

Impurity seeding for tokamak power exhaust: from present devices via ITER to DEMO

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A future fusion reactor is expected to have all-metal plasma facing materials (PFM) to ensure low erosion rates, low tritium retention and stability against high neutron fluences. As a consequence, intrinsic radiation losses in the plasma edge and divertor are low in comparison to devices with carbon PFMs. To avoid localized overheating in the divertor, intrinsic low-Z and medium-Z impurities have to be inserted into the plasma to convert a major part of the power flux into radiation and to facilitate divertor detachment. This is already necessary for very high heating powers in the all-tungsten tokamak ASDEX Upgrade, and will soon be required in the JET tokamak with the ITER like beryllium-tungsten wall when full heating power becomes available. For burning plasma conditions in ITER, which operates not far above the L-H threshold power, a high divertor radiation level will be mandatory to avoid thermal overload of divertor components. Moreover, in a prototype reactor DEMO a high main plasma radiation level will be required in addition for dissipation of the extremely high alpha heating power. Inspection of the relevant atomic data suggests a few gaseous atomic species which can be used for radiative cooling. For divertor plasma conditions in present day tokamaks and in ITER, nitrogen appears most suitable regarding its radiative characteristics. If main chamber radiation is desired as well, argon and possibly krypton are further candidates. Analytic calculations suggest the parameter P_{sep}/R , the power flux through the separatrix normalized by the major radius, as a suitable scaling for the extrapolation of present day divertor conditions to larger devices for fixed electron density. The scaling for main chamber radiation has a higher, more favourable dependence of about $P_{rad,main}/R^2$. For investigating the different effects of main chamber and divertor radiation and for optimizing their distribution, a double radiative feedback system has been implemented in ASDEX Upgrade. About half the ITER/DEMO values of P_{sep}/R have been achieved so far, and close to DEMO values of $P_{rad,main}/R^2$, albeit at lower P_{sep}/R . Prospects how these values can be further enhanced will be discussed. Considering an integrated operational scenario of a fusion reactor, fuel dilution and the impact of core radiation on energy confinement have to be taken into account. Another strong constraint for plasma parameters at the target arises from the maximum permissible erosion rate of divertor components, which translate into maximum temperatures below 3-5 eV in front of the surface.