

## Technical Requirements Specification

### Insulating coatings for the blanket system components

The Alumina coating is required on specific blanket components to prevent current flowing from the first wall modules to the vacuum vessel during operation. The consequences of failure of the coating will be an increase of the magnitude of the loads on the blanket and support system resulting in possible structural failure. This specification defines the requirements of the material and coating application to ensure a high level of confidence in the performance of the applied coating.

Approval Process			
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Change Log			
Insulating coatings for the blanket system components (D25QF6)			
Version	Latest Status	Issue Date	Description of Change
v0.0	In Work	15 Jan 2013	
v1.0	Signed	15 Jan 2013	First Issue
v1.1	Approved	07 Feb 2013	Revised to reflect the comments described by Philippe Chappuis  Functional requirements Applied Potential < 20 V Thermal cycles is 15 000 Chemical Composition TiO2 could be added in the Alumina up to 13% 6.1 Thickness the range should be 150 to 250 microns 6.3 Roughness RA better than 0.8 6.4 Electrical resistance Better than 1 k Ohm at 20 V and no current leakage when applying 500 A short circuit under 12 V DC current 6.5 Bond strength greater than 40 MPa 7.3 identical to 6.4 7.4 Bond strength minimum value should be higher than 40 MPa 7.5 impact testing refer to section 6.7 & not 6.6
v1.2	Approved	24 May 2013	Revised for Blanket PA
v1.3	Approved	14 Jun 2013	Revision following comments from RF DA as part of the Pa preparations.
v1.4	Approved	07 Nov 2013	Modification of bond strength value to 20MPa revision of a few typos
v2.0	Signed	19 Feb 2024	This BtP Specification has significantly revisited based on satisfactory qualification result of the EIC for BMC and created with help of DOORS. Validation tests have been clarified based on industrial standards. Mistake related to measurement of electrical resistance instead of resistivity has been fixed.
v2.1	In Work	13 Mar 2024	Reviewer's comments have been discussed and implemented.
v2.2	Revision Required	13 Mar 2024	Reviewer's comments have been discussed and implemented.
v3.0	Signed	13 May 2024	BtP requirements for different blanket components have been addressed. In particular, the specific requirements for the BMC and FW pad have been separated from the common requirements applicable to all blanket components.
v3.1	Approved	11 Jun 2024	1) Requirements for the Interlayer material for the BMC components and FW pad have been explicitly mentioned. 2) "Thickness verification measurement" used instead of "A check measurement" 3) Chapter "Cleanliness of Series Components" moved before the Chapter "STORAGE, PACKAGING AND DELIVERY OF COMPONENTS"

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## 1 LIST OF ABBREVIATIONS

BMC	Blanket Module Connection
DSG	Detonation Gun Spraying
FC	Flexible Cartridge
GAD	IO General Assembly Drawings
EIC	Electrical Insulating Coating
IO	the ITER International Fusion Energy Organization for the Joint Implementation of the ITER Project,
PA	Procurement Arrangement
VHB	IO Vacuum Handbook

## 2 SCOPE

**[I]** This document specifies the requirements for the supply of  $\text{Al}_2\text{O}_3$  coatings for Blanket applications. It is based on qualified program satisfying functional requirements for overall blanket system.

**[I]** The electrical insulating coating on the specific blanket components is intended to control current flowing from the first wall modules to the vacuum vessel during operation. The consequences of failure of the coating will be an increase of the magnitude of the loads on the blanket and support system resulting in possible structural failure. This specification defines the requirements of the material and coating application to ensure a high level of confidence in the performance of the applied coating.

**[I]** General Assembly Drawing (GAD) will be provided with this specification to define the coating location, thickness and required roughness.

**[I]** The supply covers the following items:

- a. Procurement of raw materials;
- b. Application of the coating using procedures approved by IO;
- c. Organisation of quality at works. Elaboration of all procedures required for the manufacture, inspection (including analyses), packaging, storage and delivery. Time schedules and documentation;
- d. Perform all the inspections and tests during and after manufacturing envisaged in this specification;
- e. Storage, packaging and delivery.

### 3 REFERENCED DOCUMENTS

[I] The following Codes and Standards shall be referred:

	Description	Reference	Version
AD1	ITER Vacuum Handbook	ITER D 2EZ9UM	V2.3
AD2	NONDESTRUCTIVE EXAMINATION - visual	ASME Section V, Article 9	2013
AD3	Determination of tensile adhesive strength	EN 582:1994	
AD4	Thermal Spraying, Determination of tensile adhesive strength	ISO 14916:1999	
AD5	Standard Test Method for Adhesion or Cohesion Strength of Thermal Spray Coatings	ASTM C633 - 01(2008)	

[I] Other equivalent national or international standards and codes may be acceptable with prior written ITER approval, provided all criteria are satisfied.

## 4 DEFINITIONS – BATCH/LOT

### 4.1 *Electrical Insulation Coating*

[I] Electrical Insulation Coating (EIC) could consist of two layers of different materials. An interlayer for better adhesion to the substrate and an insulating layer such as alumina ( $\text{Al}_2\text{O}_3$ ).

### 4.2 *Batch definition.*

[I] A batch shall be defined as:

- A quantity of powder purchased in a single transaction with one analysis certificate and purchase reference
- Additional batches may have the same analysis certificate but different purchase reference.
- Material purchased under a single purchase order reference but with different material analysis certification, is classed as multiple batches.

### 4.3 *Lot definition*

[I] A Lot shall be defined as:

- A lot shall comprise all coatings performed in a single production run using only one batch of raw material.

## 5 MANUFACTURING PROCESS

### 5.1 Common requirements

**[16-BtPEIC-139-R]** The supplier shall perform the EIC deposition according to the procedure approved by IO in compliance with requirements set in this document.

**[16-BtPEIC-141-R]** Upon receipt of components by the coating supplier, the condition of the packaging, desiccant (if present) and humidity indicator (if present) shall be recorded.

**[16-BtPEIC-142-R]** The packages shall be stored in a dry, secure area until the components are required for inspection.

**[16-BtPEIC-143-R]** The components to be coated shall be unpacked in a clean area.

**[I]** Recommended clean area class is ISO Class 9.

**[16-BtPEIC-144-R]** Lint-free and impermeable gloves must be always worn when handling components.

**[16-BtPEIC-146-R]** The components shall be visually inspected and their condition recorded. This initial incoming inspection shall look for signs of damage, corrosion or contamination.

**[16-BtPEIC-147-R]** All components shall be stored and transported being packaged in shock absorbing material (like air bubble role film) compliant with ITER VHB to prevent any surface damage during handling.

**[16-BtPEIC-148-R]** Coating material shall be complied with requirement of the ITER VHB [AD1].

**[16-BtPEIC-149-R]** Quality Certificate with chemical composition inspection results and particle size shall be provided for each batch of main raw material and raw material for interlayer if applicable. Alumina particle powder size shall be analysed by a suitably accredited laboratory.

**[I]** Final thickness of the EIC is defined on the drawings.

**[I]** Grinding may be used to achieve required roughness as per drawings.

### 5.2 Specific manufacturing requirements

#### 5.2.1 Surface preparation

**[16-BtPEIC-154-R]** Sandblasting of the surfaces to be coated shall be performed before the coating deposition process.

#### 5.2.2 Raw Material requirements

**[16-BtPEIC-31-R]** Raw powder material composition for Alumina shall be as in the table hereunder, it shall be demonstrated by corresponding material certificate of the raw powder for each batch of material or by chemical analysis of the coating after deposition using witness samples.

Material	Composition, wt.%	
	Al <sub>2</sub> O <sub>3</sub>	Other typical impurities
Al <sub>2</sub> O <sub>3</sub>	Min 99.00	May include: MgO, CaO, SiO <sub>2</sub> , Fe <sub>2</sub> O <sub>3</sub> , K <sub>2</sub> O, Na <sub>2</sub> O Each impurity oxide shall not be more than 0.9 wt. %.

Table 1: Material composition

#### 5.2.3 Interlayer deposition

**[16-BtPEIC-156-R]** An interlayer deposition shall be applied after sand blasting and before alumina coating.



#### 5.2.4 Alumina coating

**[16-BtPEIC-158-R]** Alumina shall be applied on top of the interlayer.

### 5.3 *Additional requirements for the BMC components and FW Pad*

#### 5.3.1 Surface preparation

**[16-BtPEIC-160-R]** Sandblasting of the surfaces to be coated shall be performed before interlayer deposition:

- Abrasive grain for sandblasting: electrocorundum grade 25A grain F46 or equivalent white fused alumina
- at a pressure of  $8 \div 10$  atm.
- at a distance of  $100 \div 300$  mm
- with an inclination of the treated surface from the normal not more than  $45^\circ$

**[16-BtPEIC-161-R]** Surfaces roughness after Sandblasting shall be in the range of Ra3.2–Ra7.

#### 5.3.2 Interlayer deposition

**[16-BtPEIC-163-R]** Interlayer powder shall be Nichrome, with composition at least 99.0 % of NiCr.

**[16-BtPEIC-124-R]** NiCr interlayer deposition shall be performed by detonation gun spraying (DGS) and according to the following main parameters:

- Distance from the item to the barrel cut: 150-250mm.
- Number of layers to be applied: 2
- Item temperature shall be monitored during the whole process using an infrared pyrometer and shall be in the range of 20-100C.

**[16-BtPEIC-125-R]** Final NiCr interlayer thickness shall be 0,05-0,07 mm.

**[I]** Thickness verification measurement of the NiCr interlayer on the item could be carried out using the gauge.

#### 5.3.3 Alumina Deposition

**[16-BtPEIC-164-R]** Alumina particle powder size shall be in the range between 5 and  $40\ \mu\text{m}$ .

**[16-BtPEIC-128-R]** Alumina EIC deposition shall be performed by detonation gun spraying and according to the following parameters:

- Distance from the item to the barrel cut: 150-250mm.
- the monolayer thickness shall be  $0,028\ \text{mm} \pm 10\%$ .
- Item temperature shall be monitored during the whole process using an infrared pyrometer and shall be in the range of 20-100C.

## 6 VALIDATION TESTING

### 6.1 *Visual Examination*

**[16-BtPEIC-67-R]** All external surfaces of coatings shall be examined by a visual examination in accordance with ASME Section V, Article 9. The surfaces shall be free of damage and inclusions (Cracks, pores, nicks, splits, layer separation, swelling, organic after coating are not accepted).

The supplier shall provide a test protocol and a test report for IO acceptance.

### 6.2 *Coating thickness measurement*

**[16-BtPEIC-46-R]** Coating thickness measurement procedure shall be proposed by supplier and approved by IO.

### 6.3 *Dimensional Examination*

**[16-BtPEIC-69-R]** Dimensional examination shall include checks for compliance of the component dimensions, coating thickness and surface roughness. The information shall be recorded and reported. The supplier shall provide a test protocol for IO acceptance.

### 6.4 *Electrical Resistivity of coating*

**[16-BtPEIC-132-R]** The electrical resistivity of the coating shall be measured in accordance with ASTM-D257. The supplier shall provide a test protocol for IO acceptance.

**[16-BtPEIC-55-R]** The electrical resistivity shall be  $\geq 10^5 \text{ Ohm.m}$  at RT.

The supplier shall provide a test report for IO acceptance.

### 6.5 *Adhesion strength*

**[16-BtPEIC-58-R]** Adhesion strength measurement shall be performed according to EN ISO 14916-2017. The supplier shall provide a measurement procedure for IO acceptance.

**[16-BtPEIC-60-R]** Adhesion strength shall be  $\geq 20 \text{ MPa}$ .

The supplier shall provide a test report recording adhesion strength for IO acceptance.

### 6.6 *Porosity*

**[16-BtPEIC-81-R]** Porosity measurement procedure shall be proposed by supplier in accordance with ISO/TR 26946:2011 and approved by IO.

**[16-BtPEIC-62-R]** The porosity of the final coating shall be  $\leq 5\%$ .

The supplier shall provide a porosity measurement report for IO acceptance.

## 7 RECAP OF NUMBER AND CONTENT OF TESTS / SAMPLING

### 7.1 *Non-destructive tests for qualification and series production components – frequency*

Test	Inspection
Visual Examination	100%
Coating thickness	100%

### 7.2 *Destructive tests on samples – frequency*

Test	Inspection
Electrical Resistivity -	Measured on test samples. Sample quantities and frequency to be proposed and by supplier and agreed with IO.
Adhesion strength -	Measured on test samples. Sample quantities and frequency to be proposed and by supplier and agreed with IO.
Porosity	Measured on test samples. Sample quantities and frequency to be proposed and by supplier and agreed with IO.

**[16-BtPEIC-90-R]** \* test samples shall be manufactured during the series manufacture and stored such that in the event of production issues some retrospective tests could be performed. The supplier shall propose for IO acceptance a sampling scheme to ensure adequate quality control and traceability.

## 8 QUALIFICATION OF COATING PROCESS

**[16-BtPEIC-42-R]** A validation of the coating process shall be undertaken to ensure high quality and repeatable results.

**[16-BtPEIC-43-R]** The qualification procedure for the coating process and facilities shall be proposed by the supplier for acceptance by the IO. This procedure shall include at least following inspection:

1. Visual Examination of the coating
2. Coating thickness measurement
3. Electrical Resistivity measurement
4. Adhesion strength measurement
5. Porosity measurements

**[16-BtPEIC-92-R]** Qualification of the processes shall be confirmed prior to the start of series production.

**[I]** Additional tests could be proposed depending on the component. For example, impact testing should be performed for pads, and cycling tests should be performed for FC assembly.

**[16-BtPEIC-93-R]** A qualification protocol shall be provided for IO acceptance.

**[16-BtPEIC-94-R]** A qualification report shall be provided for IO acceptance before start production coating on series components. (this is a HOLD POINT).

## 9 CLEANLINESS OF SERIES COMPONENTS

**[16-BtPEIC-96-R]** Following acceptance of all the test requirements the components shall be suitably cleaned in accordance with the requirements of the ITER vacuum handbook [AD1].

**[16-BtPEIC-131-R]** The components shall be packaged after baking in sealed bags with vacuum or nitrogen purged or a protective atmosphere with HR < 40%. Packaging of components shall be suitable for a minimum of 5 years on the shelf storage.

## 10 STORAGE, PACKAGING AND DELIVERY OF COMPONENTS

**[I]** This specification should be read in conjunction with higher level procurement documentation such as PA, contracts. Cleaning, packaging, storage, handling and traceability should be in accordance with applicable documentation.

## 11 DELIVERABLE DOCUMENTATION FOR SERIES PRODUCTION

**[16-BtPEIC-105-R]** Manufacturing report shall be provided prior to deliver the item coated with EIC. The report shall contain at least following deliverable documentation:

- Raw material certificates including the particle size.
- Coating deposition report including at least:
  - process detail and hardware,
  - main coating **deposition** parameters,
  - time and date,
  - roughness before and after interlayer deposition (if measurements will be performed)
- Inspection reports that are performed according to this specification as per 7.1 and 7.2.
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**[16-BtPEIC-106-R]** All documents shall be in the English language and all measures shall be given in the metric system SI.

**[16-BtPEIC-107-R]** Each document shall be provided as an electronic file in PDF format.

- End of the Document -