

Technical Specifications (In-Cash Procurement)

Detail design of Quartz and Sapphire windows

The purpose of this contract is to provide engineering to refine the design input and finalize the detailed design, which is required to achieve the final design review of the Quartz and Sapphire window assembly variations forming part of the first confinement boundary.

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1 Purpose

The purpose of this contract is to provide engineering to refine the design input and finalize the detailed design, which is required to achieve the final design review of the Quartz and Sapphire window assembly variations forming part of the first confinement boundary.

2 Scope

The scope of this task order is the design development of the Quartz and Sapphire window assemblies up to the final design stage. In order to address the requirements of the diagnostic systems, several variations shall be developed. They are listed in the table below.

Table 1. Diagnostic systems using Quartz and Sapphire windows

| Diagnostic system | Variation |
|--|-------------------------------------|
| <u>Quartz variations</u> | |
| F1: Electron Cyclotron Emission | 130_Qz_B_+5Y_+5Z_2 |
| C6: Polarimeter Poloidal | 82_Qz_B_5Y_5Z_0 |
| E8: Neutral Particle Analyser | |
| E3: VUV Survey | |
| EG: Divertor VUV Spectroscopy | |
| EE: Hard X-ray Monitor (H-phase) | |
| EH: VUV Edge Imaging | |
| F2: Reflectometer (Main Plasma, LFS) | 82_Qz_B_5Y_5Z_0 (to be confirmed) |
| Diagnostic system | Variation |
| <u>Sapphire variations</u> | |
| G1: IR Cameras, Vis/IR TV (Midplane) | 160_Sap_B_2Y_2Z_0 |
| G1.E0 :Temporary Vis/IR in EP16 for FP | |
| G6: IR Thermography (divertor) | |
| GC : Tritium Monitor | 160_Sap_B_2Y_2Z_0 (to be confirmed) |
| GA: IR Cameras: Vis/IR TV (Upper) | 160_Sap_B_2Y_2Z_0 (to be confirmed) |

The final design of the Quartz and Sapphire variations include the following works.

- Finalization of the diagnostic systems requirements gathered by means of the interface sheets between PBS.55.NW and each diagnostic systems making use of Quartz or Sapphire windows. This shall lead to strengthen the inputs for the final design, and freeze the material specifications of both Synthetic Cristal Quartz and Sapphire. Requirements on anti-reflection coating shall also be frozen.
- Detailed design of the several variations, taking into account the latest improvements achieved on the Fused Silica variations regarding the design of all welded junctions.
- Detailed design of the components required for baking and instrumentation, taking into account the interface with the port integration.

Apart from the final design activities of the Quartz and Sapphire windows, the interfaces of the other window variations (Fused Silica, BaF2, Small-aperture windows, CVD) shall be assessed and updated according to the design evolution of the diagnostic systems. This will require the design update relevant to the interface as well as the update of the interface sheets.

3 Definitions

| | |
|-----|-------------------------------------|
| AR | Anti-Reflection |
| CAD | Computer Aided Design |
| CTS | Collection Thomson Scattering |
| CVD | Chemical Vapor Deposition |
| DDD | Design Description Document |
| ECH | Electron Cyclotron Heating |
| FDR | Final Design review |
| FP | First Plasma |
| FSi | Fused Silica |
| IDM | ITER Document Management [software] |
| INB | Installation Nucleaire de Base |
| IO | Iter Organization |
| KOM | Kick-Off Meeting |
| MOM | Minutes of Meeting |
| MRR | Manufacturing Readiness Review |
| PIA | Protection Important Activities |
| PIC | Protection Importance Components |
| RH | Remote Handling |
| QA | Quality Assurance |
| SIC | Safety Important Class |
| SLS | System Load Specification |
| SRD | System Requirement Document |

For a complete list of ITER abbreviations see: [ITER Abbreviations \(ITER_D_2MU6W5\)](#).

4 References

4.1 Applicable documents list

| No. | IDM | Title | Version |
|------|------------------------|---|---------|
| [A1] | WYWVMP | Sub-SRD 55.NW windows | V1.0 |
| [A2] | 22MAL7 | Procedure for Analysis and Calculations | V5.1 |

4.2 Reference document list

Documents, which can be usefully consulted for exercising the activities related to the task

| No. | IDM / Link | Title | Version |
|-----|------------|-------|---------|
|-----|------------|-------|---------|

| | | | |
|------|------------------------|---|--|
| [R1] | 46NXUU | System Design Description (DDD) 55.NW Windows | |
|------|------------------------|---|--|

5 Estimated Duration

The duration shall be for 6 months. No work shall commence prior to the date of final signature of the Contract.

The system design activity requires regular presence of the contractor, who coordinates the development throughout the full contract on-site.

Engineering expertise will be carried out Off-site.

6 Work Description

6.1 System overview

6.1.1 *Main function*

The first requirement of the diagnostic window assembly is the transmission of the signal used by the diagnostic. The attenuation and disturbances induced by the window assembly shall therefore be within the limits prescribed by the specific requirements of each diagnostic system. The Quartz and Sapphire

Placed at the vacuum boundary, the window assembly shall also ensure the vacuum integrity required for the plasma.

Moreover, the diagnostic window assemblies form part of the ITER primary confinement boundary. Their integrity is consequently of prime importance in containing the reactant materials such as tritium in the inside of the vacuum vessel. Therefore window assemblies are classified Safety Component Class 1 (SIC-1). The primary confinement boundary shall be fully ensured during all the normal and accidental conditions.

6.1.2 *Brief design description*

The ITER diagnostic windows have several design variations depending on the material and size of the transparent disks: Fused Silica windows, Quartz windows, Sapphire windows, BaF₂ windows, CVD windows, small aperture windows.

The Quartz and Sapphire windows, which is the scope of this contract, are used to transfer the signals used for the diagnostic systems listed in Table 1.

The scope of this system (PBS 55.NW windows) is not only the window assemblies itself which fulfils the main function, but also the components and tools required for protection and maintenance. The system breakdown is given in Figure 1.

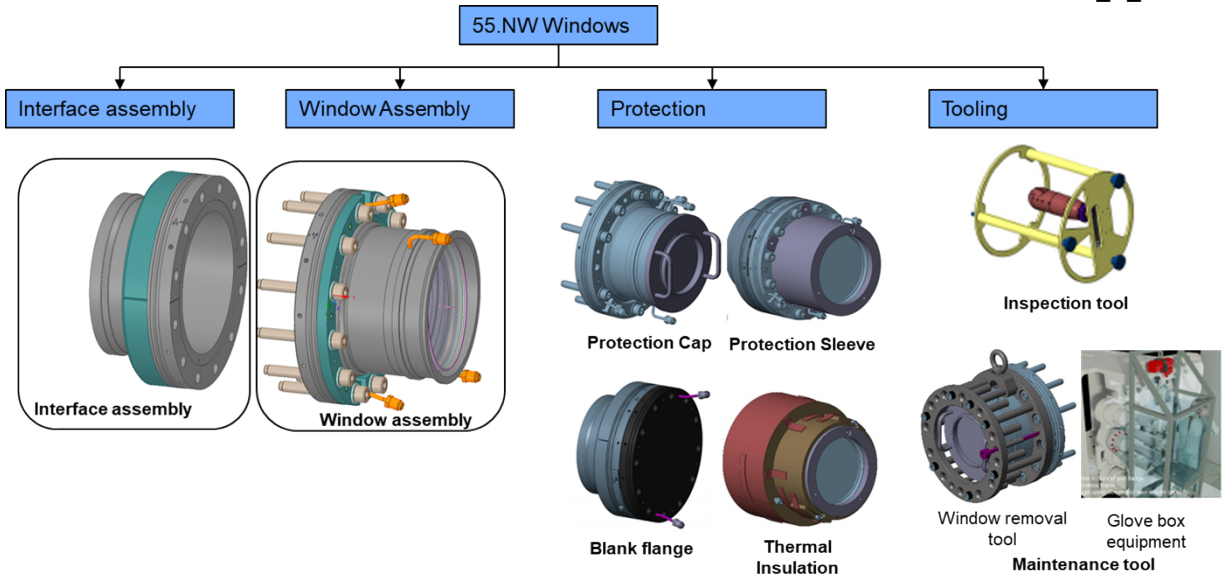


Figure 1 System breakdown of 55.NW windows

The windows have double transparent disks to provide the double confinement. Each single disk is joined to the structural body by using the diffusion bonding technology. The enclosed interspace between the two disks allows to monitor the vacuum leak. The ITER standard vacuum flange is adopted to mount the windows to the machine. See Figure 2. To improve the signal transmission efficiency, anti-reflection coating is required on the disk for some windows. Some instrumentation (ECH sensor and thermocouple) needs to be installed as well to monitor the window status during the machine operation.

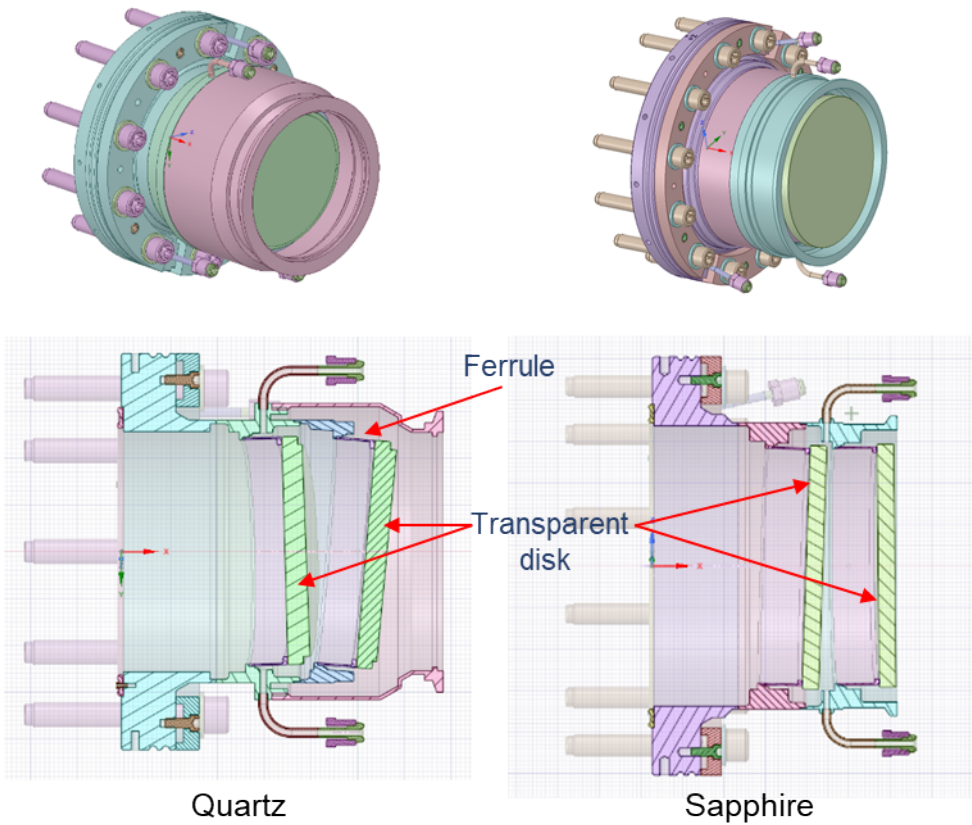


Figure 2 Preliminary design of Quartz window and Sapphire window

Though all the window assemblies share similar functions, the design of the window assemblies cannot be unique, and must accommodate the specific features of each diagnostics as well as the specific requirements for their integration on the diagnostic line (available space at the back of the port plug). In total at the maximum six variations may be developed to address the diagnostic needs (See Table 1).

6.1.3 Overall planning

| Development Phase | From | To |
|-------------------------------------|---------------|----|
| FDR date | November 2020 | |
| FDR approved | April 2021 | |
| Delivery of FP windows | November 2021 | |
| Qualification approved | January 2023 | |
| MRR for in-series production | May 2023 | |

6.2 Work packages

6.2.1 Design inputs

In order to develop the final design of the windows, the requirements from the diagnostic systems shall be gathered and finalized through the interface sheets between PBS.55.NW and each diagnostic systems making use of Quartz or Sapphire windows. Based on the requirements agreed in the interface sheets, the material specifications of both Synthetic Cristal Quartz and Sapphire and the technical specification for anti-reflection (AR) coating shall also be developed.

The interface sheets with the diagnostic systems listed in Table 1 shall be updated and refined according to the ITER guideline ([Design Interface Control Procedure \(28VNJG v4.2\)](#)). This requires the interactive with the ITER diagnostic ROs to get agreement on the interfaces.

The material specifications of Quartz and Sapphire shall be developed to be compliant with the diagnostic functional requirements as well as the ITER-specific requirements defined in the window sub-SRD ([Sub-System Requirement Document sSRD-55.NW: Windows \(WYWVMP\)](#)). As this technical specification will be used as product procurement specification of the material, it shall be detailed and precise enough. The technical specification shall at least include the requirements related to the following aspects:

- Material properties of the disk material for both the blank material and the formed and polished final products
- Optical transmission
- Mechanical testing
- Laser loads
- Radiation hardness
- Nuclear environment
- Chemical analysis

- Manufacturing
- Qualification of the material procurement
- Documentation and test report
- Dimension and tolerances
- Identification and marking
- Cleanliness
- Packaging and marking
- Quality assurance requirement

The technical specification of the AR coating shall be developed to meet (1) the functional requirements of some diagnostic system to improve the optical transmission performance and (2) environmental requirements derived from the system load specification ([55.NW - Load Specs for Fused Silica Window Assemblies \(QCN8DN v6.5\)](#)) and from the ITER vacuum handbook ([ITER Vacuum Handbook \(2EZ9UM v2.5\)](#)). The AR coating requirements shall be compliant with the window system requirements ([Sub-System Requirement Document sSRD-55.NW: Windows \(WYWVMP\)](#)) as well. The technical specification shall at least include the requirements related to the following aspects:

- AR coating performance to meet the diagnostic system requirements
- Coating design and coating technique
- Coating material
- Environmental conditions such as pressure, temperature, humidity after coolant accident, nuclear radiation resistance, vacuum, etc.
- Coating compatibility with the window manufacturing process
- Coating qualification
- Factory acceptance
- Cleanliness
- Packaging/marketing
- Quality assurance requirements

6.2.2 Finalization of detail design

The detailed design for all the variations for Quartz and Sapphire windows listed in Table 1 shall be carried out to satisfy the diagnostic measurement requirements and the functional and physical interfaces defined in the interface sheets. The design shall be compliant with the requirements specified in the following documents:

- [Sub-System Requirement Document sSRD-55.NW: Windows \(WYWVMP\)](#)
- [ITER Vacuum Handbook \(2EZ9UM v2.5\)](#)

As the windows for Quartz and Sapphire have the same design concept as the Fused Silica Windows, the input packages for FSi window FDRs needs to be referred to: [55.NW - Input Data Package List - FDR \(WAD452 v1.6\)](#). Especially, regarding all welded junction designs of the structural part, the latest improvements achieved on the Fused Silica variations [R1] shall be taken into account.

The detailed design for the following components shall be carried out as well:

- Instrumentation

- ECH monitoring sensor to measure the ECH stray load on the disk with 10% measure accuracy and response time shorter than the window failure time due to ECH stray load
- Thermocouple to measure the structural temperature
- The measurement position shall be proposed and agreed with IO before starting the design
- Design update of thermal insulation for baking
 - The thermal insulation shall be made around the window structural body in order to heat the window assembly efficiently during baking.
 - The thermal insulation should be removed and reinstalled easily for maintenance according to the ALARA principle.

These components shall be designed by considering the interface with the port integration.

The 3D CATIA models for all the design variations shall be updated or produced and after finalizing the models, it shall be registered to the ITER catalogue (CADENAS). Apart from finalization of the 3D CATIA models, 2D drawings shall be generated, which include the key tolerances.

6.2.3 *Technical support for other window variations*

For the other window variations (Fused Silica, BaF₂, Small-aperture windows, CVD), the interfaces shall be assessed and updated according to the design evolution of the diagnostic systems. This will require the design update relevant to the interface as well as the update of the interface sheets.

7 Responsibilities

7.1 Contractor's Responsibilities

In order to successfully perform the tasks in this Technical Specification, the Contractor shall:

- Strictly implement the IO procedures, instructions and use templates;
- 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.

7.2 IO's Responsibilities

The IO shall:

- Nominate the Responsible Officer to manage the Contract;
- Organise a monthly meeting(s) on work performed;
- Provide offices at IO premises;
- Provide the inputs required to carry out this task;
 - Need and requirements for anti-reflection coating

- Maximum heat deposited in the disks due to the transmission of the diagnostic signals
- Take care of the window integration in the ports concerning the interfaces related to SVS connection, thermal insulation, instrumentation, protection sleeve;
- Prepare interface drawings with the diagnostic systems and the ports
- Prepare interface sheets with the port integrator

8 List of Deliverables and due dates

T0 = Kick off meeting.

| # | Delivery | WP | Date |
|-------------|--|----|---------------|
| D1-1 | Quartz and Sapphire Interface sheets with the diagnostic systems | 1 | T0 + 2 months |
| D1-2 | Material procurement specifications for Synthetic Cristal Quartz Material procurement specifications for Sapphire Technical specifications for AR coating. | 1 | T0 + 3 months |
| D2-1 | CAD design of Quartz and Sapphire variations | 2 | T0 + 4 months |
| D2-2 | CAD design of ECH sensor and TC | 2 | T0 + 5 months |
| D2-3 | CAD design of thermal insulation | 2 | T0 + 5 months |
| D3-1 | Interface sheets revised for other window variations | 3 | T0 + 6 months |

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. These will be in the form of reports as indicated in section 8, Table of deliverables.

10 Specific requirements and conditions

Successful implementation of this contract requires a wide range of engineering expertise, a summary of which is given below:

- System level engineering expertise,
- Mechanical engineering expertise, in design and analysis,
- Experience in manufacturing and qualification/tests procedures of optical components,
- Additional expertise that would be benefit the execution of the work would be:
 - Experience and knowledge of ITER Quality policy.

11 Work Monitoring / Meeting Schedule

Work is monitored through quarterly reports (see List of Deliverables section) and at monthly project meetings for each of the four projects.

12 Delivery time breakdown

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 Software qualification policy (ITER_D_KTU8HH).

14 CAD Design Requirements

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](#)).

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 [GNJX6A](#) - Specification for CAD data production in ITER 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 and in particular Safety Important Class components (SIC), 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 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 ([PRELIMINARY ANALYSIS OF THE IMPACT OF THE INB ORDER - 7TH FEBRUARY 2012 \(AW6JSB v1.0\)](#)).

Compliance with [Defined requirements for PBS 55 - Diagnostics \(NPEVB6 v2.0\)](#) or its flowed down requirements in [SRD-55 \(Diagnostics\) from DOORS \(28B39L v5.2\)](#) is mandatory.

This task is a PIA.

“The supplier must comply with the all requirements expressed in “Provisions for implementation of the generic safety requirements by the external actors/interveners” (SBSTBM)”