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The Operational Window for Divertor Detachment in a Fusion Reactor –A Physics-Technology Integrated Approach

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The operational window of the divertor in a fusion reactor is mainly given by power handling requirements limited by the material properties, and He ash exhaust requirements limited by the effective pumping speed performance of the divertor vacuum system. Hence, the divertor has to reconcile key physics and technology functions in a sound way. This paper is presenting an integrated assessment of the operational window for an ITER-type divertor in the European pulsed DEMO1 scenario.

While the high recycling divertor regime may be acceptable for ITER, the high heat flux and the large incident ion fluxes seriously limit the lifetime of the divertor target. As a solution, the detached divertor regime is investigated here in view of DEMO. The expected detachment characteristics, such as the existence of a considerable electron pressure drop along the field lines in the scrape-off layer, and the compatibility of the decrease in plasma flux to the divertor plate with the observed increase of neutral pressure and hydrogen emission from the divertor region, are calculated in the light of an existing analytical and numerical model for plasma detachment. The detachment criterion defines very clearly operational limits that can be translated into requirements on the gas throughput and the exhaust vacuum system. In order to illustrate this interrelation, a quantitative analysis has been made for two torus exhaust vacuum system configurations in a DEMO reactor environment. One is based on scaled-up ITER style cryopumps, including their complex pumping speed dependence on pressure and gas species; the second is based on vapour diffusion pumps which have recently been introduced as reference for the European DEMO. In both cases, the geometry of an ITER type divertor is being used and Ar being utilized as radiative seeding gas, the window of divertor detachment operation is investigated depending on plasma and neutral gas densities. The analysis compares the two configurations and provides the number of pumps required for steady-state operation under detached conditions. The chosen approach is novel as such that it results in a pressure dependent pump albedo which takes into account that the neutrals are in collisional flow regime at various degrees of rarefaction. This concept represents a substantial improvement over the previously employed assumption of constant albedo.

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