SESSION EX3

Wednesday, 21 October 1998, at 10.40 a.m.

Chairman: M. Keilhacker (Germany)

DIVERTORS 1

Papers IAEA-CN-69/EXP4/05 and 06 (rapporteured by N. Hosogane)

DISCUSSION

R. MAINGI: Do you have any measurements or analysis of the change in scrape-off layer (SOL) flow with the "puff and pump" technique?

N. ASAKURA: We have not observed any change so far. Since the pumping slot is located at the inner divertor, the pumping effect might not be observed at the outer mid-plane. We plan to pump at the outer divertor next year in order to investigate this effect.

A. KALLENBACH: The main chamber Z_{eff} is compared to divertor carbon fluxes only. Can you give an estimate of the relative fractions of the core Z_{eff} caused by divertor and main chamber sources?

N. HOSOGANE: We have not measured carbon influx in the main chamber. However, assuming that carbon impurities are generated by charge exchange neutrals, carbon influxes are considered to be at the same level for three discharges, since the neutral particle flux estimated by D_α intensity is at a similar level.

D.D. RYUTOV: Do you have any information regarding the radial electric field? Can ExB drift play a role in the flow reversal?

N. ASAKURA: The electric field was evaluated from measured T_e and V_f (floating potential) profiles. In our case, the ExB term is smaller than the ion diamagnetic term in the scrape-off layer. We think the effect is small.

Paper IAEA-CN-69/EX3/2 (presented by M. Kaufmann)

DISCUSSION

R.J. HAWRYLUK: I have three questions. Firstly, did the energy confinement time improve with improved baffling of Divertor II? Secondly, did Z_{eff} decrease in Divertor II, which is a closed divertor with enhanced power radiated? Lastly, DIII-D has had difficulty in achieving internal transport barriers in detached discharges with high neutral pressure. What is your experience on ASDEX-U?

M. KAUFMANN: The energy confinement is not directly dependent on the neutral gas flow and hence, not on baffling. It depends on the plasma separatrix density, which we can control in both divertors. The Z_{eff} has not changed from Divertor I to Divertor II. It is low in any case, however - typically between 1.5 and 2. The essential progress in Divertor II is due to the geometry, where one gets twice the radiation with the same Z_{eff}. With the internal barrier we have no problems with the divertor heat load. In the ITB discharges $P_{\perp} / F$ is below 1 MW/m^2. The radiation fraction P_{rad}/P_{heat} is about 0.6, which is similar to discharges with the same $\langle n_e \rangle$ and without an internal transport barrier.

R.J. GOLDSTON: I understand that your results showing main chamber neutral density to be independent of divertor geometry explain the lack of progress on n_e vs. $n_{Greenwald}$. In the past you have reported scrape-off widths in ASDEX and ASDEX-Upgrade. Are these results, especially vs. power, consistent with any of the theories of MHD turbulence (ballooning, interchange, including line-tying and kinetic effects) that have been published?

M. KAUFMANN: The neutral gas density (or flow) has no direct influence either on confinement or on the density limit. The essential parameter is the plasma density in the separatrix region. Raising the boundary density in the H-mode leads to a limit where an MHD limit of the ballooning type, the extrapolated H-mode limit, transport degradation and full detachment come together at more or less the same time. So far, we have not been able to distinguish between those effects. As anticipated, we have found no difference between the two divertors.

With respect to the type-I ELMy H-mode boundary, the product $n \cdot T$ somewhat inside the separatrix remains constant, if one changes power or density and the gradient is close to the ballooning limit (see W. Suttrop's publications). So far, it has not been possible to derive a similar database outside the separatrix. However, the experiments indicate that also outside the separatrix $\nabla P \approx \nabla P_{ballooning}$. Assuming that the SOL broadens as power increases, this will lead to reduced power density on the target plates and should stabilize the radiation power fraction.

Paper IAEA-CN-69/EX3/3 (presented by B. Lipschultz)

DISCUSSION

R. SCHNEIDER: In the case of N_2 puffed discharges, a reduction in ion saturation current due to increased impurity losses without the onset of volume recombination is expected even from simple 2-point models, because the ion saturation current at the target plate is determined by both the net input power into the divertor recycling zone and the recombination fraction. Thus, either increasing impurity losses or volume recombination leads to ion saturation reduction.

B. LIPSCHULTZ: I agree with this explanation of the data. The important thing, however, is to verify models through experiments.

Paper IAEA-CN-69/EX3/4 (presented by H. Kawashima)

DISCUSSION

R. MAINGI: What limits the achievable density ($<n_e>/n_e^G$) of 0.7 with H-mode? Is it detachment onset or MARFEs?

H. KAWASHIMA: It depends on the increase of the core radiation by impurity accumulation at the ELM-free H-mode. When the radiation loss power exceeds ~ 70% of input power, the H-factor of the ELM-free H-mode degrades and then the H- to L-mode transition occurs. Detachment or MARFEs are, however, not observed.

I.H. HUTCHINSON: Your "IL" mode bears a close resemblance to what we call "enhanced D_α" H-mode in Alcator C-Mod, which we know is indeed H-mode in the sense that there is still a clearly measured edge pedestal and transport barrier at the edge, albeit with greater particle transport. Do you have diagnostics to determine whether there is an edge pedestal in IL-mode?

H. KAWASHIMA: Usually the $T_e(r)$ and $n_e(r)$ measured by television Thomson scattering (TVTS) are used to determine the formation of an edge pedestal. However, TVTS did not work on the IL-mode discharges, and the formation of the edge pedestal was not clear. From the soft X-ray emission profiles shown in Figs 4(b) and 5(b), some transport barrier seems to form further inside ($r/a \leq 0.5$) at the IL-mode and the core plasma confinement improves.

Paper IAEA-CN-69/EX3/5 (presented by G.F. Matthews)

DISCUSSION

X. GARBET: There exist H-modes in ohmic or ECRH heated discharges, where the amount of fast ions is low. Thus, an expression for the pedestal width based on a fast ion Larmor radius does not seem to me to be suitable in all cases. Could you comment on that?

G.F. MATTHEWS: The fast ion hypothesis applies specifically to the pedestal width for type I ELMs. I would agree that, if there are clear examples where electron heating alone produces type I ELMs, the case for the fast ion theory is weakened. Results from ICRH heated discharges on ASDEX-Upgrade presented at this conference may fall into this category. However, a full analysis needs to be carried out.

Y. KAMADA: At which radial location did you evaluate such edge parameters as $\rho_{i,thermal}$ and $\rho_{i,fast}$? How large is the pedestal width in typical cases?

G.F. MATTHEWS: The measurements are currently all made at the top of the pedestal. T_e is measured with heterodyne ECE, T_i by charge exchange spectroscopy, n_e with an edge interferometer channel, and $T_{i,fast}$ is calculated with a Fokker-Planck code for the neutral beam particles.

F. PERKINS: Is the confinement degradation observed as $n \rightarrow n_{GR}$ a degradation of edge energy content or core energy content? Fusion power in a reactor will depend principally on central pressure.

G.F. MATTHEWS: The confinement degradation is the result of a reduction in the average plasma pressure at the plasma edge. Since this is the boundary condition for the core profile, reductions in edge pressure are reflected more or less linearly across the whole core profile. Hence, lower edge pressure means lower fusion power unless compensated by an improvement in core transport.

R. MAINGI: You estimate the pedestal width by assuming a first stability limit. If you have access to second stability, particularly at the higher triangularity, this would result in an over-estimation of the pedestal width. Have you done any calculations to determine if you have second stability access?

G.F. MATTHEWS: We currently use measurements at the top of the pedestal along with the assumption that the pedestal is at the first stability limit to infer a width scaling. This is because of a lack of adequate diagnostic data for the pedestal itself. However, recent developments in edge Thomson scattering should provide us with the necessary data for the stability analysis.

G.M. STAEBLER: Nitrogen injection increases the ELM frequency and you have shown that this degrades energy confinement. What is the result with higher Z impurities like neon or argon which cause a decrease in the ELM frequency?

G.F. MATTHEWS: Deuterium fuelling does increase the ELM frequency. However, impurities used on their own, or with low deuterium fuelling rates, initially reduce the ELM frequency and thus improve the confinement. At some point, however, there is a sudden transition to type III ELMs and loss of confinement. Experiments have been carried out at JET with nitrogen, neon, argon and krypton impurities and all show the same behaviour.

Paper IAEA-CN-69/EX3/6 (presented by V. Mertens)

DISCUSSION

R.D. MONK: You have related the H-mode density limit to the detachment model of Borrass. Have you seen any reduction of the density limit in Divertor II compared to Divertor I since we have seen the lower onset of detachment in Divertor II?

V. MERTENS: We do not see any reduction of density limit in Divertor II, although the strike points detach at lower densities compared to Divertor I. This is because the outer scrape-off layer wing is still attached.

R.J. GOLDSTON: In your pellet injection experiments, what was the maximum β_N at $n = n_{GW}$? Is there any sign of increased MHD-like activity as power is increased, with β_N apparently fixed?

V. MERTENS: The maximum β_N is approximately 1.1-1.3 at $\bar{n}_e^{GW}$, and there is no MHD activity. Generally, there is no sign of enhanced MHD activity as power is increased. In some very rare cases, pellets have triggered neoclassical modes at $\bar{n}_e^{GW}$.

B. SAOUTIC: When increasing the power coupled to the plasma, one can expect an increase in pellet ablation and a decrease in fuelling efficiency. Could that explain the power limit observed to keep the H-mode at a density higher than the Greenwald density?

V. MERTENS: The mechanism you refer to holds for the standard low field side pellet injection. With the new high field side injection, there is no degradation of pellet fuelling efficiency with increasing heating power. The cause of the limitation of plasma stored energy is still unclear.

Paper IAEA-CN-69/EX3/7 (presented by R. Décoste)

DISCUSSION

M. TENDLER: Can you quantify your important result on the beneficial impact of the positive biasing of the SOL on the power threshold for triggering the H-mode?

G.W. PACHER: No power scan was performed. As an indication, at 300 kW input power, + 250 V was sufficient to produce the H-mode, and at 600 kW input power, -250 V was sufficient to destroy the H-mode. These are not necessarily minimum values, since for other conditions in which L-modes are reproducibly produced for 0 volt bias, essentially the same H-modes were produced for biasing voltages between + 100 and + 250 V.

R. MAINGI: Shaing, Itoh and Carreras have theories to indicate that neutrals at the 95% flux surface inhibit the transition. DIII-D DEGAS calculations have shown that the neutral density at the 95% flux surface scales inversely with the separatrix density. Have you investigated the role of neutrals in setting the lower density limit for H-mode access?

G.W. PACHER: We have not investigated this aspect in detail. However, we have indications that higher neutral density is not detrimental, in that H-modes appear easier to obtain if gas fuelling is present than if the density appears only from recycling. H-modes at constant power have also been triggered by a gas puff which raised the edge density.