The EUROfusion JET-ILW global confinement database

M. Maslov[1], M. Romanelli[1], M. Brix[1], J. Flanagan[1], A. Boboc[1] and JET Contributors*

[1]*United Kingdom Atomic Energy Authority, Culham Centre for Fusion Energy, Culham Science Centre, Abingdon, Oxon, OX14 3DB UK*

**See the author list of "X. Litaudon et al 2017 Nucl. Fusion 57 102001"*

1. Introduction

In 2016, the EUROfusion profile and confinement database project was launched. The goal of the project is to coordinate the databases of the EUROfusion tokamaks and contribute to building a global confinement dataset of tungsten wall experiments.

This work reports on the current status of the JET-ILW database. Scaling of the thermal energy confinement time is done for the standard IPB98y2 parameters [1]. To improve the predictive capability of the scaling laws we looked at other parameters which are known to affect the global confinement but not yet used in the international database [2].

2. JET-ILW database summary

At the time of writing the database contains 627 entries of type-I ELMy H-mode plasmas, from the stationary phases. Around 250 more entries are awaiting final diagnostic validation and will be available shortly. In all the cases gas dosing is used for ELM mitigation to prevent impurity accumulation [3], no plasmas with kicks/pellets/EFCCs [4] or impurity seeding are included.

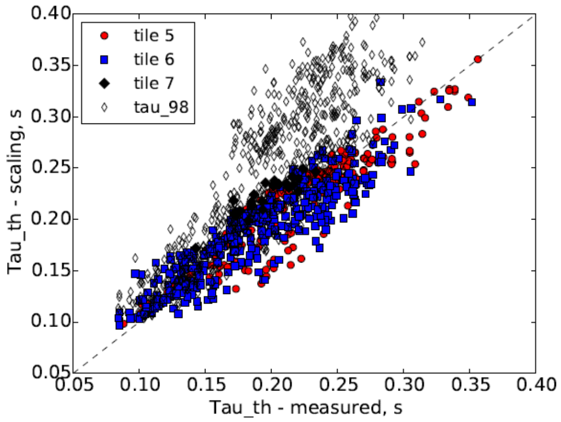

Figure 1: Energy confinement time – scaling versus experimental. Solids – JET ILW scaling separated by divertor configuration, opens symbols – τ_{98}

Log-linear scaling of the thermal energy confinement time in the database was derived using ordinary least square method. The result is shown in table 1 (see also figure 1), together with the IPB98y,2 scaling. The most notable differences between the metallic wall JET and the IPB98y2 scaling are stronger isotope mass dependence (reported in [5]), weaker power confinement degradation, lack of density dependence and small negative exponent for Bt.

Scaling	const	I_p	B_t	n_{19}	P_L	M	R	ε	κ_α
IPB98y,2	0.0562	0.93	0.15	0.41	-0.69	0.19	1.97	0.58	0.78
JET-ILW	0.0612	1.19	-0.18	0.03	-0.59	0.41	1.97	0.58	0.78

Table 1: Coefficients for the log-linear global confinement time scaling, IPB98y,2 and as derived from the JET-ILW database. Ordinary least mean square fit used, exponents for R, ε and κ_α were fixed.

3. Additional parameters affecting energy confinement

The thermal energy confinement time in JET-ILW does depend on other parameters, in addition to the standard ones shown in table 1. Additional gas dosing used to prevent accumulation of heavy impurities is known to deteriorate the confinement. The effect of the gas dosing itself depends on the location it is injected from and on the configuration of the divertor strike points, i.e. recycling and pumping. Therefore, on its own the fuelling rate is not a suitable parameter to use in the scaling, especially in case of a multi-machine database.

In this work we attempted to find a parameter which characterizes the gas dosing effect and takes into account the pumping/recycling properties of JET plasmas, therefore could potentially be used in the H-mode confinement scaling and improve predictions towards ITER. For that purpose, the following values are stored in the JET-ILW database: divertor configuration, subdivertor neutral gas pressure, main chamber neutral pressure and the near scrape of layer plasma density measured by the Li-beam diagnostic.

Divertor configuration is simplified to have only 3 possible values, corresponding to 3 divertor tiles where the outer strike point can be found: horizontal bulk W tile located at a distance from the pump throat (tile 5), horizontal W-coated tile near the pump throat (tile 6) and vertical target W-coated tile 7. In case of tile 7 configuration, the pumping throat located in the private flux region. The subdivertor neutral gas pressure is measured in the main lower port by a baratron underneath the cryopump. The main chamber neutral pressure is provided by a penning gauge located in the main equatorial port extension. The Li-beam diagnostic measures the plasma edge density at the top of the machine. The position of the separatrix is not know to the required precision, therefore, for the purpose of this work, the separatrix position was assigned to the pivot point of the density profile at the bottom of the pedestal (see figure 2). In various works it may be referred to as "pedestal foot" or "density shoulder". Note that it may not necessarily coincide with the density at the magnetic separatrix. We now look at the behaviour of these additional parameters individually.

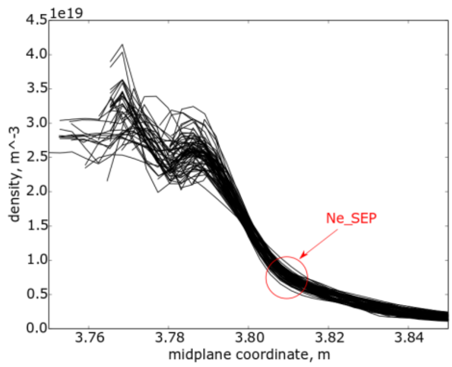

Figure 2: example of the edge density measurements overlaid, indicating where the Ne_SEP values is taken

<u>Subdivertor pressure</u>: figure 3a shows the subdivertor pressure versus the total gas dosing rate. The points are split in two groups: where the majority of the gas fuelling is done by two gas injection modules (GIMs) located in the divertor near the cryopump, known as GIM9 and 10 (red), and the second group are all other cases (black). These two divertor GIMs seem to deposit

about half of the dosing gas directly into the cryopump and only half actually enters the plasma and/or reaches the subdivertor area where the neutral pressure is measured. To account for fuelling efficiency of these particular gas modules, we introduce the effective total gas fuelling, where the contribution of GIM9+10 is taken with a factor of 0.5 (figure 3b).

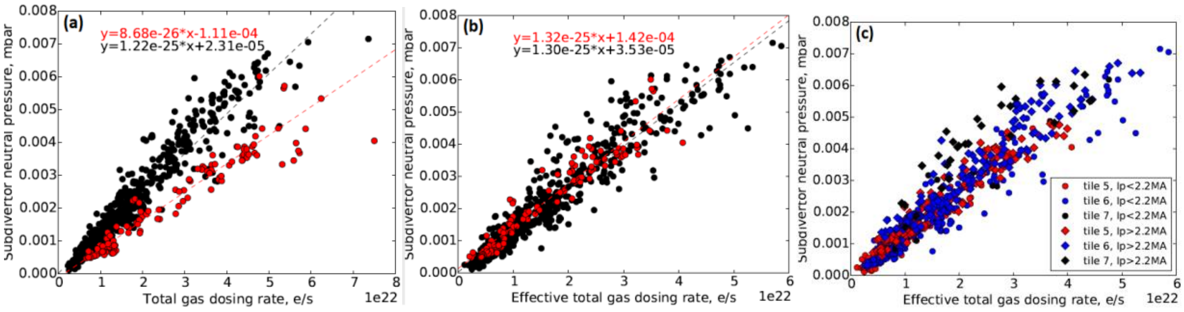

Figure 3: Subdivertor neutral gas pressure versus gas dosing before (a) and after (b) accounting for GIM efficiency. In (c) points are divided by divertor configuration and Ip value.

On figure 3c the same points are shown but separated by divertor configuration and plasma current (below and above 2.2MA). No systematic Ip dependence can be seen and tile 5/6 configurations are mixed together. Majority of tile 7 points are slightly above the general trend, but the statistics is not sufficient to conclude anything definitively.

Main chamber neutral pressure exhibits slightly different behaviour. The value is also increasing together with the gas fuelling, but there are other dependencies as well. On figure 4 one can see that the ratio of subdivertor to main chamber pressure depends on the plasma current, very pronounced if main chamber fuelling is used and less clear but still visible for divertor fuelling. In the first case tile 5 also tend to have lower P(subdiv)/P(main ch.) than tile 6, but that trend disappears for the divertor fuelling cases.

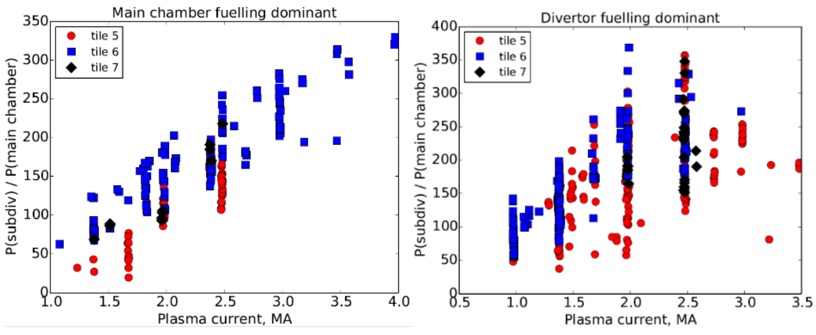

Figure 4: ratio of subdivertor to midplane neutral pressure for dominant main chamber and divertor dosing

Ne_SEP measurements are shown on figure 5a as a function of the effective gas dosing, for different divertor configurations. As one can see, Ne_SEP increases with gas fuelling for any configuration and significantly larger for the tile 5 in comparison to tile 6/7 for the same gas dosing. That is consistent with the fact that plasmas on tile 5 require about half of the dosing for the same effect on the density and ELMs than tiles 6 and 7 configurations.

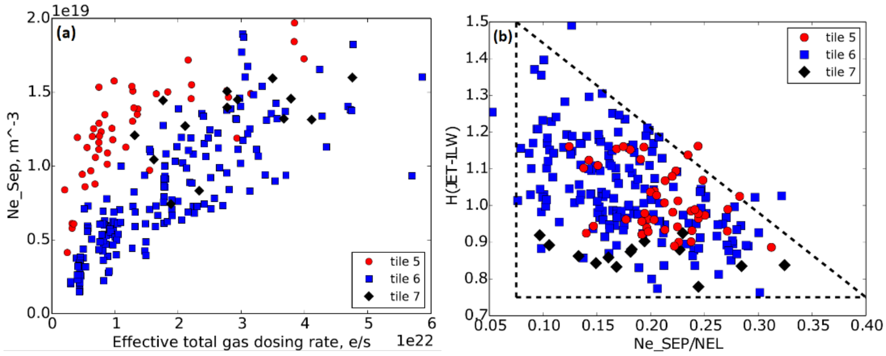

Figure 5: Ne_SEP measurement versus effective gas dosing (a), and experiment/scaling confinement time ratio versus Ne_SEP normalized to the line averaged plasma density (b).

4. Discussion and conclusions

In a steady state condition, the particle balance must be preserved, i.e. the total gas exhaust must be equal to the dosing rate minus variation in the plasma and wall fuel content. Majority of the pumping is done by the cryopump in the divertor, so once the equilibrium is settled, the neutral pressure near the cryopump is roughly proportional to the total gas input, as plasma density is constant in all database samples and wall outgassing does not seem to have a significant impact. The main chamber neutral pressure seems to depend not just on the fuelling rate but also on the SOL dynamic itself (via IP), namely how likely neutrals are to escape the main plasma before reaching the divertor area. The effect of divertor closure, too complex to describe with a simple outer strike point tile number probably also plays a role and contributes to the scatter of points on the figure 4b. At this stage we don’t think that the main chamber or subdivertor neutral pressure can be adequate parameters to characterize the effect of gas dosing on the confinement. Ne_SEP as used in this work does show both the gas dosing rate and divertor configuration dependencies, in the expected manner. Among the parameters considered here, Ne_SEP seems to be the best candidate to use in a confinement scaling in addition to the IPB98y,2 parameters. As shown on figure 5b, an increase in normalized Ne_SEP generally causes degradation of the confinement for tile 5/6 configurations. In the current dataset, confinement in case of tile 7 configurations have much weaker if any dependence on Ne_SEP, but instead shows ~15% flat reduced confinement for all the cases.

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[1] ITER Physics Expert Group on Confinement and Transport *et al* 1999 *Nucl. Fusion* **39** 2175;[2] G. Verdoolaege et al, IAEA 2018; [3] I. Nunes “Plasma confinement at JET”, Plasma Phys. Control. Fusion **58** (2016) 014034; [4] P.T. Lang et al 2013 Nucl. Fusion 53 043004; [5] C. Maggi et al, Plasma Phys. Control. Fusion **60** (2018) 014045;