IDM UID
8BK74Z

VERSION CREATED ON / VERSION / STATUS
05 Jan 2023 / 1.0 / Approved

EXTERNAL REFERENCE / VERSION

Technical Specifications (In-Cash Procurement)

Technical Specification - Support for Propellant Modelling of DMS

The scope of the work will be consulting and providing design solutions for the DMS for fluid studies. This will be predominantly Computational Fluid Dynamics (CFD) but may also include other calculation methods. The main focus of the work will be on modelling the propellant gas that is used to propel pellets of frozen gas towards the ITER Tokamak.

Table of Contents

1 Purpose

The purpose of this technical specification (ITER_D_8BK74Z) is to provide support for the development of the ITER Disruption Mitigation System (DMS) towards the Final Design Review.

2 Scope

The scope of the work will be consulting and providing design solutions for the DMS for fluid studies. This will be predominantly Computational Fluid Dynamics (CFD) but may also include other calculation methods. The main focus of the work will be on modelling the propellant gas that is used to propel pellets of frozen gas towards the ITER Tokamak, please see section 6.1 for an introduction to the ITER DMS and section 6.2 for the Engineering Analysis required for this Call For Expertise (CFE). This contract will provide guidance for future design and experimental work.

3 Definitions

For a complete list of ITER abbreviations see: ITER Abbreviations (ITER_D_2MU6W5).

4 References

[1] Template for CFD analysis reports, ITER_D_TL7H73 v1.1

5 Estimated Duration

The overall duration of this work is 12 months.

6 Work Description

The work involves provision of technical expertise and to work together with the IO-TRO and the DMS design team primarily; it may also require working with the DMS Task Force (TF) or contractors supporting the design or related research and development activities.

6.1 Introduction

The purpose of the ITER Disruption Mitigation System (DMS) is to provide machine protection in order to reduce the detrimental effects of plasma disruptions and to ensure the appropriate lifetime of all affected ITER components. It utilises cryogenic hydrogen and neon pellets which are generated inside the injectors which are located in the ISS. These pellets are pneumatically propelled in the time frame of milliseconds towards the plasma and just before entering the plasma are shattered into small fragments to enter the plasma and to reduce damage to the plasma facing components and other structures inside the ITER tokamak. A typical injector design for the equatorial ports can be seen in fig. 1.

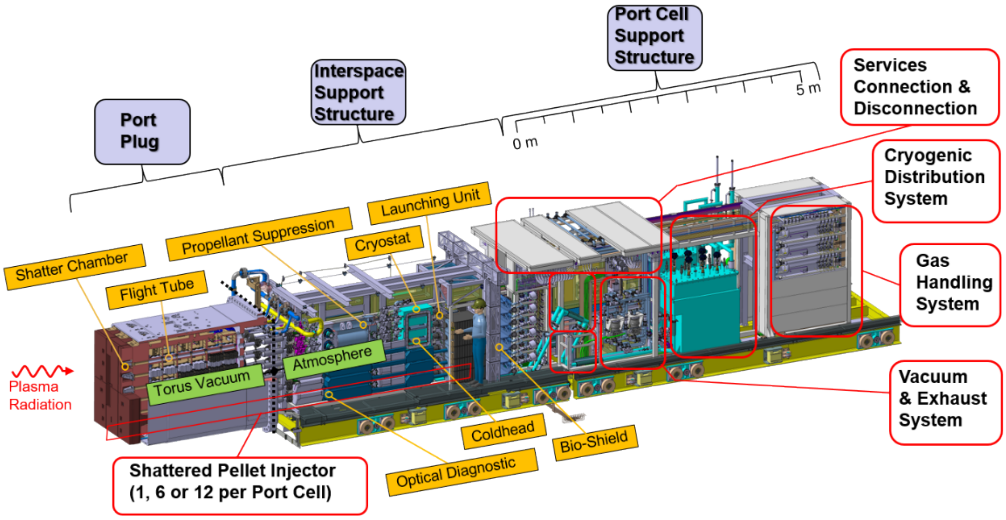

Figure 1: Typical DMS in EP integrated into the ISS and PCSS.

The Disruption Mitigation System (DMS) 18.DM is in its detailed design phase and is approaching the Final Design Review (FDR).

The DMS uses high pressure gas (as a baseline 100 barg hydrogen) to pneumatically propel the pellets towards the plasma. An area of concern is that too much propellant gas may reach the plasma before the pellets which could affect the mitigation efficiency.

The first implementation of SPI technology on DIII-D suffered due to failure to recover a significant proportion of the propellant gas. The JET DMS used an extensive vacuum system for propellant recovery that recovered a much greater proportion of the propellant gas. However, space and other constraints at ITER will prevent installation of a similar propellant recovery system. The ITER system will investigate the use of a smaller vacuum system that includes a number of structures designed to delay the propellant gas. The port plug structure will also be able to contribute towards delaying the propellant gas.

6.2 Engineering Analysis

Prepare a CFD based methodology to simulate pellet injection into the propellant suppression volume and internal and port plug in order to quantify the related exhaust of the propellant gas. The propellant suppression volume contains design features which slow down the gas propagation towards the plasma. Such structures are indicated in figure 2 where a two stage suppressor is sketched. The first stage is an extension of the barrel with slits and compartments and ensures gas retardation while guiding the pellet. The second stage comprises of a set of baffles which the pellet passes in free flight while the gas gets diverted and ultimately delayed before leaving the volume.

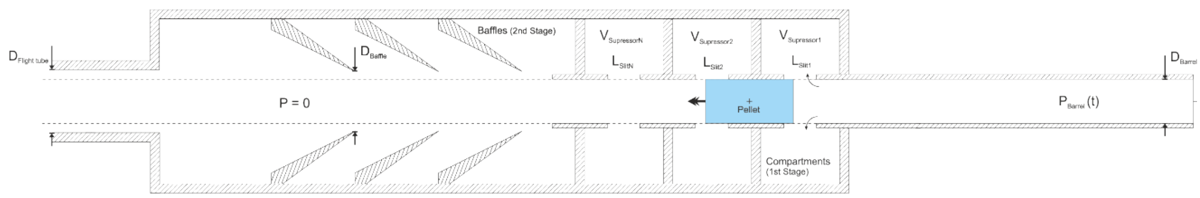

Figure 2 Two stage coaxial propellant suppressor working principle

The pellet then passes multiple opening and smaller volumes in the port plug before it enters the plasma. These volumes and compartments are shown in figure 3 4.

The primary aim is to quantify the amount of propellant gas that enters the torus ahead of the pellet and also after the pellet has entered the torus. For reference the pellet should reach the torus in around ~15ms and the time window of interest is in the range of 50ms. Since the pellet passes numerous cavities as shown in figure 3, the effect these have on the gas flow retardation will have also to be taken into account. The geometry of the DMS and the port plug will be supplied by IO. For costing purposes typical geometry will be supplied at the time of bid submission. The propellant gas profile will either be given by IO to the contractor or IO will give the contractor the information required to calculate the propellant gas profile.

The tasks to be executed in the frame of these contracts can be summarised as follows and some more details are illustrated in chapter 8:

- Investigate design solutions for structures that can be used to delay the propellant gas and quantify their performance.
- Provide recommendations for further improvement of the system design and operational performance.
- Investigate how the proposed changes are impacting the pressure load on components (e.g. the vacuum gate valve) or how the bursting disk discharge will be impacted by the introduction of compartments in the suppressor volume.
- Compare the findings of other studies in the frame of the DMS project, in both finite element methods and computational fluid dynamics and advise on a design implementation

The software used for this contract can either be commercial, open source or developed in house. The contractor will need to provide verification that the software used is suitable for this contract with their bid submission. Copies of all subroutines, input files, source codes, and compiled executables shall be supplied to IO so that the analysis can be repeated at the IO site.

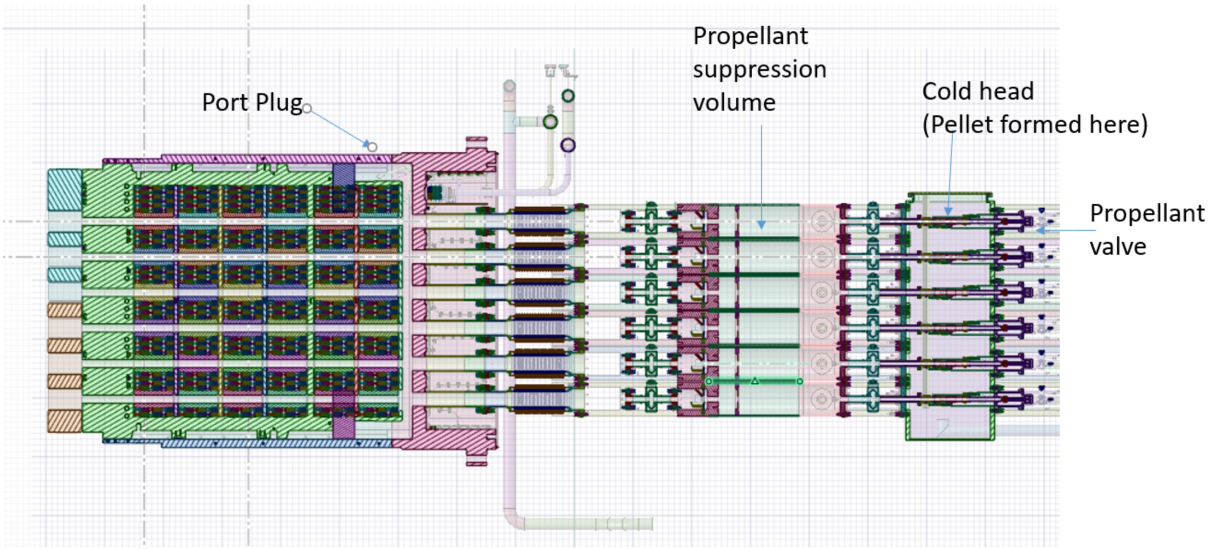

Figure 3: Cross section image showing propellant valve, cold head, propellant suppression volume, and port plug

7 Responsibilities

7.1 Contractor's Responsibilities

In order to successfully perform the tasks in these Technical Specifications, the Contractor shall:

- Strictly implement the IO procedures, instructions and use template *template for CFD analysis* [1] when creating analysis reports;
- Provide experienced and trained resources to perform the tasks;
- Contractor's personnel shall possess the qualifications, professional competence and experience to carry out services in accordance with IO rules and procedures;
- Contractor's personnel shall be bound by the rules and regulations governing the IO ethics, safety and security IO rules.
- Provide copies all subroutines, input files, source codes, and compiled executables
- Provide input to the Final Design Review in form of document review and the production of presentations on the results of this contract.

The official language of the ITER project is English. Therefore, all input and output documentation relevant to this Contract shall be in English. The Contractor shall ensure that all the professionals in charge of the Contract have an adequate knowledge of English, to allow easy communication and adequate drafting of technical documentation. This requirement also applies to the Contractor's staff working at the ITER site or participating in meetings with the ITER Organization.

7.2 IO's responsibilities

The ITER Organization shall

- Nominate the Responsible Officer to manage the Contract;
- Organise regular meeting(s) on work performed;
- Provide CAD designs of DMS and port plug by using the IO Data Exchange procedure

The ITER Organization shall in addition give the possibility to the contractor to review documents on the ITER documents database (IDM). Furthermore the IO shall make all technical data and documents available to the Contractor which will be required to carry out its obligations in a timely manner.

8 List of deliverables and due dates

D#	Description	Due Date*
D1	Report 1 on DMS Fluid Studies in preparation for FDR	T0 + 3 months
D2	Report 2 on DMS Fluid Studies in preparation of FDR execution and Chit resolution	T0 + 7 months
D3	Report 3 on DMS Fluid Studies in preparation of Chit resolution and FDR closeout	T0 + 9 months
D4	Report 4 on DMS Fluid Studies in preparation of FDR closeout	T0 + 12 months

*T0 corresponds to the date of the signature of the contract.

8.1 Progress report 1

Investigate changes to the current design, based to reduce the amount of gas that arrives ahead of the pellet. The main variables to be investigated are:

<u>Geometry Changes</u>

- Structures placed within the propellant suppression volume
    - o Improvements to the two stage approach shall be considered here where the first stage is maintaining the pellet trajectory by means of guidance and the second stage when the pellet enters free flight to retard the propellant and pellet accompanying debris by means of baffle structures.

- <u>Fast shutter</u>
    - o Use of a fast shutter downstream of the propellant suppression volume which closes after the pellet has passed the shutter location (see figure 4). This will enclose the gas upstream. Identify and assess the impact of the closing time (in the range of 0-10 ms) as well as the leak rate through the shutter on the gas flow entering the vacuum vessel.

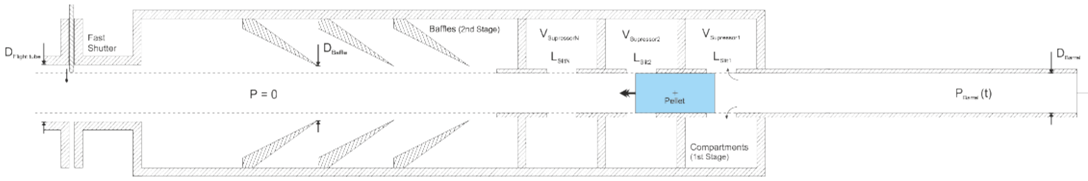

Figure 4 Propellant suppressor with fast shutter located downstream

<u>Alternative Geometry</u>

- Assessment of the feasibility considering a reverse flow baffle geometry (known as *Tesla valve*) as a second stage
    - o Investigate a simplified reverse flow suppressor geometry which could be an alternative to the regular baffles of the second stage.

For costing purposes it should be assumed that that 12 sub-models should be run testing aspects of the changes in isolation. In addition five runs of the entire ITER DMS and port plug geometry will be required. The exact details of each analysis model will be discussed and agreed throughout the duration of the contract.

12 Sub-models investigating:

- Propellant Suppression Volume geometry variations
- Fast Shutter timing
- Propellant gas profile

The five full models will be agreed during the project. But they will include aspects of the sub-models listed above and will be used to confirm the overall performance gain.

8.2 Report 2

Investigate the impact design changes and improvements bring to the design. Two different aspects shall be considered:

- Pressure loads
    - Before the pellet enters the propellant suppressor it passes the vacuum gate valve guiding ring (see figure 5). The purpose of this ring is primarily to minimise the pressure load on the internal components of the valve. However, since there is also a bursting disk in the barrel assembly, the pressure load on this bursting disk has to be assessed during the firing of the pellet to ensure its integrity.

    - In the case the pellet is not being prepared to be fired, the gate valve typically remains closed. In this particular situation a loss of cryogenic coolant would lead to the sublimation of pellet material and this will lead to an increase of pressure in the barrel assembly. Assess whether the dimension of the bursting disk and the assembly are sufficient to discharge the gas into the suppressor without causing an overpressure of the assembly.

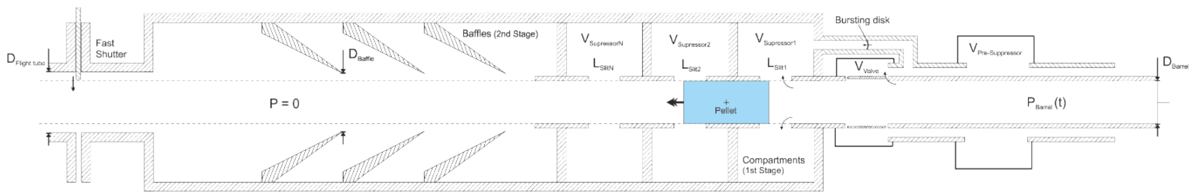

Figure 5 Propellant suppressor with pressure relief devices and additional volumes

- Smaller pellets
    - When utilising smaller pellets by replacing the barrel but leaving the suppressor geometry unchanged, the guiding features and the first stage of the suppressor will likely not work efficiently. To compensate for some of these deficiencies, slits could be introduced into the smaller barrel giving the propellant gas access to the pre-suppressor volume (see figure 6). Assess the propellant retention efficiency of such a configuration.

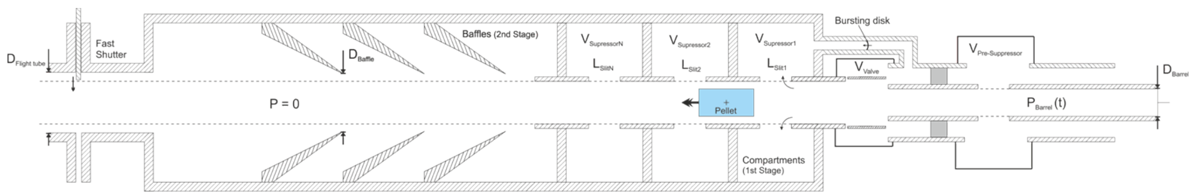

Figure 6 Propellant suppressor with smaller pellets

8.3 Report 3

This report will investigate dust migration from the torus into the port plug structure and/or the DMS components. The Tungsten and Beryllium dust will be generated from plasma surface interactions with the divertor and the first wall, this dust may become activated or contaminated with tritium during ITER operations. If sufficient quantities are present in DMS components this could cause a hazard for maintenance activities.

This report will calculate the type and quantity of dust that settles within the port plug and DMS equipment over time.

8.4 Report 4

The first report will find and detail the fundamental science and equations that describe this problem, from pellet propulsion to the propellant gas entering the torus. In addition this report will also detail how each type of problem will be solved, be it hand calculation, CFD etc. and show how the results are validated.

Furthermore, summarise and conclude on potential design solutions considering all available reports, including results of other contracts and provide support for experimental validation of the CFD findings.

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 the approval of the designated IO TRO. These criteria shall be the basis of acceptance by IO following the successful completion of the services. These will be in the form of reports as indicated in section 8, Table of deliverables.

10 Specific requirements and conditions

The person proposed shall have at least 15 years of proven experience in the following areas:

- Degree in engineering, doctorate preferred.
- Experience in rarefied gas dynamics; fundamentals and simulations.
- Experience in CFD, specifically simulation of high pressure gas discharges in vacuum.
- Knowledge of dust migration studies and analysis.
- Previous experience of engineering analysis at fusion facilities.
- Experience of validation of complex fluid problems.
- Experience with creating technical documents and presentations.

11 Work Monitoring / Meeting Schedule

The work will be managed by means of Progress Meetings and through the formal exchange of documents and transmitted by emails which provide detailed progress.

Progress Meetings will be called by the ITER Organization or the C-TRO. They will be held as needed and at least bi-monthly, either on the IO site or via videoconference. Progress meetings will involve C-TRO(s) and the IO-TRO. External experts will be invited – if needed – to discuss technical matters. The C-RO and IO-RO will be invited in case of contractual discussions.

For all Progress Meetings, minutes, including action items, shall be written by the C-TRO and be stored in the ITER IDM in order to ensure traceability (see also Deliverable D7 in section

12 Delivery time breakdown

T0 is the date of the contract signature. See Section 8 List *Deliverables section and due dates*.

13 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).

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).

14 CAD Design Requirements (if applicable)

For the contracts where CAD design tasks are involved, the following shall apply:

The Supplier shall provide a Design Plan to be approved by the IO. Such plan shall identify all design activities and design deliverables to be provided by the Contractor as part of the contract.

The Supplier shall ensure that all designs, CAD data and drawings delivered to IO comply with the Procedure for the Usage of the ITER CAD Manual (2F6FTX), and with the Procedure for the Management of CAD Work & CAD Data (Models and Drawings 2DWU2M).

Drawing Registration in the IO system shall be performed according to the Procedure for the Management of Diagrams and Drawings in pdf Format Using the SMDD Application (KFMK2B).

The reference scheme is for the Supplier to work in a fully synchronous manner on the ITER CAD platform (see detailed information about synchronous collaboration in the ITER P7Q3J7 - Specification for CAD data Production in ITER direct contracts). This implies the usage of the CAD software versions as indicated in CAD Manual 07 - CAD Fact Sheet (249WUL) and the connection to one of the ITER project CAD data-bases. Any deviation against this requirement shall be defined in a Design Collaboration Implementation Form (DCIF) prepared and approved by DO and included in the call-for-tender package. Any cost or labour resulting from a deviation or non-conformance of the Supplier with regards to the CAD collaboration requirement shall be incurred by the Supplier.

15 Safety requirements

ITER is a Nuclear Facility identified in France by the number-INB-174 (“Installation Nucléaire de Base”).

For Protection Important Components (PIC) the French Nuclear Regulation must be observed, in application of the Article 14 of the ITER Agreement.

In such case the Suppliers and Subcontractors must be informed that:

- The Order 7th February 2012 applies to all the components important for the protection (PIC) and the activities important for the protection (PIA).
- The compliance with the INB-order must be demonstrated in the chain of external contractors.
- In application of article II.2.5.4 of the Order 7th February 2012, contracted activities for supervision purposes are also subject to a supervision done by the Nuclear Operator.

For the Protection Important Components, structures and systems of the nuclear facility, and Protection Important Activities (as per *ITER D PSTTZL*) the contractor shall ensure that a specific management system is implemented for his own activities and for the activities done by any Supplier and Subcontractor following the requirements of the Order 7th February 2012 (TER_D_7M2YKF v1.7 - Order dated 7 February 2012 relating to the general technical regulations applicable to INB - EN).

Compliance with ITER D 45P8YK Defined requirements PBS 18 DMS is mandatory.