

Nuclear Analysis of the High Resolution Neutron Spectrometer (HRNS): Activation and Radioactive Waste Assessment

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The High Resolution Neutron Spectrometer (HRNS) is designed for neutron diagnostics in ITER, where accurate measurements must be combined with careful assessment of radiation-induced activation of detector and structural components. Understanding the activation behaviour of diagnostic systems is essential for evaluating operational safety, maintenance requirements, and long-term radioactive waste generation.

This work presents a comprehensive nuclear analysis of the HRNS system, focusing on activation and radiological inventory of its main components. Neutron transport and activation calculations were performed for the full HRNS assembly, including shielding and structural components, detector systems (TPR, NDD, bToF and fToF), the intermediate collimator, the electrical cabinet, and the beam dump. The analysis investigates the time evolution of specific and total activity over cooling times from seconds to hundreds of years and identifies the dominant radionuclides governing the radiological behaviour.

The results show that the short-term activity of the HRNS system is dominated by structural stainless steel components located close to the neutron source. Austenitic steels containing nickel exhibit the highest specific activation, while large ferritic shielding components govern the overall radioactive inventory due to their substantial mass. The tungsten beam dump shows very high initial activation driven by medium-lived isotopes such as ¹⁸⁵W and ¹⁸¹W. At longer cooling times, the residual activity becomes dominated by long-lived radionuclides in stainless steels (e.g. ⁵⁵Fe, ⁶⁰Co and ⁶³Ni) and by tritium produced in boron-containing materials such as B₄C used in neutron collimation and absorption components.

The study demonstrates that the radiological behaviour of fusion neutron diagnostics is controlled by the combined effects of neutron exposure, material composition, and component mass. The results provide guidance for material selection and detector design aimed at minimizing activation and optimizing radiological performance of neutron diagnostic systems in future fusion facilities.

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