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Safety and Logistics for SMRs: Brazil's Contribution to Modeling Fresh and Spent Fuel Transportation Based on PWR Data

The global energy transition points to Small Modular Reactors (SMRs) as a promising solution for decarbonization and flexible nuclear expansion. However, the success of this technology critically depends on resolving its inherent logistical and safety challenges, especially in the transportation of fresh and spent fuel. This study addresses an emerging regulatory and operational gap, using Brazil's vast and consolidated experience with Pressurized Water Reactors (PWRs), the most likely technological basis for the first generation of SMRs, as a key project and case study.

Reference articles (Nuclear Technology, 2019; Waste Management, 2018) already indicate that the modularity and compact design of SMRs fundamentally alter packaging and transportation strategies, requiring a reassessment of safety standards[1,2]. This work aims to go beyond identifying the problems, providing a practical and adaptive roadmap that ensures the radiological and physical safety of SMR-PWR fuel transportation in Brazil and, by extension, in any nation with a history of PWRs. Our methodology is anchored in the principles of the IAEA Regulation for the Safe Transport of Radioactive Material (SSR-6), the global regulatory standard that currently does not explicitly and fully address all the necessary changes for the transport of specific radioactive materials and volumes associated with Small Modular Reactors (SMRs). The current International Atomic Energy Agency (IAEA) regulations provide the fundamental safety framework for all radioactive material, but the rise of SMRs introduces new challenges that require adaptations and clarifications.[3] Integrating these standards into the Brazilian context is a primary mission of the National Nuclear Safety Authority (ANSN, Law No. 14,222, of October 15, 2021).[4] We focus on two critical areas:

1) Radiological Safety and Cask Engineering: We will analyze the suitability of traditional transport casks for the potential new characteristics of SMR fuel (higher burnup, varied cooling times).[5,6,7] Brazilian experience in source calculation (thermosource), shielding requirements, and radiological monitoring will be adapted to propose package acceptance criteria that accommodate the dimensional diversity and potential increase in the number of shipments that SMRs will generate. The conclusions of this study aim to directly inform future ANSN regulations in this area.

2) Nuclear Security and Logistics: The SMR model, with its potential dispersed deployment in licensed locations, will increase the frequency and length of transportation routes. This intensifies physical security vulnerabilities.[8] The study will detail the route security protocols (tracking, escort, and secure communications) that Brazil should adopt. The goal is to establish a defense-in-depth system that prevents material diversion and ensures prompt response to emergencies, working in close collaboration with the oversight agencies coordinated by ANSN.

This research is not merely a theoretical analysis; it presents a critical and timely contribution to global nuclear infrastructure. By adapting the experience of an established nuclear country to the emerging challenges of SMRs, and by focusing on regulatory solutions that can be implemented by the ANSN, we offer a replicable model for SMR safety and governance, vital for knowledge exchange and the formation of a regulatory consensus that supports the safe and responsible deployment of the next generation of nuclear power.

Keywords: Nuclear Reactors, Nuclear Safety, Radioactive Material Transportation, Spent Fuel, PWR.

Country or International Organization

Instructions

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