

# Key Physics and Technology Issues Compact Stellarator Power Plants

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Results of a detailed and integrated study of compact stellarator configurations as fusion power plant, ARIES-CS, are reported in this paper. The first major goal of the ARIES-CS research was to investigate whether stellarator power plants can be made to be similar in size to advanced tokamak variants. We focused our analysis on quasi-axisymmetric (QAS) configurations as they are able to operate at a low plasma aspect ratio ( $\sim 4-5$ ). Our efforts to reduce  $\alpha$ -particle loss rate led to new criteria for optimizing QAS configuration. We also developed a non-uniform blanket and a WC-shield, optimized to provide shielding comparable to a regular breeding module but with a much reduced ( $\sim 30\%$ ) radial thickness. The total tritium breeding including all modules is  $\sim 1.1$ . The second major goal of the study was to understand and quantify, as much as possible, the impact of complex shape and geometry of fusion core components. It became evident early on that the 3-D shape of the plasma and the coil (and the components between them) necessitates 3-D analyses of various components -- typical correlations and insight developed for axisymmetric fusion devices are not appropriate for stellarator geometry. As such, we directly used 3-D CAD models in many of our analyses. Moreover, we found that the results are quite sensitive to the details of 3-D shape of components and slight variations can result in substantial changes. Finally, we have found that engineering configuration as well as assembly/maintenance procedures are key elements in optimizing a compact stellarator -- in some cases, these issues determine the choice of technologies. Examples include the selected port-based maintenance scheme which requires a compatible internal design of the fusion core and led to the choice of a ferritic-steel, dual-coolant blanket; and the irregular shape of the superconducting coil that necessitates development of inorganic insulators for high-field magnets. In this paper, trade-offs among physics and engineering constraints are highlighted; key design features and analyses are described; and the major R&D issues are discussed.