Optimized design and numerical efficiency qualification of an on-line permeator (FUSKITE®) for tritium recovery from lead-lithium eutectic alloy

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A fast and efficient recovery of bred tritium is a major milestone of tritium breeding technologies R&D for the demonstration of a fusion reactor tritium self-sufficiency. Diverse tritium recovery technologies from lead-lithium eutectic (gas-liquid contactors, getters, vacuum spray columns, others) have been investigated with different degree of qualification.

Permeator Against Vacuum (PAV) runs as a single-step process for tritium on-line recovery, acts as passive systems allowing to be thermally governed can be easily in-pipe integrated in LiPb loop systems and can be conceived with high compactness. An optimal design of a PAV requires a detailed hydraulic design optimization for established operational ranges (HCLL types with lead-lithium at low mm/s velocity or in the ranges of tens of cm/s, DCLL types).

For a given tritium residence time within the PAV channel the key design issues determining its efficiency under LiPb alloy in laminar regime are: (1) the hydraulic channels cross-section between permeable walls establishing diffusive path length, (2) specific LiPb/wall wetted area and (3) a proper choice of permeable wall materials (high solubility ratio with respect to LiPb at highest diffusivities). Many other physical-chemical variables impacting on tritium recovery efficiency are discriminated.

For high velocity LiPb options (> 10 cm/s) optimized design choices should manage turbulent flow regimes at PAV fluid channels. PAV thermal and structural (wall roughness and corrugation) design should guarantee turbulence at manageable pressure drops. Under such conditions hydrodynamic correlations for large solved/wall mass exchange coefficients can be justified.

An optimal PAV design is proposed with detailed design parameterization of tritium recovery efficiency at two velocity ranges fom numerical simulation based on properly developed Openfoam® CFD code BelFoam® customized solver.