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High performance Ne-seeded baseline scenario in JET-ILW in support of ITER

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The first goal of the ITER device is to produce "burning" deuterium-tritium (DT) plasmas with ~500 MW of fusion power for durations of 300-500s. A large fraction (typically 60-70%) of the thermal plasma exhaust power (~100 MW) crossing the magnetic separatrix needs to be radiated via impurity-seeding to remain within the power handling capability of the metallic (tungsten, W) divertor targets. The required energy confinement (τ_E) on ITER necessitates an H-mode, with high pedestal pressure and temperature, usually associated with high transient heat loads (ELMs) on plasma-facing components. These loads need to be mitigated or eliminated since W target erosion will be both inconsistent with the ITER divertor lifetime and lead to excessive W core plasma contamination.

Recent experiments at JET with record input powers of P_{IN} ~35 MW have shown that neon (Ne) seeding is compatible with high performance H-mode. Previous experiments at JET at lower P_{IN} found that Ne-seeding did not achieve a significant target power load decrease without substantial pedestal degradation and periodic loss of H-mode; in fact the dual requirement of partial detachment with high pedestal pressure was only possible with nitrogen (N) seeding. Although partial detachment was also not achieved at this higher P_{IN}, the pedestal pressure improvement found with N was obtained with Ne, as well as a factor 2 decrease in effective heat diffusivity χ_{eff}. An additional and key finding of these recent higher power Ne-seeding experiments was that, at the highest achieved radiative fraction ($f_{rad} = P_{rad,tot}/P_{in}$=0.8), high performance stationary conditions with small ELMs or no ELMs were obtained, delivering a very attractive scenario. These discharges have H_{98}~0.9, β_N~2.3, Greenwald fraction $\langle n\rangle/n_{GW}$~0.68, Z_{eff}~2.7 and a neutron rate R_{nt}=1.6x10^{16} n.s^{-1}, parameters not achieved with N under the same conditions. Integrated modelling carried out with QuaLiKiz within the JETTO/JINTRAC suite of codes identifies that the increased central T_i, T_e and R_{nt} with Ne-seeding are due equally to reduced core transport (via stabilization of ITG and ETG instabilities) and as well as an increased pedestal T_i and T_e. The simulations also find that the higher value of pedestal electron density, $n_{e,ped}$ and lower T_i/T_e ratio of N versus Ne-seeded plasmas are the key reason for the lower R_{nt} . These new results are extremely encouraging for ITER, indicating that the preferred baseline scenario without N-seeding and the associated time-costly high temperature regeneration and reduced plant duty cycle is realistic.

An important as yet unresolved issue of these high-power Ne-seeded discharges is the apparent lack of clear partial detachment at the outer target. The pulses (in both N and Ne) JET higher power Ne and N-provide key benchmark discharges for plasma boundary simulations performed with the SOLPS-ITER code suite, the workhorse for the ITER divertor design. The simulations, with all drifts and currents included, show little difference between Ne and N in JET with both impurities leading to partial and even full detachment. Experimentally, this is only clearly found with N-seeding whilst simultaneously maintaining high confinement. The reason(s) for this discrepancy is being investigated and will be reported.

As part of the current JET DTE2 campaign, Ne-seeded pulses are being run for the first time with DT fuel. Predictions with QuaLiKiz expect a fusion power mostly dependent on $n_{e,ped}$ and ranging from 4 MW to 9 MW if $n_{e,ped}$ is varied from 6.6 - 4x10^{19} m^{-3}. In preparation for DT, pulses have been run in pure T, finding an increased W source in comparison with D (due to higher sputtering yield) causing low ELM frequency or ELM-free conditions prior to the Ne-seeding phase and requiring a significant increase in the gas rate in T to achieve stationary conditions. Fortunately, in DT, stationary conditions have been easily obtained for unseeded plasmas even with an increased W source with respect to D. The higher performance Ne-seeded counterparts will now be performed for the first time in DT and the results reported in this contribution.