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Insights from Systems Code Analysis on Power Exhaust Requirements for Future Fusion Power Systems

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Recent analysis using the GA systems code (GASC) has provided new insights into the power exhaust requirements for future fusion power systems. This analysis was enabled by improvements in the underlying models for power exhaust, magnet technology limits, bootstrap current, and costing as well an improved optimization algorithm capable of identifying optimum solutions for a range of assumptions and constraints. This analysis has confirmed the importance of power exhaust limitations in systems with assumed confinement quality consistent with the confinement scaling used for ITER (H98y2 = 1.0). Under such an assumption, the device size and associated cost is critically dependent on the assumed heat flux handling capability of the facility. For example, decreasing the maximum heat flux assumption from 10 MW/m2 to 5 MW/m2 for a 200 MW-e pilot plant results in an increase in device size from 6.75 m to 8.4 m (and a 20% increase in estimated capital cost). At this level of confinement, the power exhaust limitations serve as the primary constraint on the plasma device size and associated cost.

Importantly, GASC analysis indicates that this sensitivity to the assumed heat exhaust limits decreases strongly as confinement quality increases even as the overall size of the device decreases significantly. In fact, at high confinement quality (e.g., H98y2 = 1.7), the sensitivity largely disappears with other factors such as the stability limit and neutron wall loading becoming the dominant factors. Detailed analysis suggests that there are two contributing factors to this reduced sensitivity. First, as H98y2 increases, the overall heating requirement to maintain the necessary plasma energy (and hence fusion power producing capability) increases markedly. Second, higher H98y2 reduces the required level of plasma current required to provide the necessary level of absolute confinement. The reduced plasma current leads to an expansion of the SOL heat flux width and a concomitant decrease in the divertor heat flux. These effects are sufficient to overcome the impact of the smaller device size on the anticipated heat flux.

The improved heat flux models now employed GASC have also allowed exploration of the value of various techniques for reducing the heat flux. These include the ability to systematically evaluate the best impurity (or impurities) for core and divertor radiation as well as the potential gains possible through poloidal flux expansion, toroidal flux expansion, and target inclination. This along with further analysis will be presented.

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