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MBSE-derived DCLL Breeder Blanket mock-up for testing in the LIBRTI facility

This work deploys an integrated Model-Based Systems Engineering (MBSE) framework for guiding the verification and validation (V&V) of a dual-cooled lithium–lead (DCLL) breeder blanket mock-up, with a focus on neutronics, tritium behaviour and material performance under fusion-relevant irradiation. By formalising stakeholder needs and design requirements, the framework establishes a traceable pathway from high-level functional objectives to a targeted experimental programme to be carried out on the LIBRTI Facility. This campaign prioritises: neutron spectrum characterisation, tritium production, permeation kinetics, and corrosion–permeation interactions.

A sequence of complementary tests is proposed. Solid PbLi intermetallic specimens and activation foils provide neutron spectrum and reaction-rate measurements to validate cross-section data, refine neutronics models and inform Li-6 enrichment strategies. Dedicated tritium production capsules quantify yield as a function of enrichment and geometry, improving predictions of tritium breeding ratio (TBR) and tritium residence time. A liquid PbLi eutectic campaign investigates permeation behaviour on candidate structural steels to determine diffusion coefficients, solubility limits and activation energies supporting the development of neutron and tritium diagnostics instrumentation. Combined corrosion–permeation exposures evaluate how material degradation influences tritium uptake and leakage, offering insight into long-term structural integrity and operational envelopes.

The resulting data sets are linked directly to MBSE requirement nodes, acceptance criteria and analytical model elements, enabling rigorous traceability through each stage of verification and validation. This MBSE oriented approach enhances confidence in model predictions, highlights design sensitivities and provides a scalable template for breeder blanket maturation, where engineering design and operational science co-evolve to deliver comprehensive, synergistic solutions.

Acronyms:
PbLi –Lithium-Lead

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