IDM UID
PVHYAE

VERSION CREATED ON / VERSION / STATUS
03 Sep 2014 / 1.0 / Approved

EXTERNAL REFERENCE

Technical Specification

Physics-based transport modelling of main species particle and energy transport in the core plasma of ITER reference scenarios during stationary phases and post-pellet transients

Technical specifications for a contract to improve the physics basis for the evaluation of the core energy and main ion species particle transport during stationary and transient phases of ITER scenarios. This assessment will be performed by application of physics-based transport models to reproduce the behaviour of the electron and ion temperatures and densities in the ITER core plasma for reference plasma conditions during stationary and transient phases of ITER scenarios. The assessment will include ITER scenarios with plasma currents up to 15 MA and QDT =10 including He, DD and DT plasmas and H-mode and L-mode confinement regimes.

Approval Process			
	Name	*Action*	*Affiliation*
Author	**Loarte A.**	**03 Sep 2014:signed**	**IO/DG/DIP/POP/SD/CMS**
Co-Authors			
Reviewers			
Approver	**Campbell D.**	**05 Sep 2014:approved**	**IO/DG/DIP/POP**
Document Security: Internal Use *RO: Rossini Celine*			
Read Access	**RO, project administrator, LG: Contact Procurement POP, LG: View Access, LG: New Budget Officer POP, AD: Directorate - Plasma Operation, AD: IO_Director-General, AD: IC_OMPE_WG, AD: Auditors, AD: ITER Management Assessor**		

Physics-based transport modelling of main species particle and energy transport in the core plasma of ITER reference scenarios during stationary phases and post-pellet transients

Technical Specifications

Table of Contents

1 Purpose

This contract intends to improve the physics basis for the evaluation of the core energy and main ion species particle transport during stationary and transient phases of ITER scenarios. This assessment will be performed by application of physics-based transport models to reproduce the behaviour of the electron and ion temperatures and densities in the ITER core plasma for reference plasma conditions during stationary and transient phases of ITER scenarios. The assessment will include ITER scenarios with plasma currents up to 15 MA and Q_{DT} =10 including He, DD and DT plasmas and H-mode and L-mode confinement regimes.

2 Scope

2.1. Substantial efforts have already been made to analyse the viability, robustness and operational space of the ITER reference scenarios by means of 1.5D transport simulations linked to free-boundary equilibrium codes, together with appropriate controllers for the PF and H&CD systems. Due to the complexity of the modelling, this analysis is usually done by modelling plasma behaviour in a time-averaged mode where short timescale transport events are neglected (ELMs, pellet-induced transients, etc.) [Casper 2014]. Similarly, medium timescale transport events, such as L-H and H-L transitions, are modelled by applying simple ad-hoc assumptions that allow the study of plasma control of the position, shape disturbances and vertical stability control following these transport transients [Lister 2013]. Failure to control plasma position, for instance, in some of these events could lead to direct contact between the main plasma and the first wall leading to damage to the plasma facing components (PFCs), possibly, followed by a disruption. Therefore, schemes for the control and mitigation of such transport transient events need to be investigated, as they are required for the operation of the ITER machine. A necessary pre-requirement for the development of control and mitigation schemes is to determine the evolution of the expected ITER plasma parameters in these events, which include the ITER plasma specific features such as alpha heating, poor edge neutral penetration, pellet fuelling, etc.

2.2. Appropriate modelling of the timescale and plasma parameter evolution in ITER requires self-consistent modelling of energy and particle transport with models which can appropriately describe experimental plasma behaviour. In particular, particle transport plays a key role in the evolution of ITER plasmas as it determines the penetration of the DT fuel to the core (even pellet fuelling is relatively peripheral in ITER) and because it deeply influences the evolution of the heating power in the plasma through the alpha heating and the confinement state of the plasma through the H-mode access threshold power [Loarte 2013, Loarte 2014]. In this respect, ITER is expected to operate in a regime substantially different to that in present devices with very low core plasma fuelling from neutral beams, low pedestal plasma fuelling by recycling neutrals and fuelling of the edge of the main plasma by pellet injection, which itself is a source of transport transients. In particular, the fuelling of the core of ITER plasmas with T by pellets requires self-consistent time-dependent energy and particle transport modelling with appropriate sources to evaluate how the T deposited in the external part of the plasma by the pellets penetrates into the core plasma. It is therefore important to determine the dominant mechanisms for the turbulent particle transport (diffusion and convection) during transient and stationary phases in ITER in a self-consistent way with the associated energy transport as well as to determine the possibilities of its control by acting on the plasma temperature gradients with the available heating schemes in ITER.

2.3. The objective of this contract is to perform a modelling study of turbulent particle and energy transport during stationary and transient phases of ITER operational scenarios by application of an integrated transport code suite capable of modelling the core plasma in these scenarios (i.e. including appropriate heating and particle sources) with an appropriate description of the physics of the energy and particle turbulent transport, to make physics-based predictions of ITER plasma behaviour, of the possible consequences of transport transients in ITER and to investigate strategies for the control of particle transport by heating schemes which may be necessary to optimize or mitigate them.

The work in this contract involves modelling of the plasma particle and energy content behaviour with physics-based transport modelling of main species particle and energy transport in the core of ITER plasmas during stationary and transient phases. This requires self-consistent modelling of energy and particle transport of the core ITER plasma with models which can reproduce appropriately the plasma behaviour seen in the experiment during stationary phases and transients. The purpose of this study is to provide an initial assessment of the range of density and temperature profiles expected in a wide range of ITER scenarios from physics-based models, the capabilities of ITER heating schemes to affect these profiles and the optimization of pellet parameters for optimum fuelling taking into account the post-pellet transport transient.

The three subtask/deliverables in this contract are:

i) Subtask 1 –Deliverable 1. Report on expected density and temperature profiles for a range of plasma conditions in ITER reference scenarios.

This report will provide an assessment of the expected density and temperature profiles in a range of H-mode and L-mode scenarios from non-active operation to Q_{DT} =10 including He, DD and DT plasmas to determine the role of plasma particle sources (negligible in ITER), plasma collisionality and shear on the density and temperature profiles expected in ITER.

ii) Subtask 2 – Deliverable 2. Report on the capabilities of ITER heating schemes to affect the density and temperature profiles for a range of plasma conditions in ITER reference scenarios.

This report will assess the capabilities of the ITER heating schemes to affect core particle transport, through their effect on the plasma temperature gradients, during stationary phases in a range of H-mode and L-mode scenarios from non-active operation to Q_{DT} =10 including He, DD and DT plasmas.

iii) Subtask 3 – Deliverable 3. Report on the effect of post-pellet transport on the pellet fuelling efficiency for a range of plasma conditions in ITER reference scenarios.

This report will assess the influence of plasma transport on the efficiency of fuelling by pellets taking into account the associated plasma transients following pellet injection in order to determine the best operational strategies for pellet fuelling in a range of L-mode and H-mode DT stationary scenarios.

3 Definitions

In the following table denominations and definitions are given of all the actors, entities and documents referred to in this Specification, together with the acronyms used in this document. Other terminology used is standard in the field of plasma transport physics.

Denomination	Definition	Acronym
ITER Organization	For this Contract the ITER Organization	IO-
ITER Organization Responsible Officer	Person appointed by the ITER Organization with responsibility to manage all the technical aspects of this contract	IO-RO
Contractor	Firm or group of firms organized in a legal entity to provide the scope of supply.	C-
Contractor's Team	The Contractor plus all the sub-contractors/consultants working under its responsibility and coordination for the performance of the contract	C-Team
Contractor Responsible	The person appointed (in writing) by the legally authorised representative of the Contractor, empowered to act on behalf of the Contractor for all technical, administrative legal and financial matters relative to the performance of this contract	C-R
ITER Organization Task Responsible Officer	Person delegated by the IO-RO for all technical matters, but limited to one specific task order	IO-TRO
Contractor Task Responsible Officer	Equivalent to the IO-TRO in the Contractors team	C-TRO

4 References

[Casper 2014] Casper, T., et al., Nucl. Fusion 54 (2014) 013005.

[Lister 2013] Lister, J., et al., Proc. 40th European Physical Society Conference on Plasma Physics, Espoo, Finland, 2013, paper P1.164, http://ocs.ciemat.es/EPS2013PAP/pdf/P1.164.pdf

[Loarte 2013] Loarte, A., et al., Nucl. Fusion **53** (2013) 1083031.

[Loarte 2014] Loarte, A., et al., report EFDA–JET–PR(14)19, submitted to Nucl. Fusion.

5 Estimated Duration

Starting date: signing of contract.

Completion date: 12 months from the date of signature.

Number of working days required to complete the work-scope within the 12-month period: 120 days

6 Work Description

The profiles of plasma temperature and density will be evaluated for a range of stationary and transient conditions in ITER reference scenarios spanning non-active (H/He) and DD + DT operation and including L-mode and H-mode confinement regimes. This evaluation will be done taking into account appropriate description of the heating and fuelling sources in ITER as well as physics-based transport models for the core plasma in ITER and a range of assumptions regarding the conditions of the edge plasma.

The three subtask/deliverables in this contract are:

1) Evaluation of the expected density and temperature profiles for a range of stationary plasma conditions in ITER reference scenarios.

This evaluation will include a range of stationary plasma conditions from low current ($I_p \sim 5$ MA) to high current plasmas ($I_p \sim 15$ MA) in ITER and toroidal field in the range of $B_t = 2.65$ – 5.3 T in a range of H-mode and L-mode scenarios from non-active operation to Q_{DT} =10 including He, DD and DT plasmas and a range of edge plasma conditions to determine role of plasma particle sources (negligible in ITER), plasma collisionality and shear on the density and temperature profiles expected in ITER.

2) Evaluation of the capabilities of ITER heating schemes to affect the density and temperature profiles for a range of plasma conditions in ITER reference scenarios.

This evaluation will determine the capabilities of the ITER heating schemes to affect core particle transport, through their effect on the plasma temperature gradients, during stationary phases in a range of H-mode and L-mode scenarios from non-active operation to Q_{DT} =10 including He, DD and DT plasmas (I_p = 5 to 15 MA and B_t = 2.65T to 5.3 T) and a range of edge plasma conditions.

3) Evaluation of the effect of post-pellet transport on the pellet fuelling efficiency for a range of plasma conditions in ITER reference scenarios.

The evaluation will assess the influence of plasma transport in the efficiency of fuelling by pellets taking into account the expected particle source from the pellet (including ablation + drift) and the associated plasma transients following pellet injection in order to determine the best operational strategies for pellet fuelling in a range of L-mode and H-mode DT stationary scenarios plasmas (I_p = 5 to 15 MA and B_t = 2.65T to 5.3 T) and a range of edge plasma conditions.

7 Responsibilities

ITER:
ITER will provide the needed information and access to the adequate ITER files for executing this work when needed following the implementation plan.

Contractor:
The contractor will propose an Implementation Plan for the execution of the contract, to be approved by the ITER Organization, to demonstrate how the work will comply with the requirements of this specification.
The contractor will provide results according to the scope of the work outlined above and will fulfil the agreed Implementation Plan and conditions of present contract.
The majority of the work will be carried out at the Contractor's site. The work may require the presence of Contractor's personnel at the site of the ITER Organization, 13067 St Paul-lez-Durance, France, for the purpose of meetings and data gathering. The associated cost for travel and subsistence expenses for the Contractor's personnel should be included in the Contract Cost (see Section 12). The Contractor will take care of all administrative formalities required for the presence of the Contractor's Personnel at the IO site with the authorities concerned (obtaining visas, etc.).

8 List of deliverables and due dates

The deliverables of this contract are reports describing the statement of each problem, input data and approximations used in the studies and the results obtained. Two intermediate reports shall be delivered at 4 months and 8 months from the date of signature of the contract. The Final Report shall be delivered at 12 months from the date of signature of the contract. The overall content of the deliverables in this contract are detailed below:

Deliverable	Content	Time
First Intermediate report	Initial results on task 1: Evaluation of the expected density and temperature profiles for a range of stationary plasma conditions in ITER reference scenarios.	4 months after contract signature
Second Intermediate report	Final results on task 1 (Evaluation of the expected density and temperature profiles for a range of stationary plasma conditions in ITER reference scenarios), initial results of task 2 (Evaluation of the capabilities of ITER heating schemes to affect the density and temperature profiles for a range of plasma conditions in ITER reference scenarios) and initial results on task 3 (Evaluation of the effect of post-pellet transport on the pellet fuelling efficiency for a range of plasma conditions in ITER reference scenarios).	8 months after contract signature
Final Report	Final results on task 2 (Evaluation of the capabilities of ITER heating schemes to affect the density and temperature profiles for a range of plasma conditions in ITER reference scenarios) and final results of task 3 (Evaluation of the effect of post-pellet transport on the pellet fuelling efficiency for a range of plasma conditions in ITER reference scenarios).	12 months after contract signature

9 Acceptance Criteria

The IO TRO shall review the deliverables and reply, within the time specified in the 15 following days, a commented version of the deliverables.

The Contractor shall perform all the necessary modifications or iterations to the deliverables and submit a revised version.

The Contract will be considered completed after ITER has accepted the last deliverable.

10 Specific Skills and Competencies

The person/team providing the service should meet the following requirements:

University PhD degree or equivalent in plasma physics,

At least 5 years of proven experience in plasma physics R&D,

Proven experience in modelling of energy and particle transport processes in tokamaks in stationary and transient conditions with physics-based models.

The official language of the ITER project is English. Therefore excellent knowledge of English is required because all input and output documentation relevant for this contract shall be in English.

11 Work Monitoring / Meeting Schedule

The contractor will participate in a series of meetings with the ITER Organization for progress monitoring in agreement with the schedule for deliverables proposed in § 8.

At least the following meetings should be foreseen:

Scope of meeting	Point of check/Deliverable	Place of meeting
Kick-off contract	Work program	ITER site or video conference
Five Progress meetings	Checking progress of deliverables every two months	ITER site or video conference
Closing contract meeting Contract completion	Checking final report	ITER site or video conference

12 Payment schedule / Cost and delivery time breakdown

The ITER Organization will pay per each deliverable as described in Section 8 of these Technical Specifications. Payments are subject to proper approval of the deliverables by the ITER Organization. The contractor will include the cost for each deliverable in their proposal.

The foreseen payment schedule is the following:

List of Deliverables	Estimated Schedule
Deliverable 1: Intermediate Report 1	4 months from the signature of the Contract
Deliverable 2: Intermediate Report 2	8 months from the signature of the Contract
Deliverable 3: Final Report	12 months from the signature of the Contract

Prices are inclusive of all costs, including but not limited to the cost of labour, material, taxes, management, daily transport, preparation, overheads, profit and fee, and those associated with the presence of the Contractor's Personnel at the IO site as detailed in section 7, as applicable.

13 Quality Assurance (QA) requirement

The general requirements are detailed in ITER Procurement Quality Requirements (ITER_D_22MFG4).

Prior to commencement of the task, a Quality Plan must be submitted for IO approval giving evidence of the above and describing the organisation for this task; the skill of workers involved in the study; any anticipated sub-contractors; and giving details of who will be the independent checker of the activities (see Procurement Requirements for Producing a Quality Plan (ITER_D_22MFMW)). This is a separate document which comprises:

1) a workplan with proposed time schedule and agreed preliminary dates for progress meetings,

2) a statement of those involved in the activity and their approximate role and contribution in time,

3) a statement of what work will be subcontracted and who will responsible for checking this.

Documentation developed shall be retained by the contractor for a minimum of 5 years and then may be discarded at the direction of the IO. The use of computer software to perform a safety basis task activity such as analysis and/or modelling, etc., shall be reviewed and approved by the IO prior to its use, it should fulfil IO document on calculation code for safety analysis.