EFDA WORKPROGRAMME 2011

Call for Participation

(Part of the EFDA WP, PWI TF)

Deadline for Responses: 21st September 2010

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This Call for Participation aims to implement the Plasma Wall Interaction Work Programme for 2011 under Task Agreement as foreseen in the new EFDA Art. 5.

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Introduction

At its meeting in Dublin on the 23rd June 2010, the EFDA Steering Committee approved elements of the EFDA 2011 Work Programme, among which the PWI TF programme. This includes the preparation and execution of experiments performed in the Associations and the subsequent coordinated analysis of experimental data.
The PWI TF programme implemented on the basis of call for participation. The outcome of the call will be assessed by the PWI Task Force leadership and the EFDA-CSU and implemented under a number of Tasks on the basis of the provisions given in Art. 5 of the EFDA Agreement. The work Programme 2011 of the PWI TF consists of 6 Tasks which are defined and organised under the 6 Special Expert Working Groups (SEWGs) which constitute the Task Force. The tasks are summarized in table 1.

Table 1: Summary of Tasks proposed for 2011

SEWG	Proposed Tasks for 2011
SEWG Fuel retention	Fuel retention as a function of wall materials foreseen for ITER.
SEWG Fuel removal and dust in fusion devices	Exploration of fuel removal methods compatible with retention in mixed materials and metals, including beryllium and dust generation and characterization
SEWG Material Migration	Erosion, transport and deposition of first wall materials
SEWG High-Z Materials and Liquid metals	Development of the PWI basis in support of integrated high-Z scenarios for ITER and demonstration of liquid plasma-facing components
SEWG ITER Material Mix	PWI properties of alloys and mixed compounds formed under ITER relevant conditions and their influence on PWI processes and fuel retention
SEWG Transient Heat Loads	Mitigation of disruptions and investigation of ELM and inter-ELM heat loads

In line with the effort started in 2010, the programme includes the effect of seeded impurities on PWI in view of a more integrated plasma scenario, as well as the impact of loss of divertor detachment, discharge tailoring and RF cleaning processes, following recent concerns from the ITER IO. A strong effort is also put on the tungsten R&D, around the exploitation of the full W ASDEX Upgrade and the preparation of the ITER Like Wall project at JET. New elements concerning beryllium (Be) are also introduced, like the study of Be erosion yields and in particular potential Be chemical erosion, or Be melt layer dynamics. The WP 2011 finally keeps a reinforced emphasis on the interpretative modelling, to benchmark codes used to predict PWI in ITER (B2-Eirene, ERO, DIVIMP …) against present day tokamak data.

The activities under Priority Support in these Task Agreements were recommended by the EFDA Steering Committee at its meeting of 12th March 2008 in Prague (EFDA (08) 36/4.2) and endorsed by the CCE-FU at its meeting of 3rd April 2008 (EUR (08) CCE-FU 41/6.3a). This pertains to well identified actions, including:

- TF and SEWG leadership (0.5 ppy for TF leader and deputies, 0.25 ppy for SEWG leadership)
- joint activities: experimentation, modelling, support to the other Associations, etc.
- selected hardware or manpower costs involving irradiation, work on hot cells, work with tritium and/or beryllium

For 2011, the estimated Priority Support resources amount to **750 kEuro** (EC contribution) (including hardware).

Exchange of scientists between the involved Associations is planned covering:

- participation in joint experimental campaigns and modelling efforts
- attendance to the SEWG and TF meetings.

For all these exchanges, the use of the mobility agreement is foreseen with the overall mobility budget of **415 kEuro.**

Baseline Support Activities

The 2011 Call is simplifying the administrative procedures for baseline support. For tasks under Baseline Support it is no longer necessary to specify the manpower committed against each individual proposal. The Associations should enter a description of the scientific and technical work to be carried out for each proposal under Baseline Support (as before), leaving the manpower field blank. The global amount of manpower for all the proposals from your Association under PWI 2011 should then be entered by submitting a proposal under the "Task Agreement" WP11-PWI-00 (Global Baseline per Association).

1. SEWG Fuel Retention:

Task WP11-PWI-01: Fuel retention as a function of wall materials foreseen for ITER.

1.1 Introduction

The dominant retention mechanisms are codeposition and deep bulk diffusion. Codeposition has been extensively studied in laboratory experiments for C and Be. The knowledge of the dependence of deep diffusion of H in metals on flux/temperature and radiation damage is still limited and requires further research.
Progress has been made to understand apparent discrepancies between gas balance (on a single discharge) and post mortem analysis (integrated over a campaign). Both methods are complementary and should be used to assess how much fuel is retained (gas balance) and where it is trapped in the vessel (post mortem analysis)."
So far, most data on retention were obtained in all-carbon machines. First results from full W AUG are now available, but more data from carbon free machines (all-W ASDEX Upgrade, future ITER like Wall in JET) are needed for a better prediction for ITER.
The scaling of the retention rate as a function of incident flux/fluence and temperature is only poorly characterized.
The influence of material morphology, structure and radiation damage on H retention in metals is not very well understood. More data are needed for extrapolation to ITER.

1.2 Objectives

Laboratory investigations clearly point to a much lower T retention in tungsten plasma facing components (PFCs) compared with carbon based PFCs. Results obtained in ASDEX–Upgrade are in line with these investigations, but ITER will face additional effects related to the high particle fluxes (both in steady state and transient conditions), material mixing (Be-W) and neutron irradiation. A large part of this investigation will be carried out in the context of the JET Work Programme. The non-JET activities in WP2011 will focus on the comparison of fuel retention in different machines, with the goal of determining a multi-machine scaling, and the characterization of retention mechanisms. These activities will provide further insight in the retention mechanism allowing a more reliable extrapolation to ITER and DEMO.

1.3 Work Description and Breakdown

The Work Programme involves experiments on gas balance in several European fusion devices (ASDEX Upgrade, Tore Supra, TEXTOR and other possible relevant devices, JET for comparison) and subsequent surface analysis in different laboratories for comparison. It is coordinated by the SEWG on Gas Balance and Fuel Retention which:

- sets up the experimental work programme, including the request for machine time in the different fusion devices;
- follows the samples exchange for surface analysis;
- organizes SEWG meetings for collection of data, interpretation and extrapolation of results;
- summarizes the collected data in a final report.

Work under the present Task Agreement includes two subtasks.

1.3.1 Work Breakdown

WP11-PWI-01-01

Multi machine scaling of fuel retention for ITER
(AUG, TS, TEXTOR (JET for comparison), other relevant devices, PSI devices)

- Complete studies of retention in C environment for different regimes (TS, TEXTOR, and possibly other relevant devices)
- Study the retention in a full W environment for different regimes (L mode, type I ELM, type III ELMs and advanced tokamak regimes). Comparison with results in previous configurations as a function of carbon coverage (AUG)
- Study D retention in Be/W/mixed materials under high fluence (PISCES, IPP dual beam), see also SEWG on ITER material mix
- Assess the contribution of wall conditioning (boron) on the retention, in particular for metallic devices
- From all the above experiments, establish a multi-machine scaling of retention and refine the fuel retention predictions for ITER

WP11-PWI-01-02

Characterisation of retention mechanisms
(AUG, TS, other relevant devices (JET for comparison), analysis in several associations)

- Perform an extensive post mortem analysis of PFCs for comparison with integrated particle balance results.
- Assess the location of the retained fuel in the vessel: deposited layers, gaps, bulk material, flakes, remote areas, below limiter/divertor… in order to improve mitigation measures (in plasma operation as well as for the design of PFCs) and fuel removal techniques.
- For T housekeeping in ITER investigate the temperature dependence of fuel release from metals that have suffered radiation damage (influence of trap sites on release temperature).
- Retention in mixed materials in cooperation with the SEWG mixed materials. In particular for material mixes that are expected to form in large quantities in ITER or during the JET ILW. (Be_xW_y, Be_xC_y, Be_xN_y, W_xN_y…)
- Flux dependence of retention in metals: At different temperatures compare high to low flux implantation while keeping the fluence constant with respect to retention. Investigate the changes in the metals structure due to high flux implantation.
- Impact of radiation damage on hydrogen retention and diffusion in high Z metals in cooperation with High-Z SEWG
- Experimental investigations and modelling of deep diffusion and permeation in high Z metals at high fluxes and temperature.
- Investigation of hydrogen retention in W-alloys which are proposed for use in first wall applications (e.g. W/Ta, W/Re and W/La) in cooperation with High-Z SEWG
- First principles modelling of H and He in W:

- Calculate ab-initio binding energies of He and H to different defect types:Dislocations and Vacancies of different size (from mono- to N-Vacancies).
- Calculate H and He diffusion and trapping using classical and ab-initio MD methods.
- Compare the resulting effective transport rates with those in classical diffusion/trapping codes (e.g. TMAP7) which are based on experimental data.

Please ensure that when making a proposal for activities under Priority Support, a detailed proposal is submitted, including a description of the work to be performed outlining the novelty of the investigation compared with previous work and a description of the deliverables.

1.3.2 JET related activities

No JET related activities are meant to be implemented under this Task Agreement. JET related activities are implemented under EFDA Art.6. However some JET activities should be mentioned for information in this TA when they closely related to the activity implemented under Art.5. JET data collected under the JET part of the EFDA WP can be brought together with other data under this TA when relevant for the progress of the work or used in multi-machine modelling activities under Art.5.

JET TF E1/E2 and TF FT	Retention in an Be/W ITER like scenario • Characterization of mixed material layers that have formed and fuel retention therein in cooperation with the SEWG mixed materials. (TF FT) • Use gas balance and post mortem analysis to evaluate the remaining D retention after a H_2 campaign to assess “isotopic exchange” as a potential cleaning method. (TF E2)

1.3.3 Resources

Activities eligible for priority support:

- Joint post mortem analysis of tokamak PFCs coordinated within the EU associations for comparison with particle balance, identification of retention mechanisms and location of the trapped fuel. In particular, consumables, such as ^{3}He used for D retention measurements by Nuclear Reaction Analysis, could be partly funded to compensate for its recent cost increase.
- Joint experiments to establish a multi machine scaling of fuel retention as a function of the plasma parameters and device characteristics

Part of international effort (ITPA Divertor and SOL) which could lead to missions under mobility.

1.4 Scientific and Technical Reports

1.4.1: Progress reports

At the end of each calendar year, during the PWI TF annual meeting, the SEWG leader in charge of the task coordination shall present a report on all activities (under baseline and priority support) 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.

1.4.2: Report of achievements under Priority Support

In addition, achievement of Priority Support deliverables will be reported separately to the EFDA Leader. A final report shall be prepared by the SEWG leader in charge of the task coordination 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 Tasks 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 associated milestones defined.

The EURATOM financial contribution will be made after approval of these reports by the EFDA Leader.

1.4.3 Milestones and Deliverables

Milestones:
Mid 2011
SEWG Meeting: Collection and discussion of results obtained from the evaluation of experiments in 2010 and early 2011

October 2011:
Annual meeting of the EU TF on PWI: coordinated presentation of the results from the experimental campaigns in 2011

December 2011: Final report sent to EFDA-CSU.

Deliverables:
a) One technical report per facility involved according to the objectives described above by October 2011.
b) Synthetic analysis by the group of experts involved, recommendation for future work and implications for ITER by end 2011.

2. SEWG Fuel removal and dust in fusion devices:

Please note that technology oriented tasks on the development of fuel and dust removal techniques and dust diagnostics for ITER will be implemented under EFDA Emerging Technology in a later call for participation.

Task Agreement WP11-PWI-02: Exploration of fuel removal methods compatible with retention in mixed materials and metals, including beryllium and dust generation and characterization

2.1 Introduction

The retention rate of tritium in the ITER vessel is likely to require *in-situ* tritium recovery during operations or during the maintenance period (depending on the choice of first wall and divertor materials), or methods to actively control the inventory by limiting the tritium uptake during each pulse.

Most of the work on fuel removal in the past has been removal from carbon, and although there may be carbon targets in the ITER divertor, this field is already quite mature. However, ITER will certainly have issues with tritium retention in beryllium (Be) and tungsten (W), and in mixed materials involving Be and W in conjunction with carbon and oxygen impurities.

The formation and accumulation of carbon and metal dust (W, Be) in a fusion reactor may create serious safety and operational problems, some of them connected to tritium retention. A strategy to deal with the dust accumulation has been adopted in the ITER baseline.
Dust sampling and analysis have been performed in different facilities, showing discrepancies between devices.

Long term objectives :

The aims of this SEWG are to:

- Develop an integrated scenario for fuel removal in ITER:
  - Explore possible methods to limit tritium uptake during the discharge
  - Derive a credible tritium inventory control scheme relying on developed cleaning techniques to meet ITER operational requirements.
  - Assess combined efficiency, removal rates and schedule needed.
- Assess efficiency of developed fuel removal methods (chemical and photonic) for reducing hydrogenic retention in metals and mixed materials
- Explore new fuel removal methods, targeted at hydrogenic retention in metals (for ITER with future all-metal divertor)
- Investigate wall conditioning scenarios (in particular RF conditioning, in collaboration with the EFDA TG on heating and current drive).

The SEWG will concentrate on the scientific work, experimentation and modelling, complementing the technical development of systems which might find application on ITER, which is the purpose of the EFDA emerging technologies Dust and Tritium programme.

2.2 Objectives

In order to decrease the tritium inventory, several procedures for fuel removal caused by Tritium co-deposition with carbon were investigated previously. The 2011 activities will concentrate on the evaluation of their efficiency and their technological applicability. Most of these procedures work either by isotope exchange with hydrogen or deuterium or by producing volatile gas species by some kind of low temperature plasma or baking. In order to be applicable in ITER it has to be checked whether the expected large amounts of deposited Be have an impedimental impact. A large number of proposed activities will try to elucidate this issue. Most of the work on fuel removal in the past has been removal from carbon, and although there may be carbon targets in the ITER divertor, this field is already quite mature. However, ITER will certainly have issues with tritium retention in beryllium (Be) and tungsten (W), and in mixed materials involving Be and W in conjunction with carbon and oxygen impurities. Comparisons to carbon may be appropriate, and carbon may also be a convenient material for early development of new technology, but preference will be given in future work programmes to experiments involving Be (or a material of similar behaviour) and/or W and/or mixed materials. For all technologies, activities are expected to include quantification of the removal rates, and applicability to ITER in their objectives.

A very important activity is to improve the knowledge on dust generation and its characterization in different tokamaks. It also includes the development of dust generation and transport models in order to provide better predictions for ITER. Specific activities are foreseen to investigate the appearance of dust in plasma discharges and on the post mortem investigation of the dust morphology.
The most important issues to be addressed are the following:

- Mechanisms for dust generation during plasma operation and/or the maintenance phase including conditioning.
- Transport of dust particles in the plasma and development of associated codes.
- Impact of fuel removal methods on dust generation.
- Development and assessment of diagnostics for dust quantification.
- Physics basis for techniques for dust removal.

2.3. Work Description and Breakdown

2.3.1 Work Breakdown

The Work Programme involves laboratory-based experiments in dedicated facilities; experiments on fuel recovery in several European fusion devices (JET, ASDEX Upgrade, Tore Supra, TEXTOR and others); and surface analysis of treated samples in different laboratories for comparison. It is coordinated by the SEWG on Fuel Recovery and Dust which:

- identifies necessary experiments or analysis;
- supports requests for machine time in the different fusion and laboratory devices;
- facilitates exchange of treated samples for surface analysis at different laboratories;
- organizes SEWG meetings for collection of data, interpretation and extrapolation of results;

- summarises the collected data in a final report.

Work under the present Task Agreement includes seven research activities and one managing task.

WP11-PWI-02-00

Leadership of the Special Expert Working Group (SEWG) on Fuel Removal and Dust in Fusion Devices

Leadership of the Special Expert Working Group on Fuel Removal and dust is an ongoing activity and the main concern is to lead the projects towards a successful and timely implementation of the PWI work programme in the field of Fuel Removal and Dust. The SEWG leader has the following obligations:

- Lead and organize the overall SEWG activities
- Monitor progress and coordinate the research in the SEWG on Fuel Removal and Dust, in particular tasks defined in the PWI Task Agreement
- Assist the PWI TF Leaders in definition and implementation of the annual work programmes
- Provide Annual report on Tasks related to the SEWG activities
- Support the interaction with TG and other EFDA, EU and ITER related organization

Associations are invited to nominate candidates for the position of the Leader of the SEWG on Fuel Removal and Dust, which corresponds to a work load of 0.25 ppy per year in Priority Support. The application should include a CV, a short description of the relevant skills and experience, and a list of recent publications of the applicant.

WP11-PWI-02-01

Wall conditioning and discharge tailoring

- Investigate wall conditioning techniques (particularly RF conditioning) in tokamaks, with emphasis on fuel removal efficiency, operation under ITER conditions, and side effects such as dust production and plasma restart.
- Investigate the possibility of H-isotope exchange at beginning/end of discharges to limit the T retention in ITER (experiments likely to be simulations using H/D switching)

WP11-PWI-02-02

Chemical cleaning methods

- Explore the impact of repetitive oxidising plasmas (GDC/RF) on beryllium bulk properties and other in-vessel components.
- Study the effect of sample temperature for oxidative or advanced chemical cleaning (with or without glow discharge) on oxide film formation, and demonstrate beryllium oxide removal rates
- Resolve the impact of nitrogen-containing molecules on cleaning processes and understand the discrepancy between laboratory and tokamak experience

WP11-PWI-02-03

Photonic cleaning methods

- Improve the understanding of the film break-up processes in photonic "cleaning", such as measuring the hydrogenic content of the particulates relative to the film composition, optimising gaseous release, and preventing spread of dust. Assess practical methods of exploiting laser techniques in ITER in **conjunction with the EFDA Emerging Technologies** in charge of the associated technological development.

WP11-PWI-02-04

Fuel removal in gaps

- Develop methods for the removal of deposited films in tile gaps and castellations, measuring the efficiency as function of aspect ratio, etc. Possible techniques are glow discharge cleaning in oxygen or O-based gas mixtures (for which the relative importance of the ion species should be quantified), and use of a plasma torch

WP11-PWI-02-05

Dust generation in present devices

- •Metal dust formation (W and Be): Identification of dust generation mechanisms in particular the impact of transients events such as ELMs and disruptions. Validate modelling for dust creation, transport and suspension. Assess implications for a standard ITER scenario.
- •Characterize dust generation in present devices (TS, TEXTOR, AUG and possibly other relevant devices; comparison to JET): location in vacuum vessel, generation rates, physical and chemical properties. The emphasis is on the fuel content, size distribution, surface specific area and reactivity.

WP11-PWI-02-06

Conversion of co-deposits to dust

- Assess the dust conversion factor (gross erosion to dust production) for different EU devices.
- Assess dust (carbon and metals) generation by various techniques for fuel and co-deposit removal such as photonic and oxidative methods (see also SEWG on fuel removal).
- Characterise dust properties (e.g. composition, size distribution) and surface state of PFC after mechanical removal of co-deposits.
- Determine the uptake (re-take) of deuterium by layers previously depleted by oxidative or photonic (laser heating, flash-light) methods.

WP11-PWI-02-07

Dust diagnosis in plasma

- Improve detection of dust in the plasma and relate the dust generation to discharge conditions**.**
- Improve understanding of the impact of dust formation and mobilization on plasma performance and machine operation.

- Collect and characterise dust collected during plasma operation.

Please ensure that when making a proposal for activities under Priority Support, a detailed proposal is submitted, including a description of the work to be performed outlining the novelty of the investigation compared with previous work and a description of the deliverables.

2.3.2 JET related activities

No JET related activities are meant to be implemented under this Task Agreement. JET related activities are implemented under EFDA Art.6. However some JET activities should be mentioned for information in this TA when they closely relate to the activity implemented under Art.5. JET data collected under the JET part of the EFDA WP can be brought together with other data under this TA when relevant for the progress of the work or used in multi-machine modelling activities under Art.5.

JET TF E2 and TF FT	• Test fuel removal techniques on JET PFCs, in particular containing Be (TF FT) • Compare the efficiency of ICRF wall conditioning in the ILW configuration with that extracted .in the previous carbon configuration. (TF E2) • Observation of dust by visible and IR cameras (TF E2). • Dust sampling during shutdowns (TF FT)

2.3.3. Resources

Activities eligible for priority support:

- Beryllium related work: impact of repetitive exposure to GDC and/or RF oxidising plasmas of surface and bulk beryllium. Treatment of oxidised beryllium samples with glow or RF assisted plasmas (e.g. in He and Ar) to establish cleaning rates and assess removed material.
- Coordinated surface analysis of treated samples (tokamak and laboratory) to characterise surface deposits remaining after cleaning and damage to bulk material, including tritium and beryllium analyses where appropriate.
- Joint experiments on RF conditioning, to assess cleaning efficiencies and optimize the cleaning process (RF parameters, magnetic field …).
- Coordinated analysis (including fuel retention) of dust samples from different devices
- In particular, consumables, such as ^{3}He used for D retention measurements by Nuclear Reaction Analysis, could be partly funded to compensate for its recent cost increase.
- Coordinated assessment of erosion and dust production to determine the dust conversion factor, using a standardized methodology for all the devices involved;
- Diagnostic exchange between devices for joint characterization of consequences of dust on plasma operation and performances (e.g. fast cameras)

Part of international effort (ITPA Divertor and SOL), which could lead to missions under mobility.

2.4 Scientific and Technical Reports

2.4.1: Progress reports

At the end of each calendar year, during the PWI TF annual meeting, the SEWG leader in charge of the task coordination shall present a report on all activities (under baseline and priority support) 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.

2.4.2: Report of achievements under Priority Support

In addition, achievement of Priority Support deliverables will be reported separately to the EFDA Leader. A final report shall be prepared by the SEWG leader in charge of the task coordination 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 Tasks 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 associated milestones defined.

The EURATOM financial contribution will be made after approval of these reports by the EFDA Leader.

2.4.3 Milestones and Deliverables

Milestones:
Mid 2011
SEWG Meeting: Collection and discussion of results obtained from the evaluation of experiments in 2010 and early 2011

October 2011:
Annual meeting of the EU TF on PWI: coordinated presentation of the results from the experimental campaigns in 2011

December 2011: Final report sent to EFDA-CSU.

Deliverables:
- a) One technical report per facility involved according to the objectives described above by October 2011.
- b) Synthetic analysis by the group of experts involved, recommendation for future work and implications for ITER by end 2011.

3. SEWG Material Migration

Task Agreement WP11-PWI-03: Erosion, transport and deposition of first wall materials

3.1 Introduction

Present status:

- Chemical erosion of carbon-based materials is adequately described as function of temperature, energy and incident flux. Role of synergistic effects with seeding gases are not fully understood yet. Work is ongoing concerning gases like Ne, Ar and N_2.
- At plasma temperatures below 10 eV and fluxes above $10^{23}/m^2s$, new experimental data from PILOT-PSI and tokamaks available. ERO modelling is ongoing (need for plasma background as input). First measurements indicate a non linear increase of deposition measured by QMBs as a function of ELM energy. The chemical re-erosion yield of deposited layers due to ELMs is sill an open issue.
- Major trends of the global migration pattern are being identified. Experiments in AUG have confirmed that the outer midplane is the main impurity source with carbon walls. The outer divertor is a minor erosion source in comparison to the main chamber. Moreover, it can switch from being erosion-dominated to deposition-dominated by changing e.g. the geometry or the surface conditions. The transport from the outboard midplane to the inner divertor ($^{13}CH_4$ gas puffs experiments in AUG and JET) is reproduced in simulations, but absolute values are overestimated in the modelling. Re-erosion appears to be more pronounced in experiments.
- The long term material deposition is associated with the tritium retention issues, which become most prominent in PFCs with gap structure. No final conclusion on an optimum geometrical arrangement has been found yet. In particular the deposition in the bottom of gaps, far away from the top surface, is unclear and shall be investigated in the future by both modelling and experiments.
- Diagnostics for erosion/lifetime surveillance with resolution relevant for device safety are needed.

3.2 Objectives

The 2011 activities will focus on cross machine comparisons of main wall erosion and local re- and co-deposition, characterisation of outer and inner divertor erosion as well as the migration of impurities from main chamber to divertor and inside the divertor. Furtheron material migration codes shall be developed and measurement and modelling of chemical erosion of low-Z materials in tokamaks for plasmas at low temperatures including the impact of seeding gases are foreseen.

3.3 Work Description and Breakdown

The Work Programme involves experiments on material erosion and transport in several European fusion devices (ASDEX Upgrade, Tore Supra, TEXTOR, MAST, JET for comparison) and linear plasma generators (PSI-2, PILOT/Magnum). It is coordinated by the SEWG Material Migration which:

- Sets up the experimental work programme, including the request for machine time in the different fusion devices
- Supports the organisation of EU and international modelling collaborations
- Organises SEWG meetings for collection of data, interpretation and extrapolation of results.
- Summarizes the collected data in a final report

Work under the present Task Agreement includes four research activities and one managing task:

3.3.1 Work Breakdown

WP11-PWI-03-00

Leadership of the Special Expert Working Group (SEWG) on Material Migration

Leadership of the Special Expert Working Group (SEWG) on Material Migration is an ongoing activity and the main concern is to lead the projects towards a successful and timely implementation of the PWI work programme in the field of Material Migration. The SEWG leader has the following obligations:

- Lead and organize the overall SEWG activities
- Monitor progress and coordinate the research in the SEWG on Material Migration , in particular tasks defined in the PWI Task Agreement
- Assist the PWI TF Leaders in definition and implementation of the annual work programmes
- Provide Annual report on Tasks related to the SEWG activities
- Support the interaction with TG and other EFDA, EU and ITER related organization

Associations are invited to nominate candidates for the position of the Leader of the SEWG on Material Migration, which corresponds to a work load of 0.25 ppy per year in Priority Support. The application should include a CV, a short description of the relevant skills and experience, and a list of recent publications of the applicant.

WP11-PWI-03-01

Cross machine comparisons of main wall erosion and local re- and co-deposition

Measurements of local gross and net erosion in the main chamber along with local re-deposition, using midplane probes or long term samples left in place for a run campaign (e.g. ASDEX-Upgrade, MAST, TEXTOR, Tore Supra in comparison with JET and US devices). Such measurements should be performed in a coordinated spectroscopic approach (for gross erosion) to guarantee consistent measurements. Potential use of markers to track where the eroded material migrates is encouraged. In particular, the comparison of carbon and tungsten migration is of interest.

WP11-PWI-03-02

Characterisation of outer and inner divertor erosion as well as the migration of impurities from main chamber to divertor and inside the divertor

Use of ^{13}C and other marker studies for migration studies in post-campaign erosion and deposition measurements. Additionally use of ‘single marker tiles’ (for example Mo on tungsten tiles in ASDEX-Upgrade, and Mo, ^{13}C or W on C for carbon PFC machines) for toroidal and poloidal migration measurements. It should be clarified if the transport to remote areas can be attributed to chemical erosion only, or if it is a combination of physical and chemical erosion.

WP11-PWI-03-03

Further development of material migration codes
Development/improvement/combination of local and global erosion/transport codes (such as ERO …), to take into account PFC surface shaping to predict deposition patterns for both steady state diverted operation and during limiter start-up/ramp down phases. Benchmark with existing experimental data on the effect of surface roughness, shadowing effects and gap deposition. Try to use codes to find optimized shape of PFCs for ITER.

WP11-PWI-03-04

Measurement and modelling of chemical erosion of low-Z materials in tokamaks for plasmas at low temperatures including the impact of seeding gases

- Low electron temperature plasma operation at high electron density is foreseen for the ITER divertor target plates. The intrinsic radiation by carbon seems currently to be insufficient to achieve the needed radiated fraction. Therefore seeding gases for radiation are foreseen. The interaction of seeding gases such as N_2 is complicated and can cause additional chemical erosion of carbon. However, the increase of erosion might be compensated by the reduction of sputtering due to plasma cooling. Experiments in tokamaks such as AUG and TEXTOR and linear machines (MAGNUM) will be used to investigate the erosion at high deuterium ion fluxes with and without additional impurity seeding.
- Swift chemical erosion of Be. Experiments and modelling of BeD formation.
- Development and application of marker techniques (coupled with spectroscopy measurements) in the divertor PFCs in order to measure in-situ net erosion and dust generation.

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Please ensure that when making a proposal for activities under Priority Support, a detailed proposal is submitted, including a description of the work to be performed outlining the novelty of the investigation compared with previous work and a description of the deliverables.

3.3.2 JET related activities

No JET related activities are meant to be implemented under this Task Agreement. JET related activities are implemented under EFDA Art.6. However some JET activities shall be mentioned for information in this TA when they closely relate to the activity implemented under Art.5. JET data collected under the JET part of the EFDA WP can be brought together with other data under this TA when relevant for the progress of the work or used in multi-machine modelling activities under Art.5.

JET TF E1/E2 and TF FT	• Measurements (spectroscopy/QMB) and modelling (EDGE2D/EIRENE, DIVIMP and ERO) of first wall material erosion under ITER relevant conditions (TF E2)

3.3.3 Resources

Activities eligible for priority support:

- Coordinated experiments on gross and net erosion, with a standardized methodology for spectroscopic data, including hardware for marker tiles and upgrade of spectroscopic tools
- Coordinated experiments on carbon erosion associated with seeding impurities
- Development of modelling tools for erosion /deposition (in particular taking into account gaps and realistic geometries) and benchmarking against present day tokamak or lab data

Part of international effort (ITPA Divertor and SOL) which could lead to missions under mobility.

3.4 Scientific and Technical Reports

3.4.1: Progress reports

At the end of each calendar year, during the PWI TF annual meeting, the SEWG leader in charge of the task coordination shall present a report on all activities (under baseline and priority support) 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.

3.4.2: Report of achievements under Priority Support

In addition, achievement of Priority Support deliverables will be reported separately to the EFDA Leader. A final report shall be prepared by the SEWG leader in charge of the task coordination 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 Tasks 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 associated milestones defined.

The EURATOM financial contribution will be made after approval of these reports by the EFDA Leader.

3.4.3 Milestones and Deliverables

Milestones:

Mid 2011

SEWG Meeting: Collection and discussion of results obtained from the evaluation of experiments in 2010 and early 2011

October 2011:

Annual meeting of the EU TF on PWI: coordinated presentation of the results from the experimental campaigns in 2011

December 2011: Final report sent to EFDA-CSU.

Deliverables:

a) One technical report per facility involved according to the objectives described above by October 2011.
b) Synthetic analysis by the group of experts involved, recommendation for future work and implications for ITER by end 2011.

4. SEWG High-Z Materials

Task Agreement WP11-PWI-04: Development of the PWI basis in support of integrated high-Z scenarios for ITER and demonstration of liquid plasma-facing components.

4.1 Introduction

Present status:

- Successful operation with un-boronised full W tokamak (AUG) confirmed (start-up feasible, W erosion tolerable, good confinement, low D retention in W coatings, in agreement with lab. Experiments).
- Improvements to ICRH antenna design to reduce W erosion by ions accelerated by ICRH.
- With boronization impurity seeding is essential for reducing divertor heat load by radiation cooling. Nitrogen seeding, with feedback control matured into routine system, resulted in good plasma performance (confinement improvement) with no problem for operation. Interaction of nitrogen with tungsten to be further investigated
- W flushing from pedestal region more important than W erosion by ELMs.
- Initial characterization of irradiated W sample (cracks under transient heat loads) and nanostructured W surface.
- Progress of diagnostics (thermography in a full metal environment, W spectroscopy).
- Performance of FTU Liquid lithium limiter based on capillary porous system increased. No problem with tested heat load up to 5MW/m^2. First experiments with liquid Ga jet on ISTTOK. Hydrogenic retention and stability to be investigated.

4.2 Objectives

The 2011 activities will focus on the investigations of PWI in a full-W device, including PWI interpretative modelling for W migration and melting dynamics of metal PFCs under high heat fluxes. Further investigations of interaction of nitrogen with tungsten will be performed.

A completely different approach for PFC is the use of liquid PFMs. Lithium is currently the mostly used in such investigations due to its strong conditioning effect and its strong pumping capability for hydrogen. The FTU Liquid lithium limiter based on capillary porous system has been tested and first experiments with liquid Ga jet on ISTTOK have been performed. However to prove its usefulness in a reactor still major questions on power load capability, hydrogen retention and plasma dilution have to be clarified. A preliminary assessment of the perspective of the use of liquid metals for fusion reactors will be made in 2011.

4.3 Work Description and Breakdown

The Work Programme involves experiments on the compatibility of high-Z materials with plasma operation in several European fusion devices (ASDEX Upgrade, FTU, TEXTOR and possible other relevant devices). It includes as well assessment of operation of tokamaks with liquid metals PFCs and in particular:

- uptake of hydrogen in liquid metals
- power load capabilities (a new single element actively cooled and lithium refilled, able to withstand heat loads up to $10MW/m^2$ for 4s, is being designed for FTU)
- behaviour under transient plasma conditions (splashing, evaporation)
- and supporting modelling using the FOREV, MEMOS and possibly other relevant codes.

It is coordinated by the SEWG High-Z Materials which:

- Sets up the experimental work programme, including the request for machine time in the different fusion devices and plasma simulators / experimental facilities.
- Supports the organisation of EU and international modelling collaborations
- Organises SEWG meetings for collection of data, interpretation and extrapolation of results.
- Summarizes the collected data in a final report, on melt splashing and evaporation under the transient conditions.

Work under the present Task Agreement includes four research activities and one managing task.

4.3.1 Work Breakdown

WP11-PWI-04-00

Leadership of the Special Expert Working Group (SEWG) on High-Z Materials

Leadership of the Special Expert Working Group (SEWG) on High-Z Materials is an ongoing activity and the main concern is to lead the projects towards a successful and timely implementation of the PWI work programme in the field of High-Z Materials.

The SEWG leader has the following obligations:

- Lead and organize the overall SEWG activities
- Monitor progress and coordinate the research in the SEWG on High-Z Materials, in particular tasks defined in the PWI Task Agreement
- Assist the PWI TF Leaders in definition and implementation of the annual work programmes
- Provide Annual report on Tasks related to the SEWG activities
- Support the interaction with TG and other EFDA, EU and ITER related organization

Associations are invited to nominate candidates for the position of the Leader of the SEWG on High-Z Materials, which corresponds to a work load of 0.25 ppy per year in Priority Support. The application should include a CV, a short description of the relevant skills and experience, and a list of recent publications of the applicant.

WP11-PWI-04-01

PWI in a full-W device

- Participate in the control of W core accumulation under high power regimes (central ECRH, ELM pace-making)

- Characterise W erosion by ICRH (new antenna design, modelling of far SOL). Comparison with C-Mod.
- Investigate the effect of different seed impurities (Ne,Ar,N) on W erosion and PFCs heat loads (comparison with Mo erosion in FTU). Investigation of nitrogen interaction with tungsten. Mixing of seed impurities for optimising radiative cooling.
- W related diagnostic : development of W influx diagnostics. IR measurements in an all-metal machine.
- W morphology under plasma bombardment : growth of nanostructures and blister generation on W under He and hydrogenic fluxes.
- PWI related properties of tungsten alloys (erosion, retention, trannsients etc)
- Utilization of Mo markers for in situ W erosion measurement by spectroscopy; comparison with post mortem analysis.

WP11-PWI-04-02

Melting dynamics of metal PFCs under high heat fluxes

- Modelling of W/Be damage. Effect of divertor target pre-damage on device operation, effects of unmitigated and mitigated ELMs on W/Be, influence of neutron irradiation, molten material dynamics (splashing, melting, MEMOS modelling), upgrading of used and/or development of new techniques for thick W coating deposition.
- Test of shaped FW mock-ups, development of models taking into account surface shaping.
- Modelling of runaways-material interaction (in collaboration with the SEWG Transient loads)..

WP11-PWI-04-03

Interpretative PWI modelling

Benchmarking of the codes used for ITER predictions (ERO, DIVIMP, SOLPS…) against available data (in particular for AUG full-W results) in terms of W erosion, core contamination, fuel retention ....)

WP11-PWI-04-04

Potential of liquid metal PFCs

- Assessment of hydrogenic retention in and stability against transients of liquid metals (experiment and modelling). Capability of sustaining heat loads. Design, tests, installation and commissioning of liquid limiters in EU devices (FTU, IST, TJII …).
- Modelling of Li PFC evaporation and splashing.

Please ensure that when making a proposal for activities under Priority Support, a detailed proposal is submitted, including a description of the work to be performed outlining the novelty of the investigation compared with previous work and a description of the deliverables.

5.3.2 JET related activities

No JET related activities are meant to be implemented under this Task Agreement. JET related activities are implemented under EFDA Art.6. However some JET activities shall be mentioned for information in this TA when they closely relate to the activity implemented under Art.5. JET data collected under the JET part of the EFDA WP can be brought together with other data under this TA when relevant for the progress of the work or used in multi-machine modelling activities under Art.5.

JET TF E1/E2, TF FT	• Development of scenarios compatible with the JET ILW configuration from the PWI point of view (radiative scenarios, ELM mitigation, control of W accumulation) (TFE1,TFE2). • Start-up in an all-metal device without surface condition by deposition of coatings (TFE1) . • Identification of central W spectroscopic lines relevant for JET and ITER. (TFE1/E2) • Characterisation of W divertor erosion (TFE2, FT) • Hydrogenic retention in W and Be (TFE2) • Benchmarking the codes used for ITER predictions (ERO, DIVIMP, SOLPS…) against first ILW results (TFE2)IO.. • Influence of W melting on divertor and plasma performance (TFE2)

4.3.3 Resources

Activities eligible for priority support:

- Collaborative effort on assessing and reducing the impurity production during ICRH heating, on fuel retention (high-Z, liquid metals), on W related diagnostic development, on neutron irradiation tests, and on W associated modelling.
- Hardware: development of in vessel structures using liquid metals as plasma facing material, construction of FW mock-up, upgrading of laboratory plasma simulators.

Part of international effort (bilateral collaboration with US (PISCES) and RF (plasma guns), ITPA Divertor and SOL) which could lead to missions under mobility.

4.4 Scientific and Technical Reports

4.4.1: Progress reports

At the end of each calendar year, during the PWI TF annual meeting, the SEWG leader in charge of the task coordination shall present a report on all activities (under baseline and priority support) 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.

4.4.2: Report of achievements under Priority Support

In addition, achievement of Priority Support deliverables will be reported separately to the EFDA Leader. A final report shall be prepared by the SEWG leader in charge of the task coordination 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 Tasks 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 associated milestones defined.

The EURATOM financial contribution will be made after approval of these reports by the EFDA Leader.

4.4.3 Milestones and Deliverables

Milestones:
Mid 2011
SEWG Meeting: Collection and discussion of results obtained from the evaluation of experiments in 2010 and early 2011

October 2011:
Annual meeting of the EU TF on PWI: coordinated presentation of the results from the experimental campaigns in 2011

December 2011: Final report sent to EFDA-CSU.

Deliverables:

a) One technical report per facility involved according to the objectives described above by October 2011.
b) Synthetic analysis by the group of experts involved, recommendation for future work and implications for ITER by end 2011.

5. SEWG ITER Material Mix

Task Agreement WP11-PWI-05: PWI properties of alloys and mixed compounds formed under ITER relevant conditions and their influence on PWI processes and fuel retention

5.1 Introduction

- Both Be-W alloy formation and carbide formation of Be and W have been investigated in well controlled laboratory experiments and principal mechanisms are understood. However more knowledge is needed on the dynamics of these processes under high impinging flux conditions and transient surface temperature changes (see following paragraph). Studies of ternary and quaternary systems including Be, W and C and/or oxygen, have started. The complex behaviour observed in first experiments calls for intensified efforts in this area.
- Intermixing dynamics under simultaneous impact of Be, C, W and D on surfaces are subject of ongoing research in plasma simulators and dual ion beam experiments. Be-W and Be-C intermixing is being investigated in the plasma simulator PISCES-B with support by one visiting scientist from IPP Garching. Simultaneous impact of C and D on W was investigated in a dual ion beam ion facility at IPP Garching. These experiments have provided a data base for benchmarking BCA (binary collision approximation) codes such as TRIDYN and molecular dynamics simulations, which are required to extrapolate to ITER conditions.
- D retention in mixed layers deposited on surfaces of the three ITER PFMs and D release as function of substrate temperature is being investigated for all relevant binary material combinations. However, only few data exist on the influence of layer structure and layer thickness for D-retention in both the layers and the deep bulk regions below. More experiments of this kind, partly in collaboration with PISCES, are on the way.
- For all previously listed issues, the effect of transient temperature excursion, both on the scale of few seconds (loss of plasma control) and on ms scale (ELMs and disruptions) must be investigated. This requires additional experimental and modelling efforts.
- Plasma material transport codes and surface codes such as TRIDYN and specific kinetic material intermixing codes are available. Benchmarking, corresponding experiments at the JET ILW and further development are under way but require continuous work well beyond the present 2011 workplan.

5.2 Objectives

Since ITER uses three plasma facing materials (two during its nuclear phase), material migration and subsequent mix will not only strongly influence the T retention, but may also change the material’s thermo-mechanical properties. During the last years, the complicated process of C chemical erosion has been tackled quite successfully, but the migration inside the torus is not yet well understood. In order to get any reliable prediction of its impact for ITER, the existing modelling tools have to be benchmarked with experiments. In 2010, it was seen as a major goal to advance the modelling in this field and further efforts are needed in 2011 to consolidate the results. Alloying with Be has been identified as a potential threat to the tungsten PFCs in the divertor. Preliminary results show that there is only a small parameter range where a strong negative impact of the alloying is expected. In 2011, it is planned to complete this assessment in order to confirm that this is not going to affect ITER plasma facing materials.

5.3 Work Description and Breakdown

The Work Programme involves laboratory experiments on the formation of alloys and compound in the interaction of different materials proposed as plasma facing materials in ITER and their behaviour with respect to relevant PSI issues, such as fuel retention or erosion behaviour. It is important to include Be in the analysis which is an essential part of the collaboration EU-DOE in the linear plasma generator PISCES B. Dual beam experiments allow to study simultaneously the formation of mixed materials and the erosion due to hydrogen bombardment.

Work under the present Task Agreement includes three research activities and one managing task.

56.3.1 Work Breakdown

WP11-PWI-05-00

Leadership of the Special Expert Working Group (SEWG) on ITER Material Mix

Leadership of the Special Expert Working Group (SEWG) on ITER Material Mix is an ongoing activity and the main concern is to lead the projects towards a successful and timely implementation of the PWI work programme in the field of mixed materials.

The SEWG leader has the following obligations:

- Lead and organize the overall SEWG activities
- Monitor progress and coordinate the research in the SEWG on ITER Material Mix, in particular tasks defined in the PWI Task Agreement
- Assist the PWI TF Leaders in definition and implementation of the annual work programmes
- Provide Annual report on Tasks related to the SEWG activities
- Support the interaction with TG and other EFDA, EU and ITER related organization

Associations are invited to nominate candidates for the position of the Leader of the SEWG on ITER Material Mix, which corresponds to a work load of 0.25 ppy per year in Priority Support. The application should include a CV, a short description of the relevant skills and experience, and a list of recent publications of the applicant.

WP11-PWI-05-01

Formation and properties of mixed materials

- Lab studies on ternary and quaternary systems: Study of the system Be-C-W in dedicated lab experiments and the influence of oxygen on physical and chemical properties (including fuel retention) of mixed materials (IPP Garching / BESSY Berlin).
- Analysis of tokamaks deposits: Analysis of W-C (AUG, TEXTOR, with possible inclusion of oxygen) and Be-C (JET TF FT for comparison) deposits collected in tokamaks for comparison to lab. Experiments: composition, fuel retention properties.
- Influence of thermal excursions: Exposure of mixed material layers on pure substrates to repeated thermal shocks either in tokamak divertors equipped with manipulators (AUG, MAST) or suitable heat flux test facilities (FZ Jülich). This includes the potential formation of alloy phases in the Be/W system during ELM-like transients. In-situ and ex-situ analysis of erosion behaviour, fuel retention properties and structural layer damage (flake/dust creation).
- Influence of He and seeded impurities (N, Ne, Ar): Exposure of mixed material layers and pure substrates to plasmas with admixtures of He and/or impurities envisaged for seeding either in linear plasma devices (PISCES, Pilot/Magnum PSI), tokamak divertors equipped with manipulators (AUG, MAST), and dual ion beam devices (IPP Garching). Analysis of erosion behaviour, evolution of surface morphology and fuel retention properties.

WP11-PWI-05-02

Fuel retention in mixed materials

- Investigation of D retention in mixed materials and of surface vs bulk retention in systems with mixed layers on pure substrate materials as function of temperature, composition and structure of the mixed material and of incident flux composition. Influence of simultaneous impact of D and He on T-retention in such systems (PISCES under bilateral contract; dual beam facility at IPP Garching, Nat. Inst. f. Laser, Plasma and Radiation Physics, Bucharest).

These investigations are to be coordinated with the SEWG Fuel Retention.

WP11-PWI-05-03

Modelling of material mixing for extrapolation to ITER conditions

- Extension of transport codes (B2/EIRENE, DIVIMP, ERO) to simulate wall erosion, material migration and deposition/mixing for devices with several different wall materials. Extension of computational area to wall (in collaboration with the ITM TF). Experimental benchmarking data from PISCES-B, possibly Pilot-PSI and other relevant devices, as well as JET Be/C migration experiments for comparison.
- Extension of kinetic MC simulation of material mixing to include effects of diffusion (elevated temperature, transients), chemical effects, surface topology (SDTRIM-SP 2D and 3D) and material structure (trapping sites). Corresponding benchmark experiments using ion bombardment of test systems with 2D roughness topology, quantification of morpholgy evolution and influence on sputtering behaviour.
- MD modelling of mixed layer erosion processes and D-retention properties. Derivation of (analytical or tabular) approximations for use in material migration simulations in experiments with multiple first wall materials.

Please ensure that when making a proposal for activities under Priority Support, a detailed proposal is submitted, including a description of the work to be performed outlining the novelty of the investigation compared with previous work and a description of the deliverables.

5.3.2 JET related activities

No JET related activities are meant to be implemented under this Task Agreement. JET related activities are implemented under EFDA Art.6. However some JET activities should be mentioned for information in this TA when they closely relate to the activity implemented under Art.5. JET data collected under the JET part of the EFDA WP can be brought together with other data under this TA when relevant for the progress of the work or used in multi-machine modelling activities under Art.5.

JET TF FT	• Post mortem analysis on composition, fuel retention and chemical characterisation of Be-C deposits (TF FT) • Post mortem analysis of Be-deposits on W tiles (TF FT) • Experiments on Be / W migration during ILW campaign and their interpretation by integrated modelling of impurity transport and wall composition

5.3.3 Resources

Activities eligible for priority support

- Production of mixed material samples for both laboratory and fusion device PWI studies.
- Joint analysis of mixed material PWI properties particularly for samples exposed in fusion experiments, for comparison of laboratory and tokamak mixed deposits and to assess the influence of thermal excursions
- Development and benchmarking of integrated impurity edge transport - material surface modelling codes.

Part of international effort (bilateral collaboration with US (PISCES), ITPA Divertor and SOL) which could lead to missions under mobility and priority hardware support.

5.4 Scientific and Technical Reports

5.4.1: Progress reports

At the end of each calendar year, during the PWI TF annual meeting, the SEWG leader in charge of the task coordination shall present a report on all activities (under baseline and priority support) 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.

5.4.2: Report of achievements under Priority Support

In addition, achievement of Priority Support deliverables will be reported separately to the EFDA Leader. A final report shall be prepared by the SEWG leader in charge of the task coordination 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 Tasks 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 associated milestones defined.

The EURATOM financial contribution will be made after approval of these reports by the EFDA Leader.

5.4.3 Milestones and Deliverables

Milestones:
Mid 2011
SEWG Meeting: Collection and discussion of results obtained from the evaluation of experiments in 2010 and early 2011

October 2011:
Annual meeting of the EU TF on PWI: coordinated presentation of the results from the experimental campaigns in 2011

December 2011: Final report sent to EFDA-CSU.

Deliverables:

a) One technical report per facility involved according to the objectives described above by October 2011.
b) Synthetic analysis by the group of experts involved, recommendation for future work and implications for ITER by end 2011.

6. SEWG Transient heat loads and mitigation

Task Agreement WP11-PWI-06: Mitigation of disruptions and investigation of ELM and inter-ELM heat loads

6.1 Introduction

Several methods are studied presently to mitigate transient loads during disruptions: massive gas injection, pellet injection, RMP (runaway suppression) and disruption avoidance by ECRH. Scaling to ITER requires, however, more insight into the relevant physics mechanisms. The main focus here should be on

- Temporal and spatial distribution of heat loads on the main chamber PFCs and in the divertor during mitigated disruptions in comparison to non-mitigated disruptions.
- Heat load by runaway electrons. A quantification of these loads is mandatory for further load estimates for ITER. This comprises the incident angle, runaway energy and affected area.
- Heat load by radiation. Radiation is very inhomogeneous during a disruption and can lead to strong local heating of PFCs. This is especially an issue for massive gas injection.

Presently, three methods are proposed to mitigate ELM loads in ITER: perturbation fields, pellet pace-making, radiative scenarios (type-III ELMs). Quantification of the heat loads in these scenarios has started, but the database is less advanced than the one for the reference type-I ELMy H-mode scenario. Moreover, the analysis of the heat load pattern can contribute to the understanding of the mitigation process by RMP (resonant magnetic perturbation). The ELM dynamics (filaments) determines the energy distribution on main chamber wall and divertor PFCs. Extrapolation to ITER would need a more quantitative analysis of this correlation.

In addition to transient pulses due to ELMs, steady heat loads will impinge on the main chamber wall surfaces as a consequence of far scrape-off layer (SOL) tails in density and temperature driven by turbulent convective transport. This has consequences for the design of the main chamber PFCs in ITER.

The ITER divertor must operate in a partially detached state in order to stay within the steady state power handling capability of the target plates. The possibility of transient reattachment presents a potentially extremely serious threat to target plate integrity.

Beside the characterisation and quantification of transient heat loads, the impact of these loads on the material deterioration is studied in plasma simulators, plasma guns, electron/ion beam facilities and partly in tokamaks, resulting in the quantification of critical loads and material lifetimes.

6.2 Objectives

The 2011 activities will focus on the assessment of heat fluxes during disruptions in the divertor and on main chamber PFC, optimisation of disruption mitigation techniques, assessment of heat fluxes during ELMs (mitigated and unmitigated), including the spatial distribution, assessment of inter ELMs heat fluxes, including mitigation scenarios, investigations on transient reattachment and characterization of material damage due to transients

6.3 Work Description and Breakdown

The work in this task involves:

i) experiments on disruptions and ELMs in the various regimes of interest for ITER in various tokamaks with emphasis on the acquisition of the highest quality measurements possible,
ii) experiments in plasma conditions which are comparable and relevant to ITER reference plasmas, allowing an improved extrapolation of the experimental results to ITER,
iii) comparison of the measurements obtained with the available models for disruption power fluxes and evaluation of such fluxes and consequences for the plasma discharge in ITER,
iv) optimisation of mitigation techniques with relevant plasma conditions and criteria applicable to ITER.

The work programme is coordinated by the SEWG on Transient heat loads and mitigation which:

- Sets up the experimental work programme, including the request for machine time in the different fusion devices for coordinated experiments
- Supports the organisation of modelling collaborations
- Organises SEWG meetings for collection of data, interpretation and extrapolation of results.
- Summarizes the collected data in a final report

Work under the present Task Agreement includes five research activities and one managing task.

6.3.1 Work Breakdown

WP11-PWI-06-00

Leadership of the Special Expert Working Group (SEWG) on Transient Heat Loads
Leadership of the Special Expert Working Group (SEWG) on Transient Heat Loads is an ongoing activity and the main concern is to lead the projects towards a successful and timely implementation of the PWI work programme in the field on Transient Heat Loads.

The SEWG leader has the following obligations:

- Lead and organize the overall SEWG activities
- Monitor progress and coordinate the research in the SEWG on Transient Heat Loads, in particular tasks defined in the PWI Task Agreement

- Assist the PWI TF Leaders in definition and implementation of the annual work programmes
- Provide Annual report on Tasks related to the SEWG activities
- Support the interaction with TG and other EFDA, EU and ITER related organization

Associations are invited to nominate candidates for the position of the Leader of the SEWG on Transient Heat Loads, which corresponds to a work load of 0.25 ppy per year in Priority Support. The application should include a CV, a short description of the relevant skills and experience, and a list of recent publications of the applicant.

WP11-PWI-06-01

Assessment of heat fluxes during disruptions

- Measurements of power fluxes on divertor, limiter and other main chamber PFCs (including runaway fluxes) for disruption types expected in ITER and for mitigated disruptions (AUG, TS, MAST, TCV, TEXTOR, FTU, ISTTOK and C-mod/DIII-D through suitable international collaborations, comparison to JET). Particularly, this should include data about heat flux distribution caused by convective flux during thermal and current quench, heat deposition by runaway electrons and heat loads by radiation asymmetries (including local radiation by MGI). Main objective is a comparison between mitigated und unmitigated disruptions. Development of the associated modelling (e.g. runaway impact). This work is also related to gas release and wall (de)conditioning by disruptions.

WP11-PWI-06-02

Optimisation of disruption mitigation techniques

- Optimisation of massive gas injection (MGI) and other techniques for disruption mitigation and runaway suppression. For MGI, the main focus will be on gas injection rates, valve position and number of valves, and gas composition. Evaluation of size scaling and requirements for ITER
- Development of the associated modelling (gas jet penetration, gas distribution and related radiation asymmetry, etc …).

WP11-PWI-06-03

Assessment of heat fluxes during ELMs

- Characterisation/quantification of plasma parameters and heat loads on divertor and main chamber PFCs in mitigated ELM scenarios (RMP, radiative scenarios with type III ELMs, pellet pacemaking), including ELM dynamics and heat flux distribution in comparison to non-mitigated ELMs. (AUG, MAST, TCV, TEXTOR, and DIII-D through suitable international collaborations, comparison to JET).

WP11-PWI-06-04

Assessment of inter ELMs heat fluxes

- Characterisation/quantification of plasma parameters and inter-ELM heat loads on PFCs, including also inter-ELM heat loads in mitigated and heat loads in suppressed ELM scenarios (RMP, radiative scenarios with type III ELMs, pellet pacemaking). The work package also includes characterisation of far-SOL transport to PFCs and fast particles impact as well as studies of heat loads on divertor and other PFCs during loss of detachment/re-attachment events.

WP11-PWI-06-05

Material damage by transient heat loads

- Characterisation/quantification of material deterioration (e.g. erosion, cracking,) under transients heat loads in plasma simulators or other high heat flux devices and tokamaks with special emphasis on ITER relevant material (Be, W), including irradiated or otherwise pre-damaged material samples. Development and validation of associated modelling (note that melt layer dynamics is dealt with in the SEWG on High Z)

Please ensure that when making a proposal for activities under Priority Support, a detailed proposal is submitted, including a description of the work to be performed outlining the novelty of the investigation compared with previous work and a description of the deliverables.

6.3.2 JET related activities

No JET related activities are meant to be implemented under this Task Agreement. JET related activities are implemented under EFDA Art.6. However some JET activities shall be mentioned for information in this TA when they closely relate to the activity implemented under Art.5. JET data collected under the JET part of the EFDA WP can be brought together with other data under this TA when relevant for the progress of the work or used in multi-machine modelling activities under Art.5.

JET TF E1/E2	• Quantification of heat loads during mitigated and non-mitigated disruptions (including runaway loads) (TF E1/E2) • Optimisation of massive gas injection and other techniques for disruption mitigation (TFE1/E2) • Characterisation of ELM loads using fast diagnostics, in particular for mitigated ELMs (TFE2) • Characterisation/quantification of inter-ELM heat loads on main chamber wall and in the divertor, including detachment/re-attachment studies (TFE2)

6.3.3 Resources

Activities eligible for priority support:

- Coordinated experiments on ELM and inter-ELM heat loads, including studies of the impact of the loss of divertor detachment.
- Coordinated experiments on disruption mitigation, in particular for the assessment of associated heat loads on PFCs, and joint modelling of massive gas injection.
- Support for transfer of disruption mitigation equipment or diagnostics for coordinated experiments.
- Support for diagnostic development for fast transients

Part of international effort (ITPA Divertor and SOL, bilateral collaboration with RF) which could lead to missions under mobility (DIII-D, Alcator C-mod …).

6.4 Scientific and Technical Reports

6.4.1: Progress reports

At the end of each calendar year, during the PWI TF annual meeting, the SEWG leader in charge of the task coordination shall present a report on all activities (under baseline and priority support) 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.

6.4.2: Report of achievements under Priority Support

In addition, achievement of Priority Support deliverables will be reported separately to the EFDA Leader. A final report shall be prepared by the SEWG leader in charge of the task coordination 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 Tasks 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 associated milestones defined.

The EURATOM financial contribution will be made after approval of these reports by the EFDA Leader.

6.4.3 Milestones and Deliverables

Milestones:
Mid 2011
SEWG Meeting: Collection and discussion of results obtained from the evaluation of experiments in 2010 and early 2011

October 2011:
Annual meeting of the EU TF on PWI: coordinated presentation of the results from the experimental campaigns in 2011

December 2011: Final report sent to EFDA-CSU.

Deliverables:

a) One technical report per facility involved according to the objectives described above by October 2011.
b) Synthetic analysis by the group of experts involved, recommendation for future work and implications for ITER by end 2011.