the dominant mode of transport.

The diffusion and convection models establish the tritium partial pressures throughout the breeder porosity as a function of tritium generation rate per unit volume, purge channel location and spacing, and purge flow temperature and pressure. The partial pressures of tritium are then used as input to the permeation model to predict the leakage rate. Critical parameters in the permeation model are the permeability of the structural material, effectiveness of oxide barriers (i.e., oxide impedance factor), and the ratio of unoxidized tritium-to-protium on the breeder side of the structural material.

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