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Enhancing Reactor Performance: Computational Study on Optimizing Beryllium Shim Plates in the Nigerian Research Reactor-1

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This study investigates the efficiency of beryllium shim plates in the Nigerian Research Reactor-1 (NIRR-1), also known as the MNSR, to assess their impact on reactor performance. The research focuses on the reactor's unique design, the material properties of the shims, and their manufacturing accuracy. The WIMS-ANL code is utilized, employing multi-region integral transport theory, to solve the neutron transport equation and obtain group constants for various reactor components. Cross-section data, including scattering, absorption, and fission cross sections, are derived from ISOTXS files containing nuclear properties, energy levels, and decay characteristics of isotopes. The behavior of neutrons in the fuel region is analyzed using a super-cell representation, providing essential parameters such as diffusion coefficients, absorption cross sections, and fission cross sections. Group constants for non-fuel regions, including beryllium, water, control rods, and the reactor tray, are also generated. The REBUS-ANL code plays a significant role in calculating the reactor multiplication factor and excess reactivity, solving the neutron diffusion equation numerically with consideration of the reactor's geometry, material properties, and neutron cross sections. The study calculates the efficiency worth of beryllium shims in both high-enriched uranium (HEU) and low-enriched uranium (LEU) cores and presents the relationship between shim thickness and excess reactivity. The results demonstrate that beryllium shim plates effectively compensate for reactivity losses due to fuel burn-up and fission product accumulation. Optimal shim thickness is determined to maintain the desired excess reactivity level. The study emphasizes the critical role of computational tools, such as the WIMS-ANL and REBUS ANL codes, in reactor design, optimization, and safety analysis. The findings highlight the positive impact of beryllium shim plates on reactivity and safety in the Nigerian Research Reactor-1 (NIRR-1). These shims play a crucial role in maintaining reactivity levels and contribute to the overall safety features of the reactor. Beryllium's advantageous properties, including high thermal conductivity and low neutron absorption cross-section, make the shims effective heat conductors, minimizing the risk of fuel overheating. In small research reactors like the NIRR-1, effective heat management is essential for stable and safe operation, making the beryllium shims important components. Moreover, the presence of beryllium shims in the NIRR-1 allows for flexibility in adjusting the neutron flux distribution within the reactor core. By strategically placing the shims, reactor operators can optimize the neutron flux to meet specific experimental or operational requirements. This capability is particularly valuable in research reactors, enabling tailored neutron irradiation conditions for scientific studies, materials testing, neutron activation analysis, and radioisotope production. The presence of beryllium shims enhances reactivity, contributes to safety through heat conduction, and allows for customizable neutron flux distribution in the NIRR-1. These findings have implications for reactor design, optimization, and safety analysis, ultimately supporting stable and efficient operation of the Nigerian Research Reactor-1. The combined capabilities of the WIMS-ANL and REBUS-ANL codes provide powerful tools for modeling and simulating neutron behavior, calculating group constants, and determining reactor performance. These tools contribute to reactor design, optimization, and safety analysis, supporting efficient and reliable nuclear energy systems.

Keywords: Nigerian Research Reactor-1, NIRR-1, MNSR, beryllium shim plates, reactor performance, efficiency, neutron transport equation, WIMS-ANL code, multi-region integral transport theory, group constants, ISOTXS files.

Abstract Category

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