EFDA WORKPROGRAMME 2010

Call for Participation

(Part of the EFDA WP, H&CD and Fuelling TG)

H&CD and Fuelling Physics

Deadline for Responses: 20th November 2009

TG Chairmanship: Alain Becoulet, Marie-Line Mayoral (JET) Coordination Committees: Tim Jones (NBI), Laurie Porte (ECRH), Raymond Koch (ICRH), A. Becoulet (CCLH), Christian Day (Fuelling)

EFDA CSU contact person: Boris Weyssow

This Call for Participation aims to implement the EFDA Work Programme for 2010 on H&CD and Fuelling under Task Agreements as foreseen in the new EFDA Art. 5

Introduction

At its meeting in Prague on 12 March 2009, the EFDA Steering Committee approved elements of the EFDA 2010 Work Programme, including a set of tasks relating to the EFDA Topical Groups on Heating & Current Drive & Fuelling, MHD, Transport and Diagnostics. This Call covers the Heating, Current Drive and Fuelling (HCD) physics related work implemented under Task Agreements on the basis of the provisions given in Article-5 of the EFDA Agreement.

The activities to be implemented following this call for participation will be organised in7 activities as follows:

HCD-01-01: Experimental simulation of non-linear burning plasma
HCD-01-02: Reliability of Plasma Operation (conditioning and initiation)
HCD-01-03: Reliability of ICRH and LHCD
HCD-01-04: Reliability of ECH and ECCD
HCD-01-05: Specific H&CD physics for ITER
HCD-01-06: Off-axis Current Drive and rotation
HCD-01-07: Fuelling Physics

Programmatic Background

The EFDA Heating and Current Drive Topical Group will cover the physics and technology issues related to the development of the Heating, Current Drive and Fuelling systems available for fusion plasmas and the integration of these technologies aiming at steady-state plasma operation. These include Neutral Beam Injection (NBI), both based on the acceleration of positive and negative ion beams; Ion Cyclotron Resonant Heating (ICRH); Lower Hybrid Current Drive; and Electron Cyclotron Resonant Heating (ECRH) and current drive (ECCD).The H&CD will address areas of direct ITER relevance, urgent needs, with a clear link with F4E and ITER; as well as longer term developments relevant for DEMO; and urgent needs in connection with fusion device upgrades already agreed or under consideration in the EU. Under areas related to the physics aspects, modelling development, support needs and requests towards the EU experimental program in the various devices will be carried out under the coordination of the H&CD TG, while technology activities will include conceptual design studies, research and development needs among the EU fusion devices.

1. Experimental simulation of non-linear burning plasma :

Task Agreement WP10-HCD-01-01:

Experimental simulation of non-linear burning plasma

1.1 Introduction

Under conditions of strong self-heating by alpha particles, new couplings between plasma phenomena will occur. Such couplings are intrinsically non-linear, and will substantially complicate the problem of maintaining a steady-state scenario at high Q. For example, the pressure profile determines the fusion reactivity and hence alpha particle heating profile, yet the heating profile feeds back directly on the pressure profile, which in turn affects the bootstrap current profile and hence, through the influence on confinement and stability, produces a further indirect influence on the pressure profile.

1.2 Objectives

In non burning plasmas, the direct effects of alpha particle heating can be simulated in a number of important respects using ICRH driven in proportion to a real-time ‘substitute’ for the DT reactivity. A key further feature in this proposal is to combine the simulated alpha heating with a component of the LHCD (and/or ECCD), driven in such a way as to simulate the effect of bootstrap current computed from the real-time profiles and scaled to maintain appropriately chosen dimensionless parameters at values appropriate to the corresponding ITER/reactor scenario.

1.3 Work Description and Breakdown

Work Breakdown

WP10-HCD-01-01-01

Experimental simulation of non-linear burning plasma

Perform experimental demonstrations of nonlinear burning plasma dynamics in Advanced Scenarios and improve the predictive modelling of such discharges.

JET related activities

No JET experiments are foreseen to be implemented under this Task. However, should JET carry experiments or provide data in this area, a close coordination with the JET Task Forces will be sought.

Resources

Baseline Support: 3 ppy

1.4 Scientific and Technical Reports

Progress reports

At the end of each calendar year, during the Topical Group annual meeting, the Task Coordinator shall present a report on activities under the Task Agreement to the EFDA Leader for his approval. These reports shall integrate the progress made by each Association on each activity, and they shall indicate the level of achievement of the objectives, the situation of the activities, the allocation of resources and recommendations for the next year when applicable. The EURATOM financial contribution will be made through the usual procedures for baseline support through the Contract of Association.

Milestones and Deliverables

Milestones:

- Mid 2010 Activity Meetings: Collection and discussion of results obtained from the evaluation of theoretical work and experiments performed in 2009 and early 2010.
- End third trimester 2010 Annual meeting of the Topical Group: coordinated presentation of the results from the theoretical work and experimental campaigns in 2010.
- December 2010 Final report sent to EFDA-CSU.

Deliverables:

Experimental non-linear burning plasma

- Perform experimental demonstrations of nonlinear burning plasma dynamics in the Advanced Scenarios. (The milestones strongly depend upon the EU tokamaks' experimental programmes).
- Perform further work to improve the predictive modelling of such discharges.
- Provide synthetic analysis by the group of experts involved, recommendation for future work and implications for ITER/DEMO.

2. Reliability of Plasma Operation :

Task Agreement WP10-HCD-01-02:

Reliability of Plasma Operation (conditioning and initiation)

2.1 Introduction

ICRF assisted wall conditioning:

With toroidal magnetic field on, plasma production with ICRF is a promising method available to clean machine walls, reset wall initial condition, deposit layers if required, de-tritiate after discharges. A description of these low density and low temperature partially ionized plasmas is needed.

Plasma initiation:

The use of the heating systems (ECRH, ICRH and optional LHCD) in ITER during this first phase of the plasma discharges needs to be documented, in particular the plasma initiation and the volt-second consumption up to the burn-through phase. The results of the modelling and experiments could have an impact on the plans for the ITER hardware.

2.2 Objectives

Plasma initiation assist with H&CD systems:

- Perform experimental and modelling studies on plasma initiation assisted with H&CD systems with the aim of contributing to the elaboration of operational instructions for ITER.
- Assess the use of RF systems for the pre-ionisation and the avalanche phase in ITER.

ICRF assisted wall conditioning:

- Perform experimental and modelling studies to assess the quality of the RF-produced plasma and the efficiency of the wall conditioning actions.
- Identify the necessary code developments and implement them.

2.3 Work Description and Breakdown

Work Breakdown

WP10-HCD-01-02-01

Plasma initiation assist with H&CD systems

Perform experimental and modelling studies on plasma initiation assisted with H&CD systems

WP10-HCD-01-02-02

ICRF assisted wall conditioning

Perform experimental and modelling studies to assess the quality of the RF-produced plasma and the efficiency of the wall conditioning.

JET related activities

No JET experiments are foreseen to be implemented under this Task. However, should JET carry experiments or provide data in this area, a close coordination with the JET Task Forces will be sought.

Resources

Baseline Support: 7 ppy

2.4 Scientific and Technical Reports

Progress reports

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Milestones and Deliverables

Milestones:

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- December 2010 Final report sent to EFDA-CSU.

Deliverables:

Plasma initiation assist with H&CD systems:

- Analyse parameter space resulting from RF assisted plasma initiation and perform experimental and modelling work necessary.

ICRF assisted wall conditioning:

- Perform the experimental and modelling work needed for the characterisation ofICRF assisted wall conditioning.
- Provide synthetic analysis by the group of experts involved, recommendation for future work and implications for ITER.

3. Reliability of ICRH and LHCD :

Task Agreement WP10-HCD-01-03:

Reliability of ICRH and LHCD

3.1 Introduction

Coupling ICRH and LHCD power in fusion devices with respect to the H-mode edge conditions and the long distance between the antennas and the plasma expected in future devices requires attention. One of the objectives is to develop approaches to increase the level of reliable power density, improving the present forecast for ITER. The Long pulse operation of the RF systems also claims for a better understanding and management of the various mechanisms leading to local heat loads and impurity generation.

3.2 Objectives

RF Coupling:

Improve the ICRH and LHCD large distance coupling in fusion plasmas, for instance with gas puffing techniques. Develop an overall understanding of the RF coupling mechanisms influencing the long pulse operation (RF sheaths, convective cells, heat loads, impurity generation, combined ICRH-LHCD operation…). The aim should be to provide practical recommendations and operational instructions towards the existing and future RF systems, with a specific focus on ITER.

Arc detection for ITER:

Improve protection of ICRF systems against arcs, including characterisation of existing systems.

Develop ICRH arc detection systems, design and R&D of new systems, leading to recommendations for the arc detection systems of the future ICRH systems (ITER in particular)

EM compatibility of H&CD systems during arcing:

Document the EC system resistance to EM perturbations.

Conceptual study of EM robust installations for ITER & DEMO.

Neutral Pressure in front of RF antennas:

Document qualification of upgrades of the diagnostics for the measurement of the neutral pressure in front of the RF antennas.

Edge plasma modelling:

Qualify modelling procedures and models of experiments on RF sheath effects.

3.3 Work Description and Breakdown

Work Breakdown

WP10-HCD-01-03-01

RF Coupling

Coupling ICRH and LHCD power in fusion devices with respect to the H-mode edge conditions and the long distance between the antennas and the plasma.

WP10-HCD-01-03-02

Arc detection for ITER ICRH system

Arc detection development and testing for reliable and safe ICRH operation. Analyse new ideas for an integrated solution fully protecting the future antennas with tests carried out in present devices.

WP10-HCD-01-03-03

Arcing and Election Magnetic compatibility of H&CD systems

Develop compatibility criteria and testing procedures for the control systems of EC, robust against electro magnetic perturbations during testing and operations (arcs).

WP10-HCD-01-03-04

Neutral Pressure in front of RF antennas

Experiments following upgrades of the diagnostics for the measurement of the neutral pressure in front of the RF antennas, aiming at reconstructing the density profile in the scrape-off layer and edge in front of the antenna, ideally at different poloidal locations to allow for better understanding of sheath effects and convective cell generation by the RF and therefore the RF coupling.

WP10-HCD-01-03-05

Edge plasma modelling

Modelling of the scrape-off plasma with improved tools, aiming at providing reliable predictions that could be used e.g. to evaluate the performance in terms of coupling and sheath effects of ICRH antennas for ITER.

JET related activities

No JET experiments are foreseen to be implemented under this Task. However, should JET carry experiments or provide data in this area, a close coordination with the JET Task Forces will be sought.

Resources

Baseline Support:7 ppy

3.4 Scientific and Technical Reports

Progress reports

At the end of each calendar year, during the Topical Group annual meeting, the Task Coordinator shall present a report on activities under the Task Agreement to the EFDA Leader for his approval. These reports shall integrate the progress made by each Association on each activity, and they shall indicate the level of achievement of the objectives, the situation of the activities, the allocation of resources and recommendations for the next year when applicable. The EURATOM financial contribution will be made through the usual procedures for baseline support through the Contract of Association.

Milestones and Deliverables

Milestones:

- Mid 2010 Activity Meetings: Collection and discussion of results obtained from the evaluation of theoretical work and experiments performed in 2009 and early 2010.
- End third trimester 2010 Annual meeting of the Topical Group: coordinated presentation of the results from the theoretical work and experimental campaigns in 2010.

- December 2010 Final report sent to EFDA-CSU.

Deliverables:

RF Coupling:

- Perform further experiments and increase effort in edge plasma modelling in particular in the area of sheath effect.

Arc detection for ITER:

- Perform experimental and modelling work needed for the completion of a final report on an improved and qualified ICRH arc detection systems.

EM compatibility of H&CD systems during arcing:

- Perform EM compatibility experiments and modelling trying to get as close as possible to ITER relevant cases.

Neutral Pressure in front of RF antennas:

- Perform experiments following upgrades of the diagnostics for the measurement of the neutral pressure in front of the RF antennas.

Edge plasma modelling:

- Perform modelling of experiments on RF sheath effects with improved tools.

4. Reliability of ECH and ECCD:

Task Agreement WP10-HCD-01-04:

Reliability of ECH and ECCD

4.1 Introduction

Real-time polarization control for ITER EC system: Reliability of long pulse ECH and ECCD requires feedback control and optimized polarization to avoid shine through (O2) or reflection (X1) interactions with the first wall and/or diagnostics. Techniques to measure these interactions and to minimize them need to be studied and documented, with test carried out in present devices.

4.2 Objectives

Develop techniques to measure the ECH and ECCD interaction with the first wall and/or diagnostics, and to minimize them with tests carried out in present devices.

4.3 Work Description and Breakdown

Work Breakdown

WP10-HCD-01-04-01

Reliability of ECH and ECCD

Develop techniques to measure the ECH and ECCD interaction with the first wall and/or diagnostics, and to minimize them.

JET related activities

No JET experiments are foreseen to be implemented under this Task.

Resources

Baseline Support:7 ppy

4.4 Scientific and Technical Reports

Progress reports

At the end of each calendar year, during the Topical Group annual meeting, the Task Coordinator shall present a report on activities under the Task Agreement to the EFDA Leader for his approval. These reports shall integrate the progress made by each Association on each activity, and they shall indicate the level of achievement of the objectives, the situation of the activities, the allocation of resources and recommendations for the next year when applicable. The EURATOM financial contribution will be made through the usual procedures for baseline support through the Contract of Association.

Milestones and Deliverables

Milestones:

- Mid 2010 Activity Meetings: Collection and discussion of results obtained from the evaluation of theoretical work and experiments performed in 2009 and early 2010.
- End third trimester 2010 Annual meeting of the Topical Group: coordinated presentation of the results from the theoretical work and experimental campaigns in 2010.
- December 2010 Final report sent to EFDA-CSU.

Deliverables:

- Perform experimental and modelling work necessary on polarization control.
- Provide synthetic analysis by the group of experts involved, recommendation for future work and implications for ITER

5. Specific H&CD physics for ITER:

Task Agreement WP10-HCD-01-05:

Specific H&CD physics for ITER

5.1 Introduction

Non-Activated phase: ITER will start operation with hydrogen and helium plasmas for which the H&CD systems have not been optimised. An assessment of the H&CD capability/limitations and the commissioning and operational plan are needed.

DT operation scenarios: Further investigations of the power deposition and current drive distribution across the plasma in H-modes and advanced scenarios are needed, including an assessment of the requirements on H&CD systems.

Long pulse operation: Reliability requirement stems from a need to keep control over the beta and plasma inductance evolution throughout the discharge due to the limitations of the poloidal field magnets in ITER. As a result, for nearly all ITER discharges the heating system will have to demonstrate long pulse capability.

5.2 Objectives

Analyse the H&CD mix influence on ITER scenarios, in close connection with the on-going international scenario activity for ITER. Based on the results of scenario simulation codes, assess the heating or current drive needs to sustain H-modes, advanced, and radiative scenarios for ITER.

5.3 Work Description and Breakdown

Work Breakdown

WP10-HCD-01-05-01

Non-Activated phase of ITER

Experiments and/or numerical simulations to assess the H&CD capability/limitations, commissioning and operational plan in the non-activated phase of ITER

WP10-HCD-01-05-02

DT operation scenarios in ITER

Model the plasma evolution in the operational space by performing further experiments and modelling of ITER DT operation scenarios.

WP10-HCD-01-05-03

Long pulse operation in ITER

Detailed modelling of H&CD systems reliability and performance in long pulse operation in ITER

JET related activities

No JET experiments are foreseen to be implemented under this Task. However, should JET carry experiments or provide data in this area, a close coordination with the JET Task Forces will be sought.

Resources

Baseline Support: 4 ppy

5.4 Scientific and Technical Reports

Progress reports

At the end of each calendar year, during the Topical Group annual meeting, the Task Coordinator shall present a report on activities under the Task Agreement to the EFDA Leader for his approval. These reports shall integrate the progress made by each Association on each activity, and they shall indicate the level of achievement of the objectives, the situation of the activities, the allocation of resources and recommendations for the next year when applicable. The EURATOM financial contribution will be made through the usual procedures for baseline support through the Contract of Association.

Milestones and Deliverables

Milestones:

- Mid 2010 Activity Meetings: Collection and discussion of results obtained from the evaluation of theoretical work and experiments performed in 2009 and early 2010.
- End third trimester 2010 Annual meeting of the Topical Group: coordinated presentation of the results from the theoretical work and experimental campaigns in 2010.
- December 2010 Final report sent to EFDA-CSU.

Deliverables:

- Perform experiments and/or numerical simulations to assess the H&CD capability/limitations, commissioning and operational plan in the non-activated phase of ITER.
- Model the plasma evolution in the operational space by performing further experiments and modelling of DT operation scenarios.
- Determine through detailed modelling the drawbacks in H&CD systems in terms of reliability and performance in view of long pulse operation.

6. Off-axis Current Drive and rotation:

Task Agreement WP10-HCD-01-06:

Off-axis Current Drive and rotation

6.1 Introduction

NBI and LH off-axis current drive efficiency

The capability of driving off-axis current drive is a key issue for the development of long pulse operation in ITER and DEMO. Further work is needed to characterise the NBI and LH off-axis current drive efficiency.

Fast wave off-axis current drive

High frequency fast-wave (HFFW) electron H&CD is envisaged in substitution to off-axis NBCD or in DEMO in substitution to LH off-axis CD. As the frequency of the HFFW would be substantially higher than the cyclotron frequency (up to somewhat below the LH) the coupling is expected to be much higher than for the present ICRH antennas. Some attempts and results from US (NSTX) are available.

6.2 Objectives

Current drive and rotation:

Perform necessary experimental and modelling work for a final report on characterization of (off-axis) Current Drive and Rotation capability of NBI.

Fast wave off-axis current drive:

Perform theoretical investigation on the potential of such a scheme and identification of the type and characteristics of the antenna and RF power sources required. It is likely that some modelling tools should be upgraded and/or developed in purpose (Part I). If such a scheme would look promising test experiments could subsequently be proposed on existing machines (Part II).

6.3 Work Description and Breakdown

Work Breakdown

WP10-HCD-01-06-01

NBI and LH off-axis current drive efficiency

Experiments and/or simulations to test methods to drive off-axis current with NBI and LH.

WP10-HCD-01-06-02

Fast wave off-axis current drive

ITER relevant or DEMO related study to sort out theoretically, using up-to-date codes, the potential of such a scheme.

JET related activities

No JET experiments are foreseen to be implemented under this Task. However, should JET carry experiments or provide data in this area, a close coordination with the JET Task Forces will be sought.

Resources

Baseline Support: 4 ppy

Priority Support: 1.75 ppy to trigger interest in fast wave off-axis current drive physics, antenna modelling, power sources and co-ordination.

6.4 Scientific and Technical Reports

Progress reports

At the end of each calendar year, during the Topical Group annual meeting, the Task Coordinator shall present a report on activities under the Task Agreement to the EFDA Leader for his approval. These reports shall integrate the progress made by each Association on each activity, and they shall indicate the level of achievement of the objectives, the situation of the activities, the allocation of resources and recommendations for the next year when applicable. The EURATOM financial contribution will be made through the usual procedures for baseline support through the Contract of Association.

Report of achievements under Priority Support

Achievement of Priority Support deliverables will be reported separately to the EFDA Leader. A final report (and intermediate reports marking substantial progress in the achievement of deliverables, if the EFDA Leader so requests) shall be prepared by the Task Coordinator and submitted to the EFDA Leader. Each participating Association will have to report in one subsection on the degree to which the deliverables of their Task have been achieved, and shall include a breakdown of expenditure. The Task Coordinator will collect the individual subsections into the final report for Priority Support activities addressing the milestones. The EURATOM financial contribution will be made after approval by the EFDA Leader of these reports.

Milestones and Deliverables

Milestones:

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- End third trimester 2010 Annual meeting of the Topical Group: coordinated presentation of the results from the theoretical work and experimental campaigns in 2010.
- December 2010 Final report sent to EFDA-CSU.

Deliverables:

NBI and LH off-axis current drive efficiency

- Perform experiments or simulations to test methods to drive off-axis current drive with NBI and LH.

Fast wave off-axis current drive

- Launch an ITER relevant or DEMO related study to sort out theoretically, using up-to-date codes, the potential of such a scheme and to identify the type and characteristics of the antenna and RF power sources that would be required (Part I). If such a scheme would look promising test experiments could subsequently be proposed on existing machines (Part II).

7. Fuelling Physics:

Task Agreement WP10-HCD-01-07:

Fuelling Physics

7.1 Introduction

Better description of the fuelling and pumping systems used in the modelling efforts in present machines is needed to validate the solutions for ITER, and for the future machines. This requires better and validated modelling tools to be made available.

For instance, the fuelling in ITER relies on slow pellets, injected from the high field side, and on the grad B drift to increase core fuelling efficiency. Pellet ablation physics is not yet fully understood, in particular, the penetration due to the grad-B drift effect.

7.2 Objectives

Coordination the physics activities on particle sources delivered by the fuelling systems, in particular, the physics of pellet injection.

Bring the modelling communities together in the area of neutral flows in the divertor, pumps and ducts; aiming at understanding the influence of the pumping solutions for ITER on the divertor and edge particle control; and its compatibility with additional fuelling for ELM or disruption mitigation.

Further analysis of wall conditioning (fuel ratio, He, Li) in burning plasma conditions in view of reducing fuel throughput. The studies should take into account the consequences of massive gas injection for disruption mitigation and consider the available technologies for wall conditioning.

Contribution to experiments and modelling to validate ITER scenarios and controllability of burn parameters (D-T mix, burn-up fraction, He content) with relevant fuelling conditions, in particular pellet fuelling (in close collaboration with the other relevant EFDA structures).

7.3 Work Description and Breakdown

Work Breakdown

WP10-HCD-01-07-01

Pellet fuelling databases

Development of a pellet fuelling databases for extrapolation to ITER.

WP10-HCD-01-07-02

Modelling of pellet physics

Improve the modelling capability of pellet physics: drift, dispersion, evaporation.

WP10-HCD-01-07-03

Integration of particle control in ITER plasma scenarios simulations

Reinforce the activities on integration of particle control in ITER plasma scenarios simulations. Develop predictive modelling for gas flow coupling the divertor, pumping, and duct systems.

WP10-HCD-01-07-04

Pellet fuelling experiments to validate ITER scenarios

Definition of pellet fuelling experiments required to validate ITER scenarios (in collaboration with Transport and MHD Topical Groups).

JET related activities

No JET experiments are foreseen to be implemented under this Task. However, should JET carry experiments or provide data in this area, a close coordination with the JET Task Forces will be sought.

Resources

Baseline Support: 4 ppy

PrioritySupport:0.5 ppy (Coordination of activities)

7.4 Scientific and Technical Reports

Progress reports

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Milestones and Deliverables

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Deliverables:

- Development of a pellet fuelling databases for extrapolation to ITER
- Improve the modelling capability of pellet physics: drift, dispersion and evaporation in particular in the pedestal.
- Reinforce the activity on integration of particle control in ITER plasma scenarios simulations including; analysis of the consequences of ITER pumping rate on wall conditioning (GDC and RF) and on scenarios (compatibility with radiative divertor); and predictive modelling for gas flow coupling the divertor, pumping, and duct systems (also for DEMO) (detailing leaks -> pumping efficiency per species).
- Define pellet fuelling experiments required to validate ITER scenarios, to be carried in the future, in collaboration with Transport and MHD Topical Groups.