Annual Report of ITPA Topical Group on Scrape-off Layer and Divertor

For the period July 2007 to June 2008

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Executive Summary

The SOL/Div Topical Group held a meeting during the reporting period, in Avila, Spain, January 7-10, 2008. The meeting and location were arranged just before the abstract selection meeting by Program Committee of the Plasma Surface Interactions Conference. As always the focus of our meetings is split between high priority tasks, near-term ITER requests, and new subjects, which need to be investigated for their potential importance to burning plasmas such as ITER.

The primary foci of this meeting were discussions and presentations on predictions of ITER heat and first-wall loadings, as well as ITER T retention in the case with all-W plasma facing components. There were also sessions on ITER diagnostics and what can be accomplished during the ITER H phase. Finally, there were general sessions on D/T retention, dust and divertor physics.

(1) Estimations of particle flux and fuel retention on ITER for current design and W-divertor:

Particle load on the ITER first wall was predicted to be in the range of 3-7x10^{23}/s, various calculations from experiment results in the divertor tokamaks agreed within the factor of 2. Issues for fuejnTa(.S 3 the .tok)5(a)-1(a3cwC.1i57tS5],oJahluarythe-)IIuJ7x10diafgrcul0ary0ciag8340Tiwdi0go6TJ0.0xions he ca

Thermo-oxiadation for D removal were encouraging in being able to reduce and remove D retention respectively.

(3) Discussion summary of ITER H-phase and ITER divertor diagnostics:

A draft plan for the ITER H-phase was presented by A. Loarte (for the ITER Office). A number of assumptions of availability of the machine as well as diagnostic and heating systems was assumed together with a phased plan for bringing all of those systems up to full levels by staging the powers and plasma current levels at reduced pulse length (20-25s). It will be impossible to properly test the

group felt that the specification should be lower as evidenced by JT-60U results, less than 10% of the net surface erosion rate. We hope to also form a working group to obtain a better specification for the dust generation.

(6) Proposals for 2008 IEA/ITPA DSOL:

Fourteen proposals for 2008 IEA/ITPA DSOL inter-machine experiments were presented, and DSOL-11 was combined to MDC-1. Title and spokes-person for each proposal are followings;

DSOL-1 Scaling of Type-1 ELM energy loss and pedestal gradients through dimensionless variables (Loarte)
DSOL-2 Injection to quantify chemical erosion (Brezinsek)
DSOL-3 Scaling of radial transport (Lipschultz)
DSOL-4 Comparison of disruption energy balance in similar discharges and disruption heat flux(A. Loarte, D. Humphreys, G.Pautasso)
DSOL-5 Role of Lyman absorption in the divertor (Lisgo)
DSOL-8 ICRF Conditioning for hydrogen removal (Ashikawa)
DSOL-9 Tracer injection experiments to understand material migration (Philipps)
DSOL-11 Disruption mitigation experiments (Whwe [illegible]

Contents

1. Meetings and reports

A full summary of the 10th meetings of the ITPA Div/SOL Topical Group, and viewgraphs presented, are available at the website (http://efdasql.ipp.mpg.de/divsol/, and only the executive summaries repeated here. Also a summary of results on IEA/ITPA co-ordinated experiments was presented at the November 2007 planning meeting for these experiments.

1.1 Report on the 10th Meeting of the ITPA SOL and divertor physics Topical Group, Avila, Spain

The 10th meeting was held in 7-10, January 2008 at Avila, Spain, and the meeting was hosted by CIEMAT. There were 40 participants: 22 from EU, 8 from US (incl. Canada), 3 from Japan, 4 from ITER, 1 from Russia, 1 from China. The meeting was arranged just before the abstract selection meeting by Program Committee of the Plasma Surface Interactions Conference. Meeting was well organized.

The primary foci of this meeting were discussions and presentations on predictions of ITER heat and first-wall loadings, as well as ITER T retention in the case with all-W plasma facing components. There were also sessions on ITER diagnostics and what can be accomplished during the ITER H phase. Finally, there were general sessions on D/T retention, dust and divertor physics.

The ITER predictions session (4) was quite productive. The speakers had spent significant time projecting current data to ITER for a number of areas. The various calculations on a given subject (e.g. wall fluxes) agreed to factors of 2. ITER wall fluxes were predicted to be in the range 3-7x10^{23}/s. Issues for further discussion were the division of fluxes over the various first-wall surfaces (e.g. how much went to the upper divertor vs inner wall vs outer wall PFCs), the heat load distribution for ELMs, and the transport into limiter shadows (needed for limiter design).

Predictions of T retention were presented both for the current mix of materials in ITER (Be, W and C) as well as for an all-W ITER. The dominant retention for carbon PFCs was confirmed to be co-deposition as expected. Echoing the ‘Progress in the ITER Physics Basis’ the T retention for the current mix of materials, Be, C and W, leads to the 350g limit being reached after ~ 300 discharges.

The new T retention estimates presented at this meeting were on the reduction obtained by going to an all-W ITER. The estimates presented by the EU and US representatives were close. Plasma irradiation was the primary source of T retention in W with the added effect of neutron damage (based on very little published data) leading to a significant increase over ion-impact alone. The end result was that the 350 gram in-vessel T limit was reached later than for C/Be/W, at between 2000-3000 discharges, an increase of ~ x10 over the current mix of materials. The differences between

laboratory ion-beam data, which these estimates are based on, and C-Mod results, are large and need to be understood to know whether the predictions for ITER are correct.

The level of hydrogenic retention in tungsten generally is lower than for carbon based on the factor of 10 reduction in D retention (post-campaign analysis) in ASDEX-Upgrade following conversion to fully-W and from high-flux/fluence Pilot-PSI showed very low fractions of incident D^+ retained (~ 10^{-6}). While He^+ impacting surfaces leads to nanostructure growth (up to ~ microns in depth) on W in a narrow range of surface temperatures we have yet evaluate to evaluate their importance for ITER T retention.

The non-saturation of hydrogenic retention in carbon (linear in ion fluence) was demonstrated in the new Tore-Supra dedicated long pulses over 2 weeks. The co-deposition of D with Be appears to be more complicated, depending on the incident energy of deuterium, the Be deposition rate and the dependence on surface temperature. Use of scavenger gases for C layer inhibition as well as Thermo-oxiadation for D removal were encouraging in being able to reduce and remove D retention respectively.

A draft plan for the ITER H-phase was presented by A. Loarte (for the ITER Office) for comment. A number of assumptions of availability of the machine as well as diagnostic and heating systems was assumed together with a phased plan for bringing all of those systems up to full levels by staging the powers and plasma current levels at reduced pulse length (20-25s). It will be impossible to properly test the PFCs up to full power-handling capability nor the ability to handle transients such as ELMs or disruptions at full levels. Nevertheless close attention should, and will be, paid to monitoring the various surfaces during the startup phase to determine if they fail at those lower power levels.

A second aim during the H phase is to monitor the H retention. While ITER currently has no plan for this it is clear that one is needed and the SOL/divertor group will work closely with the ITER diagnostics group to agree on the proper diagnostics as well as a plan of measurment.

All of the above H-phase PFC information will go into the decision of whether to replace the C divertor PFCs with W before the D or DT phases.

Wall and divertor loadings during transients continues to be a difficult subject to understand. The ELM characteristics when they are incident on the outer limiter in ASDEX-Upgrade were inferred to be in the range 100 eV per electron-ion pair. New measurements of ELM erosion at the outer divertor (ASDEX Upgrade, session 3) show that as the local temperature drops the between-ELM erosion also drops relative to that occurring during ELMs (which is concentrated near the strike points). Increasing the impurity level through impurity puffing may increase divertor radiation but also increases erosion during ELMs. The current model of ICRF-enhanced sheaths, so-called sheath rectification, were contradicted (C-Mod) in that the plasma potential increases proportional to P_{RF} and potentials generated even when the current loop is broken by insulating tiles. The ICRF-enhanced plasma potential has been observed to occur on flux tubes connected to the antenna as well as passing in front of the antenna.

The ITER plans for diagnostic coverage of the ma

Dust is of course a very important issue for ITER and was discussed as part of the diagnostics session. Based on a lack of experimental data the IO

(5) Comparison of isotope effect of H/D edge and divertor plasmas for extrapolate to ITER H-operation (by Fundamenski)
(6) Dust movement study by dust injection (by West)
(7) Dust dynamics study (by Krasheninnikov)
He will start to discuss with dust research community in EU, and will make a proposal based on existing database. At the same time, another proposal for (4) dust growth on the material will considered to be proposed.
(5) Evaluation of carbon and methane generation fluxes based on particle balance study review work was done by Tsitrone, and some presentations in last PSI) (by Tabares)

2. High Priority Research Areas

Area	Progress Reported at ITPA Meeting
1.0 Improve understanding of Tritium retention and development of efficient T removal methods.	
1.1 Comparison of post-campaign and shot-integrated studies of retention w/respect to ion fluence (new)	Thierry Loarer (reported at Toledo PSI conference) and Volker Philipps (reported at Avila ITPA meeting) have shown that post-campaign measurements of the amount of gas injected that is retained for carbon PFC tokamaks is generally in the 1-5% range. The values for single discharge retention fractions, made using gas balance measurements, are typically higher, more in the range 7-50%. The most recent and accurate JET gas balance measurements (‘static gas balance’ with valves to pumps closed) give retention fractions in the range of 7-15%. It is the general agreement that there are several plausible reasons for the difference between post-campaign and gas balance measurements. These include gas evolving out of tiles during the campaign due to disruptions, conditioning, and general outgassing. **This task will now be closed.**
1.2 Lab & tokamak experiments and modelling of deep D retention in high- and low-Z materials (new)	Analysis of high-Z material tiles by the a number of laboratories (e.g. IPP, U. Wisconsin, U. Toronto) have shown that hydrogen can diffuse deep within such materials, long ‘tails’ deep withinsho2W0[illegible]for th

Area	Progress Reported at ITPA Meeting
current experiments (underway)	significant for the divertor conditions. It was hoped that JET would run an experiment this year to make additional measurements for modelling ~~but that did not happen~~. **This task will now be closed.**

4.2 Characterize the level and processes involved in RF enhancement of erosion (new)

4. Future meetings

The next (11^{th}) meeting of the Div/SOL Topical Group tentatively will be planned in 15-18 (3.5 days) September, 2008, Nagasaki, Japan, which is coordinated by Profs. Tanabe and Sakamoto (Kyushu Univ.) with the timing just after the ICPP international conference (International Congress on Plasma Physics 2008, September 8-12, Fukuoka, Japan).