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Overview of ARIES-CS In-vessel Components: Integration of Nuclear, Economic, and Safety Constraints in Compact Stellarator Design

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As an alternate to the mainline magnetic fusion tokamaks, the stellarator concept offers a steady state operation without external driven current, eliminating the risk of plasma disruptions. The earlier 1980s studies delivered large stellarators with an average major radius exceeding 20 m. The most recent development of the compact stellarator concept has led to the 3 years power plant study of ARIES-CS, a compact stellarator with 7.75 m average major radius, approaching that of tokamaks.

Two blanket concepts were studied for ARIES-CS: a dual-cooled LiPb/He/FS system as a reference concept and a self-cooled LiPb blanket with SiC/SiC structure as a backup. The first wall configuration deviates from the standard practice of uniform toroidal/poloidal shape to achieve compactness. Modeling such a complex geometry for 3-D nuclear analysis was a challenging engineering task. A novel approach based on coupling the CAD model with the MCNP Monte Carlo code was developed to model, for the first time ever, the complex stellarator geometry for nuclear assessments.

The most important engineering parameter that influences the machine size and cost is the minimum distance between the plasma boundary and mid-coil. Accommodating the blanket and shielding components represented another challenging task. An innovative approach utilizing a non-uniform blanket combined with a highly efficient WC shield for this highly constrained area reduced the radial standoff, major radius, and cost of electricity by 25-30%, which is significant. Equally important is the consequence of the substantial reduction in ARIES-CS radwaste volume compared to previous stellarator designs.

The objective of this paper is to review the nuclear elements that received considerable attention during the design process and provide a perspective on their successful integration into the final design. Among these elements are the radial build definition, the well-optimized in-vessel components, the carefully selected nuclear and engineering parameters to produce an economic optimum, and the overarching safety and environmental constraints to deliver an attractive, reliable, and truly compact stellarator power plant.