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INTRODUCTION

Carbon is the principal impurity in JET. Methane screening experiments [1] quantify the ability of the SOL/divertor system to ionise carbon and transport it to the divertor, preventing core plasma contamination. Previous JET publications studied ELM-averaged H-Mode screening [2], and separately, evaluated the methodology of L-Mode screening measurements [3]. This paper extends the L-Mode measurements to include relevant plasma parameter scans, and DIVIMP modelling of the L-Mode screening.

1. EXPERIMENT

The carbon screening was measured by injecting deuterated methane (CD_4) for 3s (about 6 energy confinement times) into JET plasmas from several main chamber and divertor locations (see Fig. 1 of [3]). The carbon screening, S_c is defined as:

$$S_c = \Delta N_c / (\Gamma_c \tau_p^*). \tag{1}$$

The core carbon content change, ΔN_c (due to the methane puffing) was measured by Visible Bremsstrahlung (VB) or charge exchange (CX). τ_p* was determined from the evolution of the core carbon content to be about the energy confinement time, τ_E. The screening so defined is the fraction of injected carbon that reaches the last closed flux surface (LCFS) [1]. JET L-Mode plasmas had S_c values in the range of .05 to .2 for methane puffed from the outer, horizontal mid-plane (Fig.1). The screening is determined by SOL phenomena and the JET SOL characteristic lengths depend upon density, applied power, and connection length [4]. L-Mode screening was measured scanning those parameters as well as the methane injection rate, and plasma current. Empirically, an L-Mode scaling, S_c*, for carbon injected as methane at the horizontal mid-plane, with the carbon content measured by VB, was obtained by regression:

$$Sc^* = 0.1 / (n_e(0)\ \tau E). \tag{2}$$

In equation (2), the central density, ne(0), has units of $10^{19}/m^3$ and the gross energy confinement time, τ_E has units of sec. The regression coefficients have been rounded to unity which accounts for the slightly poorer fit of the data in the current scan than in the density scan (Fig.1). Equation (2) describes the JET L-Mode data within the 20% measurement uncertainty.

2. MODELLING

DIVIMP [5] was used to model the experiment, calculating that carbon injected at the mid-plane injected was ionised about 1 to 3cm from the Last-Closed-Flux-Surface (LCFS). DIVIMP also calculated that the thermal forces and the Coulomb coupling to the deuterium SOL flow dominated the parallel motion of the carbon ions. The carbon diffusion perpendicular to the field lines, has an unknown coefficient that might be related to the SOL ion thermal conductivity. Onion Skin Modelling

[6] determined that the ion thermal conductivity was 0.1 to 0.15m^2/sec for these L-Mode plasmas. The DIVIMP code fits the measured S_c^{VB} or S_c* (Equation (2)) if the carbon diffusion coefficient is slightly smaller than the ion thermal conductivity and increases with density. The DIVIMP modelling gives a clear physical origin for the density dependence of the screening. At higher density, the carbon is ionised further away from the LCFS, and is more likely to transport to the divertor where it is deposited. We have yet to explore the meaning of S_c*'s dependence upon confinement time and independence from connection length. Using CX data (for ΔN_c in Equation (1)) yielded screening values 0.35% lower than using VB data (Fig. 2). That agreement is considerably better than reported in [3] due to re-calibration of the CX system alignment. The Carbon particle diffusion coefficient required by DIVIMP to fit the CX experimental screening is also correspondingly reduced. The general features of the CD_4 fuelling location scan (Fig. 2) were modelled by DIVIMP with the worst screening observed at the mid-plane and the best screening observed in the divertor. The screening at the machine top was twice as good as that observed at the horizontal mid-plane, and indicated the importance of the SOL flow (usually measured to be a Mach number of 0.5 at the vessel top but, presently not understood, and therefore not calculated in DIVIMP). Flows could be imposed upon the DIVIMP SOL, and SOL flow patterns with a stagnation point near the vessel top had worse screening at the top, relative to the mid-plane. Also shown in Fig. 2 is the screening of similar JET L-mode, limited plasmas. These plasmas had 3 to 5 times worse screening than the diverted plasmas, indicating the effectiveness of the divertor/SOL at screening hydrocarbon sources located in the main chamber or divertor. The screening of the limited plasmas was independent of methane fuelling location. The DIVIMP calculation of the divertor screening indicates better screening was calculated than was observed. Possibly, the experimental values were influenced by methane gas leakage out of the divertor.

3. DISCUSSION

Screening was also measured for different plasma configurations (Fig. 3). Operation with the strike points located in the corner (the pump port in the divertor) did not change the screening though increasing the deuterium pumping. A "high clearance" plasma was designed to increase the main chamber clearance (closest approach) of the LCFS from typically 5cm to 15cm. However, the screening for methane injected at the horizontal mid-plane, did not change. Apparently, location of material surfaces (such as RF antennae or poloidal limiters) inside the main chamber and within 5cm of the LCFS do not affect the methane screening or divertor performance.

Operation with the X-Point embedded into the top of the Septum, did not significantly change the methane screening. Such operation makes the divertor similar to a pumped limiter. The fact that the screening was unchanged (or slightly improved) may indicate that it is possible to separate the carbon impurity pumping from the heat flow.

The horizontal mid-plane, CD_4 screening of helium L-Mode plasmas (heated by Helium neutral beams) was also consistent with equation (2). Apparently, the helium SOL screened carbon similarly to a deuterium SOL even though the higher Coulomb collisional coupling to helium should accelerate Carbon ions faster towards the divertor.

SUMMARY.

Methane screening experiments in JET L-Mode plasmas indicate the divertor is effective at preventing impurities from reaching the plasma core. Empirically, the screening improved at higher density and higher energy confinement.

REFERENCES

[1]. G.M.McCracken, *et a*l, Nucl. Fus. **33**, 1409 (1993)

[2]. M.F.Stamp, *et a*l, J Nucl. Mat. **266-269**, 685 (1999)

[3]. J.D.Strachan, *et a*l, J. Nucl. Mat. **290-293**, 972 (2001)

[4]. S.K.Erents, *et a*l, Nuclear Fusion **40**, 295 (2000)

[5]. P.C.Stangeby, *et a*l, J. Nucl. Mat. **241-243**, 358 (1997)

[6]. P.C.Stangeby and J. D. Elder, J. Nucl. Mat. **196-198**, 258 (1992)

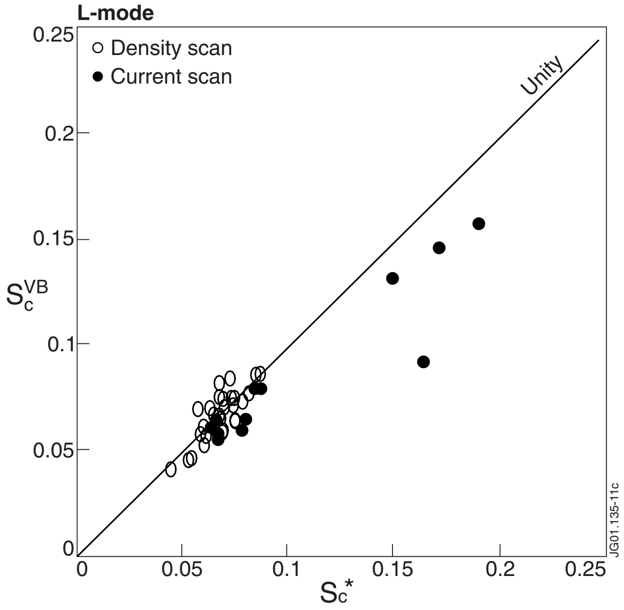

Figure 1: L-Mode screening measured by visible Bremsstrahlung for density and current scans as a function of the JET empirical scaling, Equation (2).

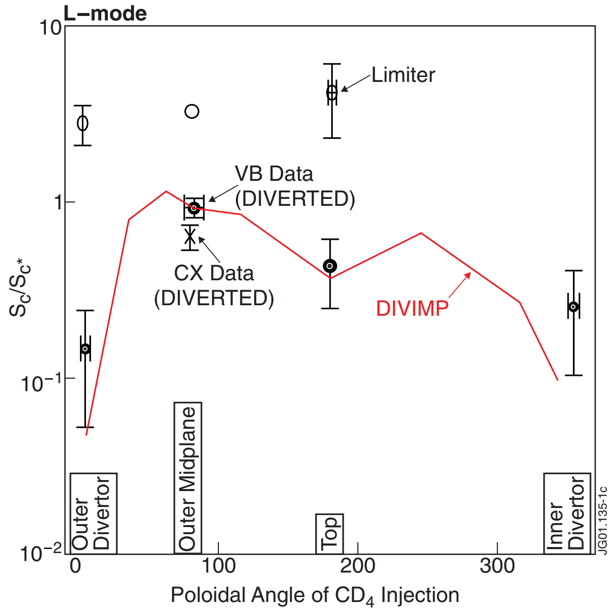

Figure 2: Comparison of DIVIMP and JET L-Mode Screening normalised to Equation (2) plotted vs the poloidal angle of methane injection. Similar L-mode plasmas were run on the vertical divertor targets and on the outer limiters.

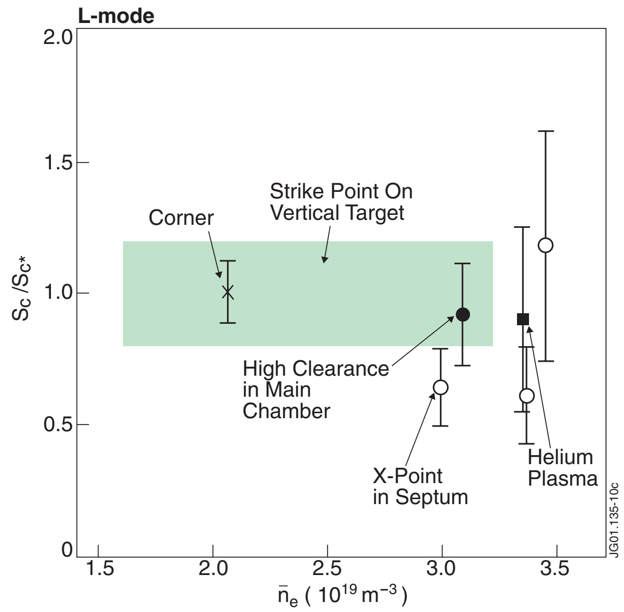

Figure 3: The carbon screening normalised to Equation (2) for 2.5MA L-Mode plasmas plotted vs density. The shaded region represents the deuterium plasmas from Fig. 1 with strike points on the vertical targets in the divertor and X-Point about 10cm above the Septum surface. Mid-plane methane injection was used for all discharges.