GA–A26649

L-H TRANSITION STUDIES ON DIII-D TO DETERMINE H-MODE ACCESS FOR NON-NUCLEAR OPERATIONAL SCENARIOS IN ITER

by

P. GOHIL, T.E. EVANS, T.H. OSBORNE,

O. SCHMITZ* and J.T. SCOVILLE

APRIL 2010

GENERAL ATOMICS

DISCLAIMER

GA–A26649

L-H TRANSITION STUDIES ON DIII-D TO DETERMINE H-MODE ACCESS FOR NON-NUCLEAR OPERATIONAL SCENARIOS IN ITER

by

P. GOHIL, T.E. EVANS, T.H. OSBORNE, O. SCHMITZ* and J.T. SCOVILLE

This is a preprint of a paper to be presented at the 23rd IAEA Fusion Energy Conference, October 11–16, 2010 in Daejon, Republic of Korea and to be published in Proceedings.

*Forschungszentrum Jülich GmbH, IEF4-Plasma Physics, Jülich, Germany

Work supported in part by
the U.S. Department of Energy
under DE-FC02-04ER54698

GENERAL ATOMICS ATOMICS PROJECT 30200
APRIL 2010

GENERAL ATOMICS

A comprehensive set of L-H transition experiments has recently been performed on DIII-D to determine the requirements for access to H-mode plasmas in ITER's first (non-nuclear) operational phase with H and He plasmas, and second (activated) operational phase with D plasmas. The results from these experiments have revealed that the H-mode power threshold, P_{TH}: (a) increases with the applied torque for all 3 main ion species (H, He, D); (b) increases in the presence of n=3 resonant magnetic perturbations; (c) can be significantly reduced by changing the plasma geometry; (d) exhibits a weak dependence on the edge electron and ion temperatures, but shows a strong dependence on the edge toroidal rotation; and (e) is not significantly affected by the application of magnetic error fields expected from test blanket module assemblies in ITER.

Each of the above results has a strong bearing on achieving H-mode plasmas in ITER, which are necessary for ITER to attain the high performance plasmas required for high fusion production and Q values. Earlier results on the P_{TH} dependence on main ion species indicated that H plasmas had over a factor of 2 higher threshold powers than equivalent D plasmas. New results with near pure He plasmas (>90% purity) indicate that P_{TH} in He plasmas is about 30%-50% higher than D plasmas depending on the applied torque (Fig. 1). This is in contrast to previous results from ASDEX Upgrade that indicated that P_{TH} is the same for He and D plasmas. P_{TH} is about the same for both electron cyclotron heating (ECH) and neutral beam injection (NBI) at moderate to high densities (>3.0×10^{19} m^{-3}) in H and He plasmas, whereas D plasmas exhibit a lower threshold power with ECH (by up to 30%) than NBI at these densities. At low densities (<2.5×10^{19} m^{-3}), P_{TH} with ECH can be significantly higher (up to 50%) than with NBI for all the species. In terms of energy confinement in H-mode, τ_E(He) ~ τ_E(H) and τ_E(He) ~ 0.6-0.7 τ_E(D).

In order to better understand the physics behind the differences in the H-mode power threshold for the different ion species and different torque values, the edge plasma conditions (e.g. T_e, T_i, v_ϕ, etc.) were examined at the L-H transition for the various species. Figure 2 shows the edge electron and ion temperatures and the edge toroidal rotation versus the H-mode power threshold at different applied torque. The data points for the various quantities correspond to the values just before the L-H transition for plasma discharges with positive, negative and near zero torque for all 3 main ion species (H, He, D). No systematic variations in the edge T_e and T_i are observed with the H-mode power threshold. However, a significant variation of P_{TH} is seen with the edge toroidal rotation, v_ϕ. The main reason for this effect is the influence of the toroidal rotation on the edge radial electric field, E_r, from force balance. The presence of a large v_ϕ positive component competes against the negative diamagnetic term and hence reduces the shear in the

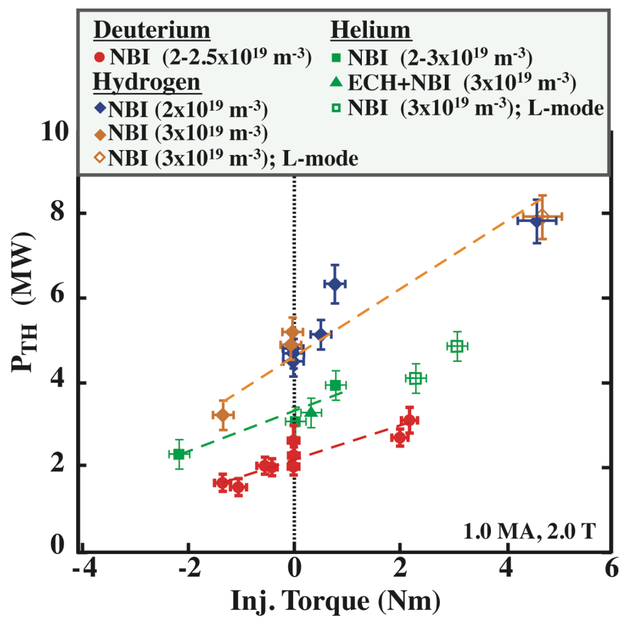

Fig. 1. The net power required to access the H-mode as a function of the injected torque for various target densities and heating methods for hydrogen, deuterium and helium. The open symbols denote discharges that failed to transition to H-mode at the applied power.

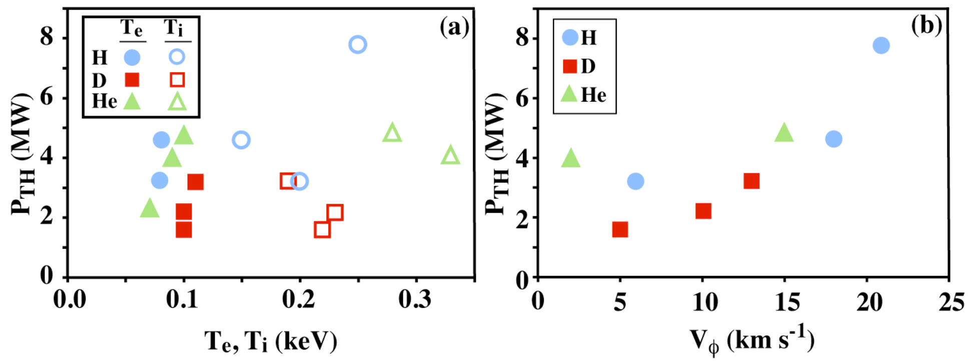

Fig. 2. The edge electron and ion temperatures and the edge toroidal rotation (measured 1 cm inside the last closed flux surface) versus the H-mode power threshold at different applied torque. The data points for the various quantities correspond to the values just before the L-H transition for plasma discharges with positive, negative and near zero torque for the 3 main ion species (H, He, D) shown in Fig. 1.

edge E_r and makes it harder to attain the necessary conditions for turbulence suppression. Further details of the influence of v_ϕ will be presented in the paper.

Another set of recent experiments with He plasmas indicates that P_{TH} increases with the application of the I-coil current, which is normally used to induce *n*=3 resonant magnetic perturbations required for edge localized mode (ELM) suppression. Figure 3 shows that P_{TH} increases with I-coil current for He plasmas, which will be used during the first operational phase of ITER. The I-coil current is applied during the L-mode prior to the main heating phase and P_{TH} is observed to increase significantly even at low I-coil currents of 2 kA, whereas the normal range of I-coil current for ELM suppression is 4 kA and above. Note that the increase in P_{TH} is observed for on-resonance q_{95} value (i.e. q_{95}=3.5) and no increase in P_{TH} is observed for off-resonance q_{95} values (q_{95}=4.1). This behavior for on-resonance q_{95} value indicates that, for ITER applicability, operational scenarios have to be developed that do not affect the L-H transition while fully suppressing ELMs. In contrast, experiments with the magnetic error fields from a mock-up of the test blanket module (TBM) assembly to be used in ITER indicated no significant change in the H-mode power threshold for either ECH or NBI heating in D plasmas. Therefore, the presence of the ITER TBMs is not expected to significantly change the H-mode power threshold for the ITER operational scenarios.

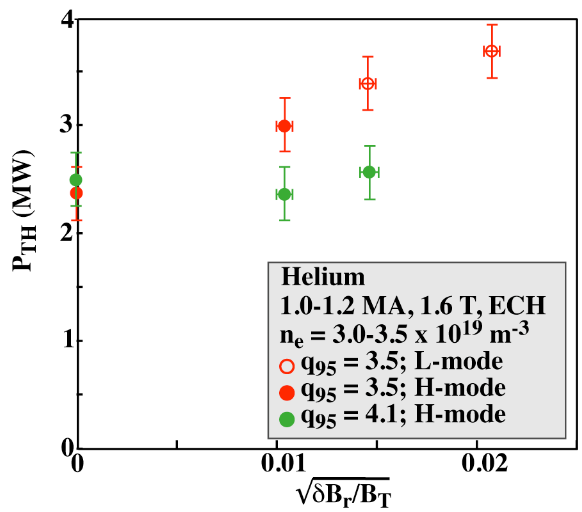

Fig. 3. ECH H-mode power threshold as a function of the change in the edge radial magnetic field (11/3 component) induced by the I-coils for He plasmas. The open symbols represent discharges that failed to transition to H-mode at the applied power. The effect is dependent on the edge q_{95} where the greatest effect is observed at values similar to that required for RMP ELM suppression.

This work was supported in part by the US Department of Energy under DE-FC02-04ER54698.