

Challenges in Adapting Existing Nuclear Standards for Fusion Breeding Blanket Design and Manufacturing

Nuclear design codes and standards play a critical role in ensuring the safety, reliability, and efficiency of systems, structures, and components in the nuclear industry. Developed by internationally recognized bodies (such as ASME, AFCEN, etc.) based on decades of operational experience and research, with extensive contributions from field experts, these standards reflect proven practices, evolving technologies, and lessons learned from nuclear operations world over. These codes and standards (e.g., ASME BPVC, AFCEN RCC-MRx, etc.) provide rigorous guidelines for material selection, design methodologies, fabrication, inspection, and quality assurance. In addition, they help establish a common framework for regulatory compliance, reducing operational risk and facilitating international consistency and collaboration and are very essential for safeguarding public safety and upholding credibility of the nuclear sector [1-2].

While the existing codes and standards are well-established frameworks for fission reactor components as these codes were primarily developed based on materials, loading conditions, and operating environments typical of fission systems, they present significant limitations when applied to fusion reactor components and lack provisions for the unique challenges encountered in fusion. That said, codes like RCC-MRx offer significant advantages over the ASME BPVC for the design of fusion-specific components, such as the breeding blanket, thanks to their more comprehensive treatment of high-temperature behaviour, irradiation effects on candidate materials, and support for advanced manufacturing techniques. Nevertheless, important gaps remain, and continued development is essential to fully address the complex requirements of fusion reactors. For instance, while RCC-MRx explicitly recognizes diffusion welding as a special welding process applicable to both homogeneous and heterogeneous alloy joints, the ASME BPVC does not. Furthermore, neither code currently includes provisions for additive manufacturing techniques even for components classified as Safety Important Component-3 (SIC-3) or Safety Related (SR) or non-SIC, despite its growing importance in producing complex geometries typical of fusion reactor designs [3-4].

The present work highlights these important aspects by critically examining the applicability of existing nuclear design codes, particularly assessing the RCC-MRx and ASME BPVC, to fusion reactor components, with a focus on the breeding blanket design and manufacturing. It assesses the strengths and limitations of both the codes in addressing fusion-specific challenges and their progress toward harmonization through integration within national regulatory licensing frameworks. By pinpointing existing gaps and outlining areas for improvement, this work aims to support the ongoing development and adaptation of nuclear codes to better meet the complex requirements of fusion energy systems.

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