Technical Specifications (In-Cash Procurement)

CFE: Neutronics Analysis of Upper Launcher

This document provides the technical specification for radiation transport analysis and a shielding assessment for the ECH Upper Launcher (UL) system as a CFE. This analysis includes the determination of the radiation conditions in the relevant port interspace. A comparison with the relevant requirements and proposals for improved shielding shall be provided.

Technical Specifications

Neutronics Analysis of ITER EC Upper Launcher

Table of Contents

1 Purpose

This document provides the technical specification for radiation transport analysis and a shielding assessment for the ECH Upper Launcher (UL) system. This analysis includes the determination of the radiation conditions in the relevant port interspace. A comparison with the relevant requirements and proposals for improved shielding shall be provided.

2 Scope

The electron cyclotron (EC) system is one of the four auxiliary plasma heating systems to be installed on the ITER tokamak. The ITER EC system consists of 24 gyrotrons with associated 12 high voltage power supplies, a set of evacuated transmission lines and two types of launchers. The whole system is designed to inject 20 MW of microwave power at 170 GHz into the plasma. The primary functions of the system include plasma start-up, central heating and current drive, and magneto-hydrodynamic instabilities control.

There are two type of antennas (or launchers) used to inject the Electron Cyclotron power into the plasma, one is in the equatorial port (EL) and the other occupy four upper ports (UL). The power from a given gyrotron can be directed to either launcher with the choice depending on the physics objectives.

Each of the launchers are also called port plugs as they form the first confinement boundary acting as "plugs" to the vacuum vessel ports. Each plug includes in-vessel waveguides, mirrors, shielding blocks, sensors etc.

The objectives of this contract are to provide the ITER Organization with neutronic assessments of the UL. This activity will cover the determination of neutron and gamma fluxes as well spectra, evaluation of nuclear heating, shut down dose rates (SDDR), nuclear damage, helium generation, material activation, radwaste assessment and human dose rates as required.

3 Definitions

IO: ITER Organization
DA: Domestic Agency
SDDR: Shut Down Dose Rate
IO-TRO: ITER Organization technical Responsible Officer.
NIU: Nuclear Integration Unit
For a complete list of ITER abbreviations see: ITER Abbreviations (ITER_D_2MU6W5).
Other abbreviations are explained in the text.

4 References

Links inserted in text.

5 Duration

The duration of the services is 1 year from the contract start date.

6 Work Description

The work to be done is in collaboration with the IO Technical Responsible Officer (TRO). It involves many areas of activity that have to be documented:

1. Provide scoping analysis (local approach) for the optimization of the SDDR (by means of D1S method) in the port interspace. This includes:
   a. A first estimation of SDDR with the UL MCNP model provided by IO TRO
   b. Proposals for improved shielding
   c. The modification of the MCNP input to set up different configurations as required for improved shielding such us: selection of materials (e.g. different % of SS/H2O), shielding geometry, etc.
   d. Nuclear heating calculation in the UL first wall with the baseline case. For this, a detailed MCNP model (CAD provided by IO) of the first wall including cooling channels will be required.

2. Final analysis of the UL (CAD will be provided by IO. This includes:
   a. Build radiation transport model (MCNP model) of the UL and integrate it into the last version of C-Model. The UL MCNP mode should include all relevant UL structures:
      i. UL plug (CAD provided by IO TRO)
      ii. Port interspace structures (CAD provided by IO TRO)
      iii. Bio-shield plugs (CAD provided by IO TRO)
   b. Global calculation to estimate the radiation conditions in UL plug and associated SDDR at the UL interspace. This calculation will be done considering the worst case for the UL in ports 12, 13, 15, 16 in terms of SDDR at the UL interspace. This case will be selected by IO TRO in collaboration with NIU. When applicable, neighbouring ports (MCNP models) required to perform the global analysis will be provided by IO.
      i. Nuclear heating in UL plug components
      ii. He production and dpa in UL plug components
      iii. Activation calculations (decommissioning)
      iv. Nuclear heating in VV and ITER magnets
      v. SDDR estimation in port interspace by means of D1S method

3. Scoping analysis with previous model including additional shield blocks (outside of the UL boundaries) in order to optimize SDDR. The additional shield blocks will be provided by IO as part of the general model. The list of cases to be run will be agreed upon the contractor and IO to be consistent with the time available and the needs of shielding identified along the execution of the contract.

4. Document work as required: reports of the activity carried out, presentations.

5.   Review technical designs/models provided by IO according to ITER_D_TP4LL9 - Instructions for verification of input for radiation transport calculations.

6.   Promoting safety and quality at all times in all job site activities.

7.   Ability to provide and deliver documentation in appropriate way

IO will provide all IO IDM access as necessary, CAD data and all other relevant database/documents for performing the above mentioned activity.

7   Responsibilities

Services to be provided mainly (~ 85%) at the Contractor site and (15%) at IO site.

The ITER Organization may request Contractor's staff to travel and work at places other than ITER site (F4E, Barcelona), in this case travel mission expenses are claimed by the Contractor according to the following principles:

- Only economy class flights are reimbursed by the ITER Organization;
- Subsistence expenses reimbursement rate for the Contractor's employee shall be reimbursed at ITER Organization's per diem rates (DSC, daily subsistence Ceiling) for each   overnight on mission, from the time of departure until the time of return, on the basis of the quickest, most direct route. If travelling lasts more than 30 consecutive days, the DSC will be reduced by 20% starting on the 31st day overnight inclusively;
- Travel by train (second or first class);
- Travel by private car reimbursement rate is 0.50 € / km plus toll and parking expenses when flight or train are not available;
- Visa expenses (only fees of embassy, consulate or visa centre) will be reimbursed

All other expenses are considered to be included in the DSC. All claims for mission travel will be reimbursed only when supported by invoices and flight tickets.

7.1   Contractor's Responsibilities

In order to successfully perform the tasks in these Technical Specifications the contractor shall comply with the following requirements:

- The contractor shall conduct the work at described in section 6 and 7 and provide the deliverables according to the schedule given in section 8.
- The contractor shall take into account any anticipated changes to relevant systems so they can be taken into consideration in uncertainty and safety factor assessments.
- The contractor shall present all MCNP models to the IO TRO for verification that the latest designs are used.
- The contractor shall report progress regularly to the contract TRO.
- The contractor shall produce a report with details of how the requirements of the INB Order have been met (a conformance report).

- The contractor shall ensure that the input data and results are to the best of his/her knowledge accurate and complete.
- The contractor shall certify that staff performing the tasks have appropriate qualification and experience (see chapter 13 on Quality Assurance)

7.2 IO's Responsibilities

In order to successfully perform the tasks in these Technical Specifications the IO shall comply with the following requirements:

- IO TRO shall provide the latest MCNP models of the ECH systems. Where these models are not available or when applicable, IO TRO shall provide CAD models of the systems.
- IO TRO shall inform the contractor of any anticipated changes to any of the systems so that the contractor can take these into consideration in uncertainty and safety factor assessments.
- IO TRO shall review the MCNP model in collaboration with the contractor and confirm that representation is based on the latest designs.
- IO TRO shall review any proposed shielding modifications and verify that there are consistent with the UL design.
- IO TRO shall provide the MCNP models as agreed in section 6 and nuclear radiation sources.
- IO TRO shall provide technical advice and confirm decisions on the analysis methodology.
- IO TRO shall verify that all relevant safety requirements have been considered.

8 List of Deliverables and due dates

The table below summarizes the main deliverables (together with the corresponding due dates) that will be provided by the contractor. T0 shall be understood as the date of the kick off meeting after contract signature:

Deliverable	Content	Deadline
D1	Scoping analysis with the UL MCNP model provided by IO. This analysis should include: - A first estimation of SDDR with the UL MCNP model - First set of recommendations for proposals of improved shielding. A list of cases to be run under the scope of this contract is to be agreed during this phase among IO TRO and the contractor.	T0 +2
D2	Provide an MCNP model of the UL first wall panel for nuclear heating evaluation	To+3
D3	Provide scoping analysis for the optimization of the SDDR in the port interspace with the list of cases agreed in D1.	T0+4
Hold Point	IO will implement the design recommendations in the UL model	T0+5
D4	Build radiation transport model (MCNP model) of the UL and integrate it into the last version of C-Model. The UL MCNP model should include all relevant UL structures: i. UL plug (CAD provided by IO TRO) ii. Port interspace structures (CAD provided by IO TRO) iii. Bio-shield plugs (CAD provided by IO TRO)	T0+7
D5	Global calculation to estimate the radiation conditions in UL plug and associated SDDR at the UL interspace. This calculation will be done considering the worst case for the UL in ports 12, 13, 15, 16 in terms of SDDR at the UL interspace. This case will be selected by IO TRO in collaboration with NIU. When applicable, neighboring ports (MCNP models) required to perform the global analysis will be provided by IO. i. Nuclear heating in UL plug components ii. He production and dpa in UL plug components iii. Activation calculations (decommissioning) iv. Nuclear heating in VV and ITER magnets v. SDDR estimation in port interspace by means of D1S method	T0+9
D6	Scoping analysis with previous model including additional shield blocks (outside of the UL boundaries) in order to optimize SDDR. The additional shield blocks will be provided by IO as part of the general model. The list of cases to be run will be agreed upon the contractor and IO to be consistent with the time available and the needs of shielding identified along the execution of the contract.	T0+12

Report describing the results of all analyses or the models and incorporating changes to the draft deliverables as requested by ITER (these changes will not constitute substantive changes to the scope of this contract.) These reports must conform to the requirements described in Quality Assurance section.

The reports shall have an appendix with a complete list of all relevant IO IDM links, CAD reference and all other relevant database references with version number.

Calculation results must be provided in an auditable form, i.e. code version and input data are part of deliverables.

9 Acceptance Criteria

The deliverables will be posted in the Contractor's dedicated folder in IDM, and the acceptance by the IO will be recorded by their approval by the designated IO TRO. These criteria shall be the basis of acceptance by IO following the successful completion of the services.

10 Specific requirements and conditions

The contractor shall have their own licenced copy of MCNP and adequate computer resources for the radiation transport simulations described herein.

The work is to be done off-site with visits to IO (as per mutual agreement).

Demonstrable experience in MCNP complex analysis.

Due to the strict time limitations associated to this work, enough calculation capability is highly desirable.

Demonstrable experience in D1S calculations.

Experience in the preparation of analysis reports is required.

Experience in the analysis of ITER components is required.

11 Work Monitoring / Meeting Schedule

A Kick-off meeting between contractor and IO TRO will be organized at T_0 (at an agreed date after contract signature) followed by biweekly meetings. Minutes of meetings will be issued by Contractor at $T + 5$days for IO acceptance. The frequency of these meetings can be amended with agreement of IO. Regular progress meetings will be held by video conference.

There shall be a close out meeting to conclude the contract to verify all deliverables are satisfactory and to confirm all requirements for protection important activities have been respected.

12 Quality Assurance (QA) requirements

The organisation conducting these activities should have an ITER approved QA Program or an ISO 9001 accredited quality system.

The general requirements are detailed in ITER Procurement Quality Requirements (ITER_D_22MFG4).
Neutronic analyses have to be performed following the ITER QA requirements for analyses and calculations: ITER_D_22MAL7 - Analyses and Calculations and ITER_D_R7XRXB - Instructions for Nuclear Analyses.

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)).

Documentation developed as the result of this task shall be retained by the performer of the task or the DA organization 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, in accordance with Quality Assurance for ITER Safety Codes (ITER_D_258LKL).

Deviations and Non-conformities will follow the procedure detailed in the IO document: ITER_D_22F53X - Requirements for DA / Supplier / Subcontractors Deviations & Non-conformities.

13 Safety requirements

In application of the ITER agreement, article 14, ITER follows the French Regulation for Nuclear safety. Because of its inventory in nuclear materials, ITER has been classified in France as a nuclear facility "Installation Nucléaire de Base" and in particular numbered as INB no.174 per the French ITER_D_CZK7M5- Decree No. 2012-1248 dated 9 November 2012 authorizing IO to create a basic nuclear facility called "ITER" and the associated decision form the ASN (French Safety Authority) ITER_D_LYH6QS-ASN Decision 2013-DC-0379 dated 12 November 2013 establishing the prescriptions applicable to ITER Organization for the licensed nuclear facility INB No. 174 called ITER. ITER Organization (IO) is the nuclear operator of this INB and understood like that in the framework of this contract.

As required by the INB Order, and notably its article 2.2.1, the nuclear operator (IO) must notify the external interveners of the necessary provisions for application of the INB order.

The supplier must comply with the all requirements expressed in ITER_D_SBSTBM-Provisions for Implementation of the Generic Safety Requirements by the External Interveners.

The contractor must be aware of ITER_D_43UJN7- ITER Policy on Safety, Security and Environment Protection Management and must be also known, understood and applied by all staff of the contractor and cascaded down in the managerial lines of the contractor and all of their sub-contractors (when applicable).

13.1 Protection important activities

As per articles 1.3 and 2.5.2 of the Order of 7 February 2012:
"Activity important for protecting the interests mentioned under Article L. 593-1 of the Environmental Code (nuclear security – i.e. nuclear safety, radiation protection, the prevention and fight against malicious acts, and also civil security actions in the event of an accident –, public health and sanitation or protection of nature and the environment), i.e. activity that falls under the technical or organizational provisions mentioned under the

second paragraph of Article L. 593-1 of the Environmental Code or that is liable to affect them;"

In practice, the calculations to be carried out in the scope of this contract are a PIA. The defined requirements associated to this PIA are also included in ITER_D_T6XFXM - SRO Surveillance Plan for NIU - Annex 2: Detailed list of PIAs and defined below:

Defined Requirement	Provisions to be implemented in this contract
The input data shall be: - Up to date - Validated - Consistent with safety demonstration For undefined input data: - Clearly identified and referenced assumptions - Sensitivity study to assess the impact of the range of assumptions or use of non-arguable conservative assumptions - Formally validated baseline or conservative input data in the document in support of the safety analysis	- Input data to be provided by IO to ensure that the input is formally validated baseline or conservative input data in the document in support of the safety analysis. - The contractor shall apply the instructions for verification of input for radiation transport calculations ITER_D_TP4LL9 - Instructions for verification of input for radiation transport calculations, as per section 6. - The contractor shall apply the instructions for nuclear analysis ITER_D_R7XRXB - Instructions for Nuclear Analyses, as per section 6. - The contractor shall clearly define and identify the assumptions taken.
The calculation model used shall always be equally or more conservative than the Configuration Management Model (CMM).	Input data to be provided by IO to ensure that the input is formally validated baseline or conservative input data in the document in support of the safety analysis
The method and code shall be qualified according to ITER_D_258LKL - Quality Assurance for ITER Safety Codes Procedure.	The contractor shall apply the instructions for nuclear analysis ITER_D_R7XRXB - Instructions for Nuclear Analyses,, as per section 6.
The method and code shall be used within its qualification domain.	The contractor shall apply the instructions for nuclear analysis ITER_D_R7XRXB - Instructions for Nuclear Analyses, as per section 6 and the requirements stated in this specification.
The uncertainties associated with the methods shall be estimated, or additional margins shall be added and substantiated, through sensitivity studies.	The contractor shall apply the instructions for nuclear analysis ITER_D_R7XRXB - Instructions for Nuclear Analyses, as per section 6 where the estimation of uncertainties is part of the output data and acceptance criteria.
The parameters (including input data) that have strong impact on the results shall be identified.	As part of this contract, the contractor shall identify the parameters (including input data) that have strong impact on the results and provide it in the final report.
All input data, methods codes and their validity domain and uncertainties shall be included in the report.	The contractor shall apply the instructions for nuclear analysis ITER_D_R7XRXB - Instructions for Nuclear Analyses, as per section 6 and the requirements stated in this specification.
Intermediate and final results shall be expressed in international units.	Intermediate and final results shall be expressed in international units.

A sensitivity studies shall be performed for covering uncertainties or additional safety factor in the results and the results shall be integrated in the report.	The contractor shall apply the instructions for nuclear analysis ITER_D_R7XRXB - Instructions for Nuclear Analyses, as per section 6 where the estimation of uncertainties is part of the output data and acceptance criteria.
The acceptance criteria shall be included in the report; all margins and safety factor shall be expressed in safety limits.	**Appendix A** gives all the requirements associated with the scope of this work. These analyses shall show whether those requirements are met or issues. In the case the requirements are not met, the contractor shall provide proposals/recommendations for additional shielding to ensure conformity. All margins and assumed safety factors shall be given in the final report.

Appendix A: Requirements

The requirements associated with this work as related to the UL system, are listed below.

The launchers shall have sufficient shielding capability as regard to the global requirement to ensure that that the dose rate in the region requiring human maintenance access in the port interspace is as low as reasonably achievable and ≤100 μSv/hour at 10^6 sec (about 12 days) after the shutdown, without formal project approval. The dose will be estimated 30 cm from the nearest accessible surface and must take into account the surface contamination, airborne tritium as well as activated materials *.

Note that the disassembly of ex-vessel waveguides or an entire launcher is considered as intervention (not maintenance) while all necessary in-service inspection is considered maintenance.

(*) Surface contamination and airborne tritium are out of the scope of this contract.

Neutron and gamma irradiation effects evaluation on nearby components -The design of the EC Upper Launcher components shall be done so the following project requirements are met. Therefore, with nuclear analysis, it shall be verified that:

- Nuclear Heating in the ITER Coils is < 1kW/m3 (as per SRD-11, 28B2N5)
- VV heating is <0.61 Mw/m3 (as per SRD-15, 28B2PM)
- Shutdown dose rate in interspace are ALARA to contribute to <100uSv/h (as per Project Requirements, 27ZRW8)
- He appm in locations where re-weldability is foreseen (in the launchers):
    - <1 appm for thick plate welding
    - < appm for thin plate or tube welding