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Neutron Activation Analysis of Tungsten in Divertor and Breeding Blanket Armor for EU DEMO

Ensuring the efficient performance of fusion devices requires a comprehensive understanding of plasma-facing materials and components under extreme operational conditions and neutron fluxes, particularly in the EU DEMO system. Neutrons with energies up to 14 MeV play a dual role in tritium breeding and energy production but also interact with in-vessel materials, causing activation, decay heat, and radiation hazards. This study evaluates the activation, decay heat, and contact dose rates in two component parts made of different tungsten-based materials. The first part is the breeding blanket (BB) module's first wall, and the second is the divertor plasma-facing component. In the different configurations of MCNP models, that component could be made either out of pure tungsten or alloy with impurities (purity 99.9595%). The BB acts as a cooling system, shielding sensitive components like superconducting magnets, and serves as the site of tritium production. The divertor, meanwhile, dissipates heat and removes helium ash. Examined parts of both components are predominantly constructed from tungsten, which absorbs the majority of high-energy neutrons and ensures the structural integrity of the reactor.

Using advanced computational tools such as MCNP6 with the FENDL-3.2 nuclear data library and FISPACT-II with TENDL-2017, neutron-induced activities, decay heats, and dose rates were calculated for cooling times spanning from immediate shutdown to 1000 years. In pure tungsten, 187W dominated shortly after irradiation, transitioning to radionuclides such as 179Ta after 10 years. In tungsten alloy, impurities like 60Co and 108mAg significantly increased long-term activation parameters, resulting in higher values than in pure tungsten.

The comparison of specific activity and contact dose rate between alloy and pure tungsten in divertor and breeding blanket armor calculations reveals several key trends. In the WCLL model, the specific activity ratio between alloy and pure tungsten starts at approximately 1 and increases over time, reaching more than 20 after 100 years before decreasing to 10 at 1000 years. In the HCPB model, the ratio starts at 0.9 and rises to 11 over the same period. For armor calculation for both breeding blanket cases, the initial ratio is around 0.8. Because specific activities later are generated from alloy composition impurities, the specific activity ratio reaches up to 17.

Regarding contact dose rates, the alloy initially showed a 15% higher dose rate than pure tungsten, which increased to 27% and, in extended periods, up to 200%. In the breeding blanket armor, the contact dose rate for pure materials is initially 25% higher but becomes similar to the divertor case after one year. These findings highlight the significant influence of material composition, including alloy impurities, on specific activity and contact dose rates over extended periods.

Primary author: BREIDOKAITE, Simona (Lithuanian Energy Institute, Laboratory of Nuclear Installation Safety)

Co-author: STANKUNAS, Gediminas (Lithuanian Energy Institute)

Presenter: BREIDOKAITE, Simona (Lithuanian Energy Institute, Laboratory of Nuclear Installation Safety)