§33. New Interpretation of Boundary Control Effects on Edge and Core Plasmas in Magnetic Fusion Devices

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It is widely recognized in the magnetic fusion community that high-performance core plasmas often favor reduced edge recycling. The first-of-a-kind demonstration was done in TFTR after wall conditioning of the graphite bumper limiters. Shown in Fig. 1 is the relationship between energy confinement time vs. D_α intensity data [1], including those from the final DT-campaign. One can readily find that the more reduced edge recycling is, the better confinement can be achieved. Ever since a variety of wall condition techniques have been applied to control edge recycling in a number of magnetic fusion experiments. However, due to the surface saturation with implanted particles, the efficacy of wall conditioning to provide "passive" pumping has a finite lifetime, necessitating re-conditioning.

Recently, a similar but more intuitive relationship has been reported on the data from LHD [2], as shown in Fig. 2, where the edge temperature gradient increases, leading to limited energy transport, with decreasing edge density. Importantly, the effect of heating power is incorporated here, meaning that one can expect improved confinement by increasing the heating power.

To corroborate this point, it has been observed in DIII-D [3] and many other devices that soon after the NBI power increased, the stored energy increases, namely, core confinement improves to H-mode, etc. Interestingly, as core confinement improves, edge recycling measured with D_α intensity decreases.

It follows from these arguments that reduced recycling and improved core confinement are equivalent , i.e. necessary and sufficient conditions, to each other. Despite the critical importance, this has never been clearly addressed in the magnetic fusion community.

The question is how one can maintain reduced recycling conditions in steady state fusion devices. To resolve this steady state issue, all the possible plasma-facing component concepts have been proposed over the past decade. Most of these concepts employ some kind of self-replenishing surface component, either solid or liquid, to provide "active" wall pumping. One such concept proposed by Hirooka et al. [4] features a moving-belt with an in-line getter film deposition system. A series of PoP (for proof-of-principle) experiments have been conducted on this concept with the moving-belt simplified by a rotating drum [5]. Results indicate that not only hydrogen but also helium recycling can be reduced to levels significantly lower than 100% even at steady state, so long as the rotating drum surface is gettered with lithium.

Encouraged by these PoP experiments, a similar but custom-designed rotating drum setup has been constructed to be used as a poloidal limiter in the CPD compact spherical tokamak. Details have been presented at the 18th PSI-conference in 2008 [6]. Most importantly, while the flat-top density barely changes a few percent, the core electron temperature has been found to jump from ~7eV to ~20eV, i.e. a significant increase in plasma pressure, having resulted in a factor of 2-3 increase in toroidal plasma current, as illustrated in Fig. 3, the similarity of which one immediately finds to the data shown in Fig. 1.

Based on these experiences, currently planned is lithium vapor injection into the edge region of LHD during confinement discharges, expecting uniform deposition on the divertor plates by polidal and toroidal transport. This will lead to hydrogen codeposition and hence reduced recycling. A prototypical vapor injector and its control system are being put together for this purpose.

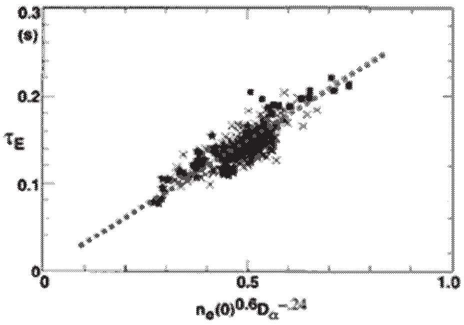

Fig. 1 TFTR database (after J. D. Strachen [1]).

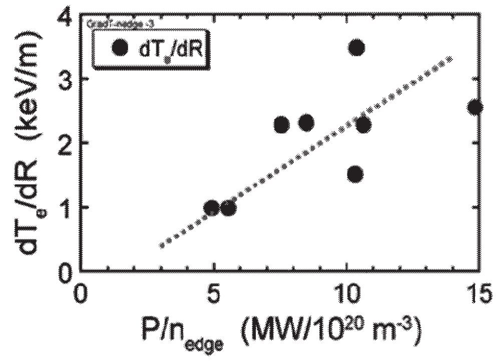

Fig. 2 LHD database (after Y. Ohyabu [2]).

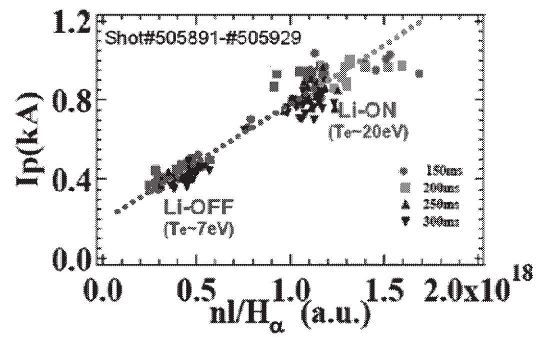

Fig. 3 CPD database (after Y. Hirooka [6]).

1) Strachan, J. D., Nucl. Fusion 39(1999)1093.
2) Ohyabu, Y. et al., PRL97(2006)055002.
3) Jackson, G. et al. PRL 67(1991)22.
4) Hirooka, Y. et al., Proc. 17th IEEE-SOFE, San Diego, Oct. 6th -10th , 1997, pp.906.
5) Hirooka, Y et al., J. Nucl. Mater. **363-365** (2007)775.
6) Hirooka, Y et al., J. Nucl. Mater. **390-391** (2009)502.