

**Technical Specifications (In-Cash Procurement)****Technical specification for measurement of TCC in  
vacuum**

This testing specification aims at accurately measuring of the TCC for different material coated and not coated with the EIC and threads used in the Blanket in vacuum conditions

## SERVICE

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### 1 Preamble

[I] This Technical Specification is to be read in combination with the General Management Specification for Service and Supply (GM3S) [AD1] that constitutes a full part of the technical requirements.

[I] In case of conflict, the content of the Technical Specification supersedes the content of [AD1].

### 2 Purpose

[I] ITER in-vessel water cooled components are equipped with interfaces (bolts, pads...) that play a role in the global thermal behaviour.

[I] This testing specification aims at accurately measuring of the TCC for different material coated and not coated with the EIC and threads used in the Blanket in vacuum conditions.

## 3 Acronyms & Definitions

### 3.1 Acronyms

[I] The following acronyms are the main one relevant to this document.

| Abbreviation | Description                                             |
|--------------|---------------------------------------------------------|
| CRO          | Contract Responsible Officer                            |
| GM3S         | General Management Specification for Service and Supply |
| IO           | ITER Organization                                       |
| CRO          | Contract Responsible Officer                            |
| TCC          | Thermal Contact Conductance                             |
| EIC          | Electrical Insulating Coating                           |

### 3.2 Definitions

**Contractor:** shall mean an economic operator who have signed the Contract in which this document is referenced.

**Effective TCC:** Thermal Contact Conductance (TCC) used in the Finite Element models with simplified thread simulation as a cylindrical (line) bonded contact.

## 4 Applicable Documents & Codes and standards

### 4.1 Applicable Documents

[I] This is the responsibility of the Contractor to identify and request for any documents that would not have been transmitted by IO, including the below list of reference documents.

[I] This Technical Specification takes precedence over the referenced documents. In case of conflicting information, this is the responsibility of the Contractor to seek clarification from IO.

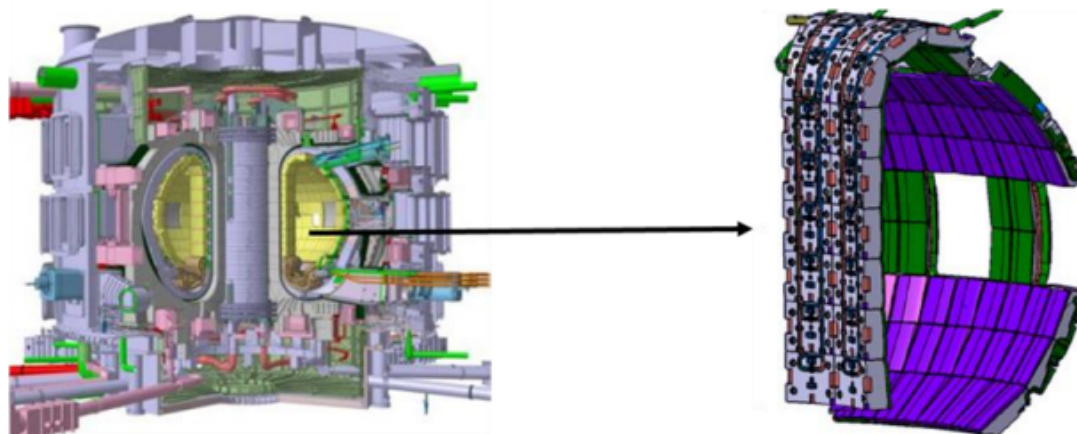
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[R] Upon notification of any revision of the applicable document transmitted officially to the Contractor, the Contractor shall advise within 4 weeks of any impact on the execution of the contract. Without any response after this period, no impact will be considered.

| Ref | Title                                                          | IDM Doc ID | Version |
|-----|----------------------------------------------------------------|------------|---------|
| AD1 | General Management Specification for Service and Supply (GM3S) | 82MXQK     | 0.0     |
| AD2 | Insulating coatings for the blanket system components          | D25QF6     | 3.0     |

## 5 The ITER Blanket System

[I] The nuclear energy generated in the hot plasma during the fusion process is deposited mostly in the modular structure of the in-vessel Blanket system that surrounds the plasma. This Blanket structure covers a plasma-facing surface of  $\sim 610\text{m}^2$  and consists of 440 Blanket Modules mechanically attached to the Vacuum Vessel (VV). There are two main parts of the Blanket system – the inboard and the outboard located on the inner and outer side of the donut shaped reactor chamber, respectively. The Blanket is the innermost system located inside the Vacuum Vessel and directly interacts with the hot plasma.



*Figure 5-1. Identification of the Blanket components inside ITER machine*

[I] The operational conditions of the Blanket system are such that components will need to function in a hostile environment (including neutron irradiation, elevated temperatures, and ultra-high vacuum) under cyclic mechanical loads and must be secured to the VV wall with a high level of confidence that the operational conditions will not loosen the component. The exploitation phase of the ITER machine is anticipated to be 20+ years.

[I] Each blanket module is composed of a detachable First Wall (FW) bolted to a Shield Block (SB).

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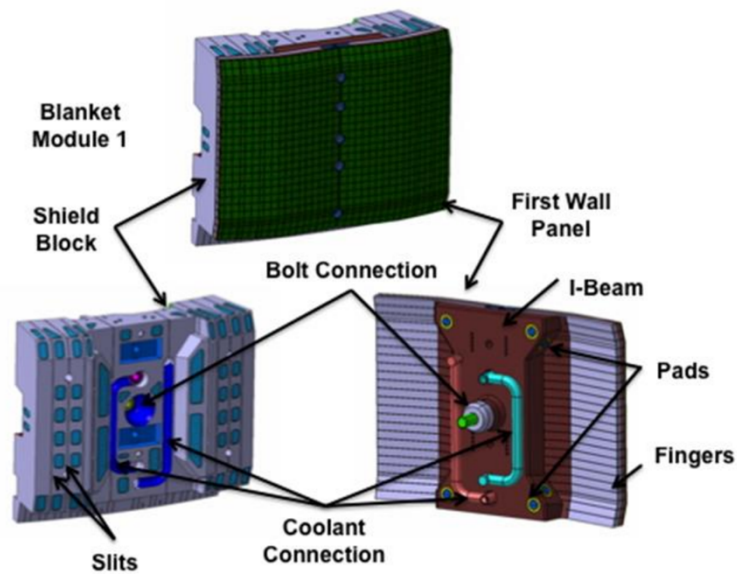


Figure 5-2

*Figure 5-2. Schematic of Blanket Module showing the First Wall panel and the Shield Block*

[I] The thermal loading of the Blanket system is mainly due to plasma surface heating (radiation & convection) and volumetric neutron heating. A pressurized water circuit flowing through the main components (FW and SB) allows cooling down the system. But some elements (pads, bolts, etc.) imbedded in the system are only cooled by thermal contact (and radiation) to the main water-cooled components, this conduction needs to be quantified accurately according to blanket operational conditions.

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## 5.1 Test sets and conditions

[R] Four types of contact shall be considered:

- 1) Test set #1 - Flat contact between two bare metals
- 2) Test set #2 - Flat contact between metal coated with EIC and bare metal
- 3) Test set #3 - Flat contact between two metals (one coated with EIC) and peelable shim between them
- 4) Test set #4 - Threaded joint

[R] All test sets to be tested and the test conditions are presented in the Table 5-1 for the flat contact, in the Table 5-2 for the contact with peelable shim and in the Table 5-3 for the threads.

*Table 5-1. Test samples with flat contact.*

| Test set | Contact surface 1 |               | Contact surface 2                               |               | Pressure, MPa                                                                                                                                      | Temperature at the contact, C |
|----------|-------------------|---------------|-------------------------------------------------|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|
|          | Material          | Roughness, Ra | Material                                        | Roughness, Ra |                                                                                                                                                    |                               |
| 1.1      | 316L              | 1.6           | AlBr                                            | 0.8           | 1, 5, 20, 50, 100, 150 for RT,<br><br>5, 20, 50 for 250C (final number of pressure points and its value will be specified based on results for RT) | RT (20), 250                  |
| 1.2      | 316L              | 1.6           | 316L                                            | 1.6           |                                                                                                                                                    |                               |
| 1.3      | 718               | 0.8           | 718                                             | 0.8           |                                                                                                                                                    |                               |
| 1.4      | 660               | 0.8           | 718                                             | 0.8           |                                                                                                                                                    |                               |
| 1.5      | W                 | 2.5           | 316L                                            | 1.6           |                                                                                                                                                    |                               |
| 1.6      | W                 | 2.5           | 718                                             | 1.6           |                                                                                                                                                    |                               |
| 2.1      | AlBr              | 1.6           | AlBr coated with Al <sub>2</sub> O <sub>3</sub> | 1.6           |                                                                                                                                                    |                               |
| 2.2      | 316L              | 1.6           | AlBr coated with Al <sub>2</sub> O <sub>3</sub> | 1.6           |                                                                                                                                                    |                               |
| 2.3      | AlBr              | 1.6           | 718 coated with Al <sub>2</sub> O <sub>3</sub>  | 1.6           |                                                                                                                                                    |                               |
| 2.4      | AlBr              | 1.6           | 660 coated with Al <sub>2</sub> O <sub>3</sub>  | 1.6           |                                                                                                                                                    |                               |
| 2.5      | W                 | 2.5           | 316L coated with Al <sub>2</sub> O <sub>3</sub> | 1.6           |                                                                                                                                                    |                               |

**SERVICE***Table 5-2 Test samples with peelable shim*

| Set | Contact surface 1                               |     | Contact surface 2     |                    |               | Contact surface 3 |     | Pressure, MPa                                                                                                                                    | Temperature at the contact N1 (between surface #1 and #2), C |
|-----|-------------------------------------------------|-----|-----------------------|--------------------|---------------|-------------------|-----|--------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------|
|     | Material                                        | Ra  | Material              | Ra                 | Thickness, mm | Material          | Ra  |                                                                                                                                                  |                                                              |
| 3.1 | AlBr coated with Al <sub>2</sub> O <sub>3</sub> | 1.6 | Peelable shim (316L), | 1.6 top<br>0.6 bot | 1 mm          | 316L              | 1.6 | 1,5, 20, 50, 100, 150 for RT,<br><br>5, 20, 50 for 250C (final number of pressure points and its value will be specified based on results for RT | RT (20), 250                                                 |
| 3.2 | AlBr coated with Al <sub>2</sub> O <sub>3</sub> | 1.6 | Peelable shim (316L), | 1.6 top<br>0.6 bot | 2 mm          | 316L              | 1.6 |                                                                                                                                                  |                                                              |
| 3.3 | AlBr coated with Al <sub>2</sub> O <sub>3</sub> | 1.6 | Peelable shim (316L), | 1.6 top<br>0.6 bot | 3 mm          | 316L              | 1.6 |                                                                                                                                                  |                                                              |

*Table 5-3 Test samples with threads*

| Set | Contact surface 1 |                 | Contact surface 2 |                   | Tensile Force, kN | Temperature on the thread, C |
|-----|-------------------|-----------------|-------------------|-------------------|-------------------|------------------------------|
|     | Material          | Thread          | Material          | Thread            |                   |                              |
| 4.1 | AlBr              | Male M64x2 15mm | 316L              | Female M64x2 15mm | 10, 50, 100       | RT (20), 250                 |
| 4.2 | 660               | Male M64x2 15mm | 660               | Female M64x2 15mm | 50, 100, 250*     |                              |
| 4.3 | 316L              | Male M8 10 mm   | 316L              | Female M8 10 mm   | 0.5, 2, 5         |                              |

\*) Higher force could be considered if the thread length could be increase without significant impact on the test setup and the cost.

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[R] The test samples shall be manufactured from materials presented in the Table 5-4.

Table 5-4 Materials

|       | Material                                                  |
|-------|-----------------------------------------------------------|
| Al Br | Ni Al Bronze (UNS C63200, CuAl10Ni5Fe4)                   |
| 660   | SS660 (X6NiCrTiMoVB25-15-2, DIN 1.4980)                   |
| 718   | Nickel alloy 718 (UNS N07718, Grade 718, Inconel 718)     |
| 316L  | X2CrNiMo17-12-2, DIN 1.4404 (ASTM steel 316L, UNS S31603) |
| W     | Pure Tungsten Grade W1, W2 (GB/T 4187-2017)               |
| EIC   | As per IO Specification [AD2]                             |

[I] The test sets are shown in Figure 5-1

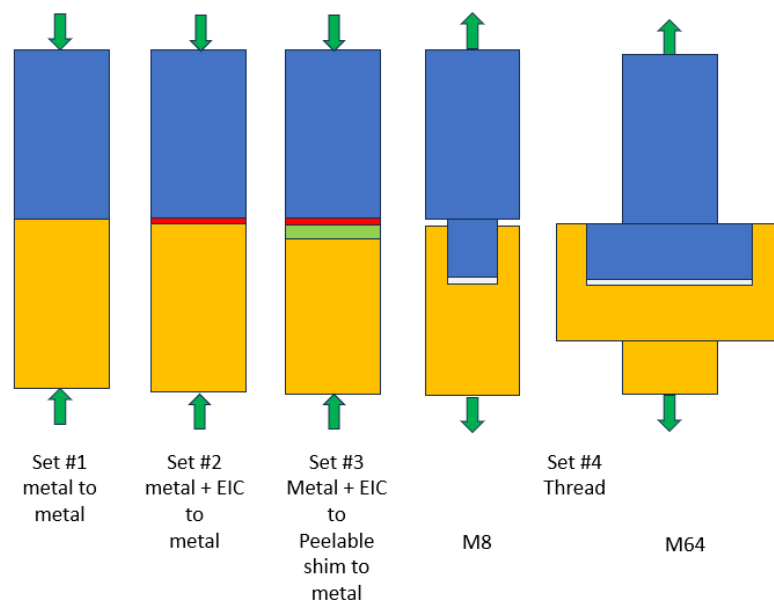


Figure 5-3. Test sets.

## 6 Scope of Work

[I] This section defines the specific scope of work for the service, in addition to the contract execution requirement as defined in the [AD1]

### 6.1 Scope of work #1: Development of the test procedure and test set-up

[R] The Contractor shall develop the procedures for the TCC measurements for the flat contact and effective TCC evaluation for thread, test set-up and design of the test samples considering the following requirements:

- The experimental device shall provide a vacuum better than  $10^{-2}$  Pa
- A global thermal balance shall be monitored and recorded. Input/output power and radiation loss shall be assessed.
- Radiation heat transfer from the samples (radiation loss) shall be minimised with target value  $< 5\%$ .
- Input power shall be sufficient to provide a temperature jump at the contact interface minimum 10x larger than temperature measurement accuracy for all tested sets.



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- e. The experimental device shall provide tensile and compression force in range of 0 - 400 kN

[R] The accuracy of the TCC measurement shall be characterized (as well as Thermocouples accuracy) as part of the test facility validation program.

[R] The Contractor shall perform thermal and structural analysis to optimize the test samples with thread.

[R] The Contractor shall validate the test facility and the test setup prior to conducting the experiments with the real test samples.

[I] The pair of samples fabricated from the same rod with short length and the test sample that is twice length could be used for the validation.

[R] The validation procedure and corresponding test samples shall be agreed with IO.

[I] The Contractor may choose to perform the validation process in either a vacuum or in air. Proposed conceptual test set up is shown in Figure 5.1

[R] The Contractor shall provide the test procedure, description of the test setup, test facility validation report and thermal-mechanical analysis report for threaded samples to IO for approval.

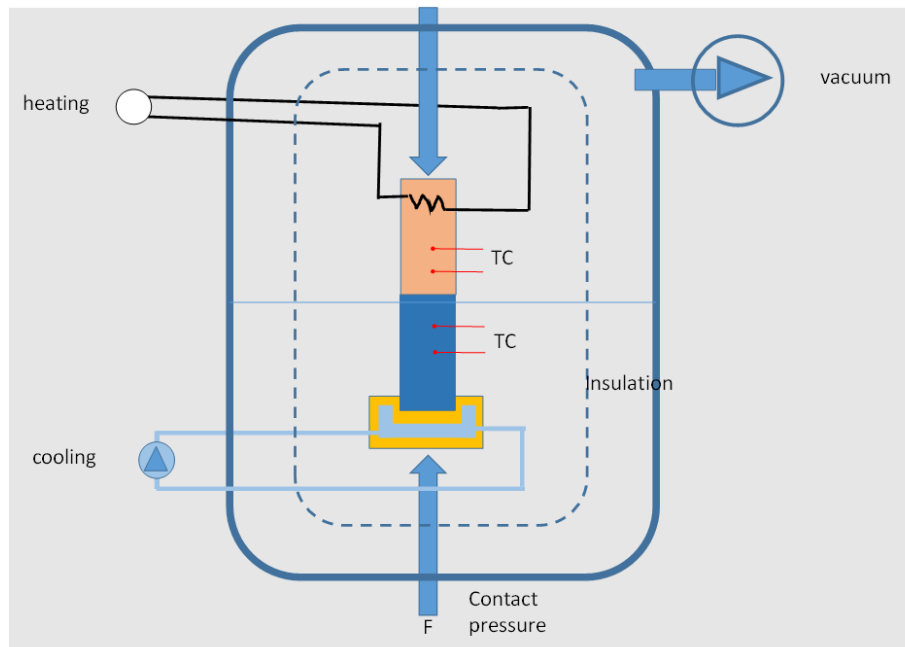


Figure 5-2. Proposed conceptual test setup.

[I] Proposed design of the test samples with flat contact is shown in Figure 5-2

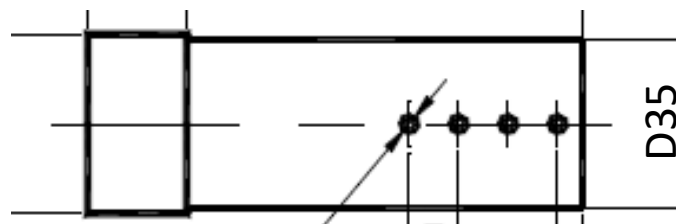


Figure 5-3. Proposed conceptual design for the test samples with flat contact.

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### Deliverable #1:

- The Contractor QP and sub-contractor(s) QP if any

### Deliverable #2:

- Test protocol including:
  - The procedure for measuring of the TCC for flat contacts and procedure for evaluation of the effective TCC for thread.
  - Design of the test set up and of the test samples (drawings and 3D models)
  - Test facility and test setup validation report
  - Results of thermal-structural analysis for the threaded test samples

**SERVICE****6.2 Scope of work #2: Test samples manufacturing**

[R] Based on the acceptance of deliverables #1, the Contractor shall manufacture the test sample and test jig in accordance with Table 6-1 and Table 6-2.

[I] Contractor may manufacture spare (additional) samples at his discretion.

*Table 6-1 Test samples for flat contact*

| Test sample | Material           | EIC | Roughness, Ra                  | Number of samples | Test set                       |
|-------------|--------------------|-----|--------------------------------|-------------------|--------------------------------|
| 1           | 316L               | No  | 1.4 – 1.8                      | 2                 | 1.1, 1.2, 1.5<br>2.2, 3.2, 3.2 |
| 2           | AlBr               | No  | 0.6 – 1.0                      | 1                 | 1.1                            |
| 3           | 718                | No  | 0.6 – 1.0                      | 2                 | 1.3, 1.4                       |
| 4           | 660                | No  | 0.6 – 1.0                      | 1                 | 1.4                            |
| 5           | AlBr               | No  | 1.4 – 1.8                      | 1                 | 2.1, 2.3, 2.4                  |
| 6           | W                  | No  | 2.2 - 2.8                      | 1                 | 1.5, 1.6                       |
| 7           | AlBr               | Yes | 1.4 – 1.8                      | 1                 | 2.1, 2.2, 3.1,<br>3.2, 3.3     |
| 8           | 718                | Yes | 1.4 – 1.8                      | 1                 | 2.3                            |
| 9           | 660                | Yes | 1.4 – 1.8                      | 1                 | 2.4                            |
| 10          | 316L               | Yes | 1.4 – 1.8                      | 1                 | 1.6                            |
| Shim 1      | 316L Thickness 1mm | No  | 1.4 – 1.8 top<br>0.4 – 0.8 bot | 1                 | 3.1                            |
| Shim 2      | 316L Thickness 2mm | No  | 1.4 – 1.8 top<br>0.4 – 0.8 bot | 1                 | 3.2                            |
| Shim 3      | 316L Thickness 3mm | No  | 1.4 – 1.8 top<br>0.4 – 0.8 bot | 1                 | 3.3                            |

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Table 6-2 Test samples for threaded contact

| Test sample | Material | Thread   |        | Number of samples | Test set |
|-------------|----------|----------|--------|-------------------|----------|
| 9           | AlBr     | M64x4 g6 | Male   | 1                 | 4.1      |
| 10          | 316L     | M64x4 H7 | Female | 1                 |          |
| 11          | 660      | M64x4 g6 | Male   | 1                 | 4.2      |
| 12          | 660      | M64x4 H7 | Female | 1                 |          |
| 13          | 316L     | M8 g6    | Male   | 1                 | 4.3      |
| 14          | 316L     | M8 H7    | Female | 1                 |          |

[R] The roughness, the flatness, and the coating thickness (when present) of the contact surfaces are important parameters and shall be measured and recorded.

[R] The Contractor shall:

1. Purchase all needed materials and equipment including the vacuum shamber.
2. Manufacture the test samples with the specified material including deposition of the EIC based on the specifications [AD2] on the samples to be coated.
3. Purchase the peelable shims and adopt them to the test setup if needed.
4. Provide a manufacturing report demonstrating that all manufacturing requirements are met.

### Deliverable #3:

- manufacturing report including:
  - material certificates
  - metrology report (with roughness and coating thickness measurements).

## 6.3 Scope of work #3: Experiments

### 6.3.1 Task 3.a: TCC measurement for flat contact

[R] The TCC shall be measured in accordance with developed and approved procedure for all test sets presented in the Table 5-1 and Table 5-2 in vacuum ( $10^2$  Pa) at RT (20C) under 6 different pressures (1, 5, 20, 50, 100 and 150 MPa)

[R] The TCC shall be measured in accordance with developed and approved procedure for all test sets presented in the Table 5-1 and Table 5-2 in vacuum ( $10^2$  Pa) at elevated temperature (250C) under minimum 3 different pressure (5, 20 and 50 MPa). Additional pressure points and pressure value could be specified based on the experimental results for RT.

[R] The TCC shall be measured when the heat transfer flow is stabilized.

[I] Heat transfer flow is characterized by a global heat balance and a conductive heat flow measurement in the samples.

[R] The Contractor shall assess how much heat is transferred by the interface, what is the input/output power (heater and cooler) and how much is lost by radiation.

[R] The results of measurements shall be presented in the form of tables and graphs.

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### 6.3.2 Task 3.b: *Effective TCC evaluation and assembly heat transfer characterization for threaded samples*

[R] The effective TCC shall be evaluated in accordance with developed and approved procedure for all test sets presented in the Table 5-3 in vacuum ( $10^2$  Pa) at RT (20C) and elevated temperature (250C) under 3 different tensile forces specified in the Table 5-3.

[R] The heat flow shall be measured when the heat transfer flow is stabilized through the assembly.

[R] The results of measurements shall be presented in the form of tables and graphs.

[R] A finite element simulation shall be performed to evaluate the effective TCC in threaded.

[I] Heat transfer flow is characterized by a global heat balance and a conductive heat flow measurement in the samples.

[R] The Contractor shall assess how much heat is transferred by the interface, what is the input/output power (heater and cooler) and how much is lost by radiation.

#### Deliverable 4a:

- The test report for the TCC measurements for the sets with flat contact:
  - The TCC variation with contact pressure and temperature with an error bar (Tables and Charts)
  - Heat transfer flow characterization: assessment of the input/output power and heat lost by radiation.

#### Deliverable 4b:

- The test report for the effective TCC evaluation for the sets with thread:
  - The effective TCC variation with tension forces and temperature with an error bar (Tables and Charts).
  - The results of FE analyses performed during evaluation of the effective TCC.
  - Heat transfer flow characterization: assessment of the input/output power and heat lost by radiation.

## 6.4 Service Duration for Full Scope of Work

[R] The Contractor will propose a detailed schedule of work, taking into account the scope and deliverables of work. If any mandatory information is required, the bidder, as an expert of the field, must identify and include this in the planning.

[R] The anticipated duration of this contract is 18 months from the formal kick-off meeting.

## 7 Location for Scope of Work Execution

[R] All activities shall be executed at the Contractor sites or/and at the sub-contractors sites (if applicable).

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## 8 IO Documents

[I] Under this scope of work, IO will deliver the following documents by the stated date:

| Ref | Title                                                                               | Doc ID      | Expected date    |
|-----|-------------------------------------------------------------------------------------|-------------|------------------|
| 1   | <a href="#">Insulating coatings for the blanket system components (D25QF6 v3.0)</a> | D25QF6 v3.0 | kick-off meeting |
| 2   | <a href="#">Procedure for the management of Deviation Request</a>                   | 2LZJHB v8.1 | kick-off meeting |
| 3   | <a href="#">Procedure for Management of Nonconformities</a>                         | 22F53X v9.1 | kick-off meeting |

## 9 List of deliverables and due dates

[R] The Contractor shall provide IO with the documents and data required in the application of this technical specification, the GM3S [AD1] and any other requirement derived from the application of the contract.

[I] A minimum, but not limited to, list of documents is available hereafter with associated due dates:

| Del | Technical Design Family (TDF)                | Generic Document Title (GTD) | Further Description                                                                      | Expected date (T0+x) * |
|-----|----------------------------------------------|------------------------------|------------------------------------------------------------------------------------------|------------------------|
| 1   | Contract Management                          | Quality Assurance Plan       | Contractor QP including sub-contractor QP plans                                          | 1                      |
| 2   | Operation Instruction or Procedure           | Operating Procedure          | Test protocol                                                                            | 4                      |
| 3   | Other Manufacturing Output                   | Manufacturing Dossier-MD     | Manufacturing report                                                                     | 12                     |
| 4a  | Review or Decision or Recommendations Report | Progress Report              | Preliminary report. Test report for the TCC measurements for the sets with flat contact. | 16                     |
| 4b  | Shipping or Logistics Record                 | Delivery Report              | Final Report. Test report for the effective TCC evaluation for the sets with thread      | 18                     |

(\*) T0 = Formal kick-off meeting; X in months.

[R] The Contractor is requested to prepare their document schedule based on the above and using the template available in the GM3S [AD1] appendix II ([click here to download](#)).

## 10 Quality Assurance requirements

[R] The organization conducting these activities shall have an ISO 9001 accredited quality system or equivalent accreditation.

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### Deliverable 1:

[R] Prior to commencement of the task, a Quality Plan must be submitted for IO approval prior to the start of any activities, giving evidence of the above and describing the organization 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. The quality plan shall in accordance with Requirements for Producing a Quality Plan (22MFMW) and be updated in the case of a change to the scope and will then be submitted to IO for approval prior to the start of the activities covered by the revised scope.

[R] Manufacturing and Inspection Plan (or Inspection Plan) shall be implemented to monitor quality control and acceptance test. The contractor are subject to Requirements for Producing an Inspection Plan (22MDZD)

[I] Deviations and Non-conformities will follow the procedures detailed in IO document.

[I] Requirements for Deviations (2LZJHB) and Nonconformities (22F53X). The documents will be provided to the Contractor at the start of the contract.

[R] 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.

## 11 Safety requirements

[I] No specific safety requirement related to PIC and/or PIA and/or PE/NPE components apply.

## 12 Specific General Management requirements

### 12.1 Work Monitoring

[R] The Contractor shall submit periodic reports to the IO and agree on periodic review meetings to monitor contract execution. The Contractor shall also ensure that its sub-contractors maintain data and documents. Such reports, data and documents shall be transmitted to the IO, if required, for the approval/acceptance of milestones by the IO

[R] The Contractor shall hold at the disposal of the IO and make available to it such information and documentation as the IO deems necessary to determine the progress, quality and status of the work.

[R] All documentation to be delivered to the IO must be in English. All documentation and correspondence shall be using Microsoft office software standards or Adobe PDF software.

[R] The Contractor shall ensure that all documents and records are uniquely identified and traceable.

[R] The Contractor will report as soon as possible to the IO of any occurrence that could delay or jeopardize the proper execution of activities related to this contract.

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[R] The following control points are proposed for the program: IO approval will be required before the follow-on task in the sequence can be initiated.

| List of Control Points |                      |               |
|------------------------|----------------------|---------------|
|                        | Description          | Control Point |
| 1                      | Kick off Meeting     |               |
| 2                      | Test protocol        | Hold point    |
| 3                      | Manufacturing report | Hold point    |
|                        | Final Report         |               |

Hold Point - A Hold Point (HP) is a milestone where the Contractor is required to notify the IO, that it has completed a specific task or a specific deliverable and must stop the associated processes until IO written approval is granted.

### 12.2 Meeting Schedule

[I] The following meetings can be anticipated.

| Meeting | Topic                   | Anticipated Date | Location              |
|---------|-------------------------|------------------|-----------------------|
| 1       | Kick-off meeting        | T0               | Contractor or IO / VC |
| 2       | Presentation of Task 2  | T0 + 4 Months    | Contractor or IO / VC |
| 3       | Presentation of Task 3a | T0 + 16 Months   | Contractor or IO / VC |
| 4       | Final presentation      | T0 + 18 Months   | Contractor or IO / VC |