EUROPEAN FUSION DEVELOPMENT AGREEMENT

EFDA–JET–CP(00)02/02

J Hogan [2], C Grisolia[1], D Hillis[2], W Fundamenski, J Spence, G Corrigan,
P Morgan, G Matthews[3], V Philipps[4]
and the EFDA-JET 2000 work programme contributors

Dependence of Divertor Helium Pressure on Power, Geometry and Confinement Mode in JET*

Dependence of Divertor Helium Pressure on Power, Geometry and Confinement Mode in JET*

J Hogan [2], C Grisolia[1], D Hillis[2], W Fundamenski, J Spence, G Corrigan,
P Morgan, G Matthews[3], V Philipps[4]
and the EFDA-JET 2000 work programme contributors

[1]CEA-Cadarache, F-13108, St Paul lez Durance, France, [2]Oak Ridge National Laboratory, Oak Ridge, TN, USA,
[3]EURATOM/UKAEA Fusion Association, Culham, UK , [4]IPP, Forschungszentrum Julich Gmbh, EURATOM
*Association, D-52425 Julich, Germany**

*This research was sponsered in part by the U.S. Department of Energy, under Contract No. DE-AC05-WO00R22725

1. INTRODUCTION

Experiments carried out as part of a campaign of a JET Exhaust Task Force aimed at characterising divertor and scrape-off layer parameters [1] have also extended the database describing the dependence of the sub-divertor helium pressure on ELM frequency, configuration, and confinement mode. During the characterisation campaign the ELM frequency was varied with a scan in neutral beam power, whilst the configuration was varied by sweeping the separatrix from the corner to the vertical target in the MkIIGB divertor and L-, H-mode and ohmic conditions were obtained. Sub-divertor helium partial pressure was measured with a species-sensitive Penning gauge. When combined with the main results of the characterisation of edge and divertor parameters, this sub-divertor pressure database will in future permit more detailed modelling with the edge codes available at JET. As a preliminary step, a comparison is made of the measured divertor parameters with EDGE2D and SOLPS code results for typical discharges.

2. BACKGROUND

Previous study of helium exhaust and transport in large tokamaks has focussed on the suitability of helium exhaust to meet existing ITER requirements, which have typically been expressed as achieving $\tau He^{*} / \tau E$ (ratio of core helium particle replacement rate to the core energy confinement time) < 10 and $\eta > 0.2$, where the relative divertor enrichment $\eta \equiv$ cHe, div / cHe, core; and cHe, div (resp. cHe, core) is the relative divertor (resp. core) helium concentration. Experiments have thus been carried out under conditions as close as possible to those foreseen for the then-current ITER design, for which these figures of merit were derived. As options for additional flexibility in ITER design have emerged, (e.g. ITER/FEAT) it is seen as desirable to enlarge the existing database by exploring the dependence of key helium exhaust parameters more systematically. Thus, during a JET campaign whose purpose was to characterise scrape-off layer and divertor plasma parameters in the JET MkIIGB (Gas Box) configuration [2], dedicated parasitic experiments were conducted to add to the existing JET database the properties of divertor helium parameter dependence on power, geometry and confinement mode. This database, when combined with the completed database on scrape-off layer and divertor plasma parameter characterisation, will enable more detailed modelling with edge plasma codes (such as the EDGE2D and SOLPS codes installed at JET) along with the neutrals codes EIRENE and NIMBUS.

(This research is sponsored in part by the U.S. Department of Energy, under Contract No. DE-AC05-00OR22725 with Oak Ridge National Laboratory managed by UT-Battelle, LLC. This work was performed under the European Fusion Development Agreement [EFDA].)

A full diagnostic complement for the core parameters was not available for this parasitic experiment: LIDAR profiles for electron density and temperature, and charge-exchange recombination helium concentration profiles are lacking. Thus a complete analysis of the helium compression and enrichment dependence for these discharges is not possible at present. However, as the objective of the characterisation campaign is to make a detailed analysis of divertor transport under the same conditions for which the helium data were obtained, it is expected that the latter results, when available, will be applicable for the helium transport analysis.

A previous study [3] for the Mk I configuration was done under complementary conditions: core profiles were available but the sub-divertor Penning gauge had not yet been installed. It was found that ELMs determine the global helium and neon confinement time, and that radial helium transport is sharply reduced between ELMs. Thus, a study of sub-divertor pressure dependence on ELM frequency has been made for the present data set. This will be useful in the design of future JET helium transport and exhaust experiments, using argon frost, since the dependence of sub-divertor helium pressure on the ELM frequency is an important factor in optimising the helium removal rate.

These experiments add to an extensive growing JET helium transport and exhaust database [3-6].

3. EXPERIMENTAL CONDITIONS; DIVERTOR PRESSURE DEPENDENCE

Table 1 shows characteristic parameters for typical helium seeded discharges obtained during the divertor / edge characterisation experiments. The helium was typically injected in a single short pulse and the configuration was held constant during the helium evolution to equilibrium. Helium concentrations < 30% were obtained.

TABLE 1

Characteristic parameters for typical helium seeded discharges

Shot	Time(s)	Mode	P_{NB} (MW)	W_{ELM} $^{(s-1)}$	$n_e dl$ ($10^{19}m^{-2}$)	$I_{p\ (MA)}$	$\Gamma^{div}(10^{23}$ pt $m^{-2}s^{-1)}$ outer / inner	T_e^{div} (eV) outer / inner
50737	60.0	L	3.9	--	7.6	2.5	19.0 / 15.6	25.0 / 7.0
50739	60.0	H	12.0	5.0	20.0	2.5	19.0 / 12.5	30.0 / 20.0
50741	61.0	H	12.0	5.0	21.7	2.5	43.8 / 19.0	12.0 / 9.0
50741	65.0	L	12.0	--	21.7	2.5	19.0 / 15.6	20.0 / 4.0
50765	72.0	H	3.0	20.0	10.0	0.94	6.3 / 2.5	4.0 / 3.0

The sub-divertor helium partial pressure was obtained for the pulses in this database. Figure 1(a) and (b) show the variation in sub-divertor helium pressure (P_{He}) and helium concentration in discharge 50741. Partial pressure and concentration both rise at t = 22s, when the X-point is raised to a higher position on the vertical target. In neither configuration is there a direct connection of the separatrix to the pumping slot (which would lead to a conductance change) and there is no helium pumping for either configuration. Thus, the strike point movement to a higher position would be expected to reduce the direct flux of helium to the sub-divertor, and thus reduce the sub-divertor helium pressure. However, the change in configuration directly increases the sub-divertor helium concentration and pressure (Figure 1(a) and (b)). There is an increase in the ELM frequency, as is seen in Figure 1(c), at constant beam power and current. The increase of the sub-divertor helium pressure with ELM frequency is related to deterioration of particle confinement in the edge zone, a key ingredient in helium removal [3]. This dependence is further observed in a wider examination of the newly acquired database for this series of experiments. Figure 2(a) shows the observed dependence of ELM frequency on neutral beam power for cases in the database, and the expected increase in ELM frequency with power is observed. Figure 2(b) shows the sub-divertor pressure increase with ELM frequency, with the partial pressure rising toward the level observed in L-mode at high ELM frequency. This dependence is an important element of the design of experiments for optimal helium removal in ELMy H-mode, since there is need to minimise deuterium poisoning of the argon frost layer.

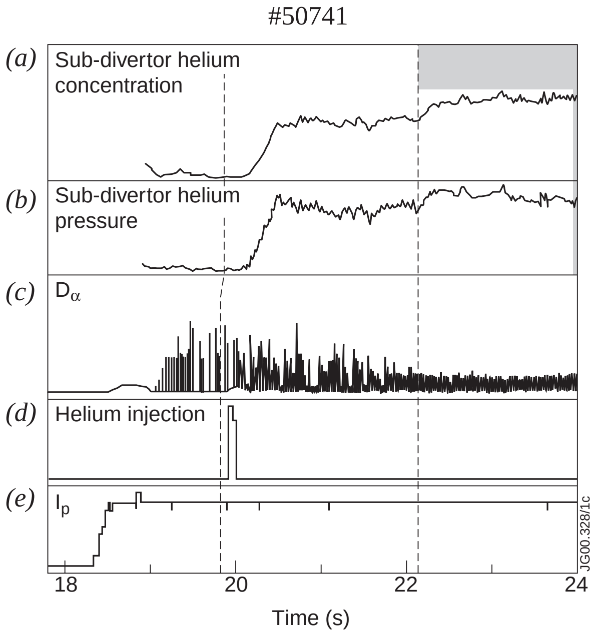

Figure 1: (a) Sub-divertor helium concentration (b) partial pressure (c) D_α signal, (d) injected helium (e) plasma current for #50741

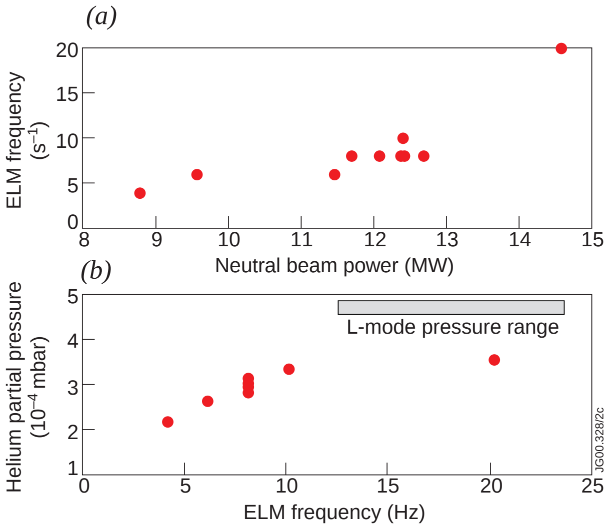

Figure 2: (a) dependence of ELM frequency on beam power (b) dependence of sub-divertor helium pressure on ELM frequency

4. MODELLING

As a first step in the exploitation of this database for helium transport and exhaust studies, the conditions of pulses 50739 and 50741 of Table 1 have been modelled with the EDGE2D and SOLPS codes installed at JET. Figure 3 shows the results of an EDGE2D simulation of the background parameters of #50739. The calculated divertor parameters are in reasonable agreement with the measured values, (e.g., $T_e < 30$ eV, n_e in the range $4 \times 10^{19} m^{-3}$). Similarly, the SOLPS code obtains reasonable agreement for discharge 50741. Because of the sensitive dependence of divertor helium pressure on ELM frequency (Figure 2), however, development of a predictive model for helium transport and exhaust for next step machines will require the validation of a time-dependent impurity coupled core-edge transport model; for example, the COCONUT or b2-Eirene code suites.

5. CONCLUSION

These experiments have enlarged the existing JET helium transport and exhaust database, by adding information on the dependence of helium exhaust parameters on power, configuration and confinement mode. A consistent trend, whereby increased ELM frequency leads to an increase in the sub-divertor helium concentration and pressure, has been observed. This is a trend which will play a role in optimising helium exhaust with argon frost. The divertor pressure database, when combined with the completed database on scrape-off layer and divertor plasma parameter characterisation, will enable more detailed modeling with edge plasma and neutrals codes. And a preliminary simulation of two cases in the helium database has been made with the EDGE2D and SOLPS codes (Figure 4).

REFERENCES

[1] G F Matthews et al, this meeting

[2] G Vlases et al, J. Nucl. Mater 266-269 (1999) 160

[3] D Hillis, J. Hogan, J. Nucl. Mater J. `Nucl. Mater 266-269 (1999) 1084

[4] M Groth et al, in Controlled Fusion and Plasma Physics (Proceedings of the 25th EPS Conference, Prague), Vol. 22C, p. 39 (1998)

[5] H-Y Guo in Controlled Fusion and Plasma Physics (Proceedings of the 26th EPS Conference, Maastricht), Vol. 23J, p. 205 (1999)

[6] D Stork et al, in Controlled Fusion and Plasma Physics (Proceedings of the 26th EPS Conference, Maastricht), Vol. 23J, p. 205 (1999)

[7] M Groth et al, J. Nucl. Mater (Proceedings of the 14th PSI, to be published)

[8] M Fichtmuller et al J. Nucl. Mater 266-269 (1999) 330

[9] D Hillis et al, this meeting

[10] M Wade et al Nucl Fus 38, 1839 (1998)

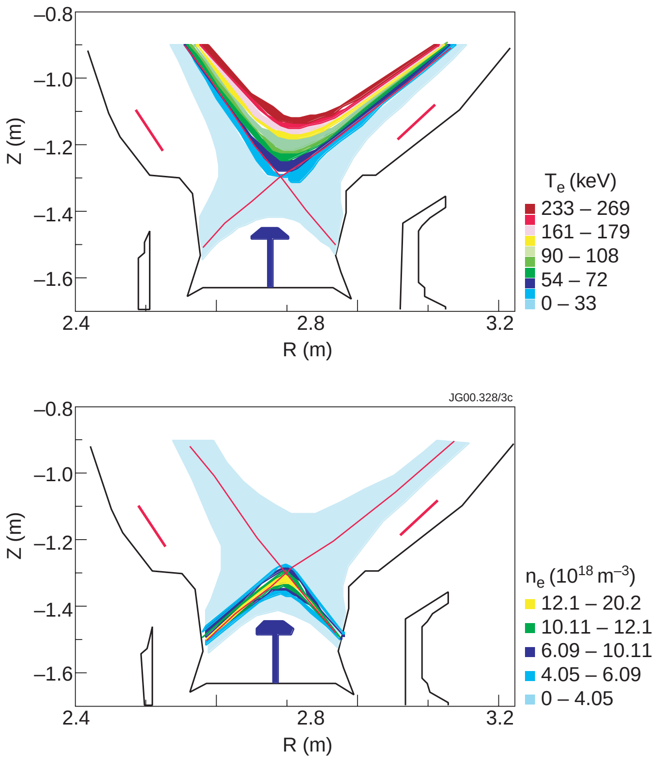

Figure 3: EDGE simulation for pulse 50739

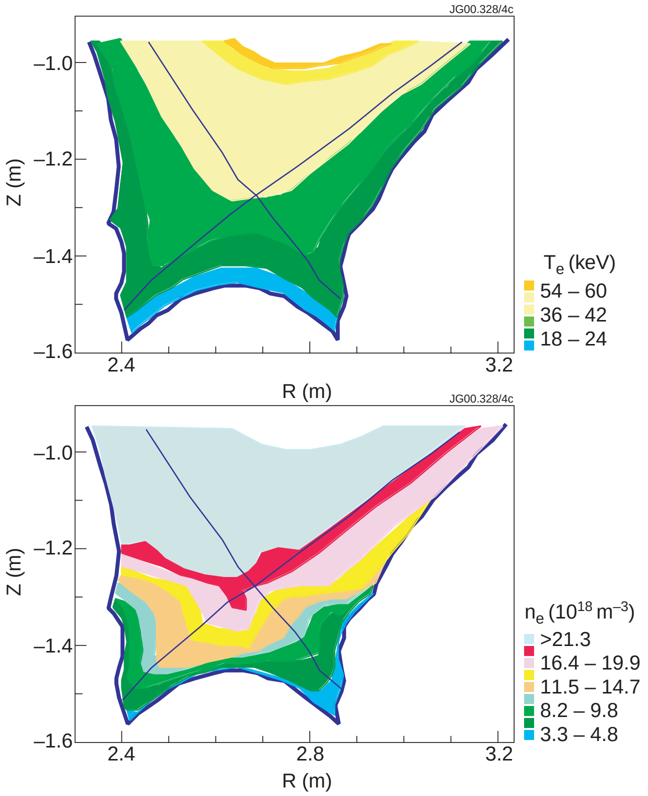

Figure 4: SOLPS simulation for pulse 50739