

Challenges Related to Tritium Transport in Fusion Reactors: From Component to System Level

Tritium management is central to the safe and economic operation of future fusion power plants, yet it remains one of the most complex aspects of reactor design. At the component level, accurate prediction of hydrogen isotope behaviour in breeder materials, structural alloys, and plasma-facing components is required to ensure compliance with safety standards on tritium retention, permeation, and inventory. Advanced modelling tools such as FESTIM enable detailed simulations of tritium transport, trapping, and release across materials and interfaces, offering insights into component performance under fusion-relevant conditions. At the system level, the integration of tritium transport into plant-wide analyses is essential for licensing and design optimisation. Tools such as PathView support this by enabling dynamic simulations of tritium flow across interconnected subsystems, from breeder blankets and permeator units to fuel cycle components.

To support these efforts, we have initiated the Hydrogen Transport Materials (HTM) database, an open-source repository of validated diffusivity, solubility, and trapping parameters for a broad range of fusion-relevant materials. By providing transparent, curated datasets, the HTM database complements modelling activities and reduces uncertainty in tritium predictions.

This presentation will highlight the challenges in bridging component-scale physics with system-scale modelling, and discuss implications for the development of applicable codes and standards. Particular attention will be given to areas where existing standards (e.g. for structural materials or pressure boundaries) are insufficient to capture tritium-specific phenomena such as isotope exchange, permeation under neutron irradiation, and transient release. Establishing appropriate methodologies for validating models and integrating shared data resources like HTM into design practices will be key for ensuring both regulatory compliance and public confidence in tritium-handling strategies for next-generation fusion reactors.

Technical Categories Addressed

Tritium breeder blankets (ex. molten salts, liquid metals)

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