DSOL-23 Efficiency of ICRF conditioning

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| **TG priority:** High | **Start date:** | **Status:**  On-going | **Personnel exchange:** |
| **IO priority:** | **End date:** | **Motivation:** Plasma Operations | |

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| --- | --- | --- | --- | --- | --- | --- | --- |
| **Device /**  **Association** | **Contact**  **Person** | **2016 TG Request** | **Activity (from JEX/JA spreadsheet)** | | | | |
| **2012** | **2013** | **2014** | **2015** | **2016** |
| WEST | D. Douai | Desirable | Considering | Done | Done |  |  |
| JET | D. Douai  T. Wauters | Desirable | Committed | Committed | Committed | Not doing |  |
| ERM-KMS | T. Wauters | Desirable |  |  |  |  |  |
| LHD | N. Ashikawa | Desirable |  | Analysis | Analysis |  |  |
| EAST | J. Hu | Desirable | Committed | Committed | Committed | Committed |  |
| AUG | V. Rohde  D. Douai  T. Wauters | Desirable | Committed | Analysis | Analysis | Committed |  |
| KSTAR | S.-H. Hong | Desirable | Considering | Analysis |  | Committed |  |
| ITER | R. Pitts | Desirable |  |  |  |  |  |

* **JET**:

**2014-2015:**

* + Changeover experiments with ICWC, GDC or L-mode plasmas were performed in JET-ILW with walls at 200°C. The analysis learns that applying tokamak plasmas for T inventory control by isotopic exchange is not a viable scenario for ITER as the PWI interaction areas are not sufficiently different from those in interaction during normal operation. ICWC on the other hand was found to remove fuel from at least a part of the tokamak plasma permanent codeposition areas. Glow discharge conditioning has the largest interaction area. However GDC may be applied only at maximum frequency of once a week in ITER.
  + In order to understand the interaction mechanisms between hydrogenic species and beryllium co-deposits, a 1D Diffusion Trapping Model of Isotopic eXchange in Be (DITMIX) has been developed. The model, validated against laboratory data (collaboration CEA, UCSD, Mephi, IPP and RUB), shows that the main factors determining isotopic exchange are the irradiation flux, fluence and the surface temperature. When applied to JET GDC and ICWC experiments (at the same energy, flux, fluence and surface temperature), the simulated amounts of exchanged hydrogen isotopes (removed and trapped) compare well with those obtained from the gas balance analysis performed. Complementary ICWC experiments are therefore suggested in the JET-ILW with walls at ITER relevant temperatures: 70°C for ICWC as inter-shot cleaning technique, 200°C or 320° for GDC, operated in ITER in combination with FW baking at 240°C and DIV baking at 350°C.

**Plans for 2016:**

* + To address the question on the dependency of isotopic exchange on the wall temperature, an experiment has been proposed in C37 (and beyond) consisting is using the opportunity of having several successive campaigns in D, H and T foreseen in S1-2018 or S2-2020 to assess changeover efficiency at different wall temperature with JET walls either at high (320°C) or low (as close as possible to 70°C) temperature.
* **AUG**:

**2015:**

* + Experiments are scheduled end November. The efficiency of He-ICWC will be assessed for fuel removal, by particle balance and analysis of pre-characterized W samples loaded with D, inserted via the mid-plane manipulator of AUG. He retention in W will be assessed as well. Retention and removal will be correlated with plasma parameters obtained either at the vicinity of the samples characterization (Langmuir probes) or in the bulk of the discharge (NPA, OES…)

**Plans for 2016:** tbd

* **EAST**:

**2015:**

* + New ICRF generator is installed, tested, and successfully operated routinely at night to remove impurity and deuterium retention;
  + Deuterium partial pressure is successfully measured in helium atmosphere by QMS with TIMS method;
  + The cleaning efficiency on deuterium is increased with increased duty cycle of ICRF wave, but ICRF power dependence in 10 – 30 kW is very weak;
  + In He-ICRF discharge cleaning with following parameters: helium 0.05 Pa, 27.12 MHz, 10 -20 kW, 0.5 – 1 T, the conditioning efficiency on deuterium retention is ~（4 - 20)×1017 D-atoms/s, under different wall conditions.

**Plans for 2016:**

* + Study ICWC with higher power (>30 kW) injection;
  + Compare the conditioning efficiency of ICWC between He-ICRF cleaning plasmas and He main plasmas;
  + Study the cleaning effect of ICWC on the fuel retention in the gaps by samples;
  + Study the effect of He-ICRF cleaning between shots for plasma recovery after major disruptions.
* ERM:
  + Analysis of 2014 JET and ASDEX Upgrade experiment. JET results on ILW learn that ICWC applied after a 400s DT pulse on ITER can remove significant amount (>50%) of the T that is expected to be stored in codeposits within the 400s DT discharge. Exposure of surface samples on ASDEX Upgrade show that the bonding energy of (C)-deposits is an important factor for efficient removal by ICWC.
  + Plasma breakdown modeling with RFdinity using antenna ITER ICRF antenna vacuum electric field profiles show that RF plasmas can be produced on ITER with modest power levels (1MW) and typical ICWC pressures. (ii) The effect of plasma on RF fields is considered. The code is being upgraded to a PIC code to include effects of electrostatic electric field produced by inhomogeneous charge distributions. A new Helios cycle was approved for 2015.
  + ICRF plasma production simulations with RFdinity show that plasma production should be possible by standard antenna on the linear Ishtar device. As the installation of an ICRF antenna on this device was delayed, experiments will be scheduled in 2016. A dedicated ICWC antenna is proposed for TOMAS device in Julich. The antenna and matching system is being designed. The systems RF amplifier is acquired and will be delivered end of 2015.
  + The 1-D ICWC plasma code TOMATOR was coupled with a 1D low density and temperature RF wave module and tested for simple plasma cases.

**Plans for 2016**

* + Participating to experiments on JET and ASDEX Upgrade.
  + The work on plasma breakdown modeling with RFdinity will focus on (i) further development of the PIC-Monte Carlo model and (ii) incorporate influence of plasma effects on the electric fields upon reaching higher densities. A new Helios cycle was approved for 2016.
  + Dedicated ICWC antenna system will be constructed for TOMAS device in Julich and experiments are planned on the linear Ishtar device. Both devices will allow assessing the safe operation margins for ICRF plasma production and comparison with RFdinity simulations.
  + The 1-D ICWC plasma code TOMATOR including 1D low density and temperature RF wave module will be further developed and compared to the extensive experimental ICWC data-base (TORE SUPRA, TEXTOR, ASDEX Upgrade and JET).
* KSTAR:

**2015:**

* + Applied ICWC as inter-shot wall conditioning technique for several days to see effects on long pulse operation
  + Retention during a long pulse shot (more than 20 sec) exceeds 1021 D atoms/s, and ICWC removal rate is around 1-10×1018 D atoms/s with 100 kW power, which needs to be improved.
  + Vacuum seal has been broken, thus, ICWC couldn’t performed further.

**Plans for 2016:**

* + Design of dedicated antenna for ICWC is planned.
  + Apply ICWC as regular inter-shot wall conditioning technique for long pulse operation
  + Measurements of overall impurity removal efficiency.

**Purpose:** Further work is needed prior to the validation and the application to ITER of Ion Cyclotron Wall Conditioning (ICWC), for routine plasma start-up and operation and Triitum removal in the nuclear phase A database on ICWC efficiency from multi-machine experiments has now been built, and fuel removal efficiency in ITER can be extrapolated. Present data from ICWC in JET-ILW suggest that these discharges could remove up to 0,4 gT between plasma shots, compared to a 0,14 and 0,5 gT uptake per nominal 400 sec. long D:T plasma at Q=10 in ITER. The accessible reservoirs need to be identified, especially for the Be/W case. Experiment and modelling on the interaction of ICWC discharges with different reservoirs, in particular Be layers, must be pursued in this respect, in order to assess the ability of these to access long term retention. RF parameters, gas breakdown phase must be carefully studied and modelled, with a view to operate safely the standard ICRF heating systems of each device.