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Technical Requirements Specification

APPENDIX B1_09: Dimensional inspection activities for Ex-Vessel Components

This technical appendix details the dimensional control requirements for the Contract. It highlights requirements specific to the contract which are supplementary to the mandatory requirements detailed in the ITER Dimensional Metrology Handbook as defined by the allocated Alignment and Metrology (A&M) classification.

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Table of Contents

1 Purpose

This technical appendix details the dimensional control requirements for the contract. It highlights requirements specific to the contract which are supplementary to the mandatory requirements detailed in the ITER Dimensional Metrology Handbook as defined by the allocated Alignment and Metrology (A&M) classification.

2 Scope

The following technical appendix establishes the requirements to follow during the execution of dimensional controls on Interspace Support Structure components, sub-assembly parts or completed assembly parts. The scope of this technical appendix is to organize dimensional inspections activities considering the characteristics of the object to inspect, the time of inspection and the accuracy required.

General requirements applicable to dimensional inspection activities according to reference documents, Codes and Standards (section 4) are described in section 5.

During the different stages of the ISS manufacturing several methods of dimensional examination may be required. Such inspections could be carried out by traditional linear measuring systems (meter, calliper, micrometre, thickness gauge) or by 3D dimensional inspection equipment (CMM, laser tracker, laser scanner, photogrammetric).

Particular requirements applicable to specific measuring methods are also stated in section 6 of this Technical Specification.

Section 7 deals with requirements related to measurement equipment calibration and traceability assurance.

Finally additional requirements regarding qualification of dimensional inspection personnel as well as reporting are discussed in sections 8 and 9 respectively.

3 Definitions

The meanings of the main acronyms included in this report are:

- A&M: Alignment and Metrology
- C&S: Codes and Standards
- CAD: Computer Assisted Design
- CMM: Coordinate Measurement Machine
- ISS: Interspace Support Structure
- EAL: European cooperation for Accreditation of Laboratories
- GPS: Geometric Product Specification

4 Applicable documents and Standards (C&S)

[B1_09-RQ-001]

The applicable manufacturing Code RCC-MR 2007 shall be followed.

[B1_09-RQ-002]

Dimensional inspection and control activities shall also be consistent with the ITER Dimensional Metrology Handbook (46FN9B v2.1).

[B1_09-RQ-003]

Additionally, the following Standards as well as the others included in paragraphs of this Technical Specification shall also be applicable. In the event that codes conflict, the RCC-MR shall prevail.

- EN 286-1: ISO System of limits and fits. Part 1: Bases of tolerances, deviations and fits.
- EN 286-2: ISO System of limits and fits. Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts.
- EN ISO 965-1:2013 General purpose metric screw threads
- EN ISO 1502:1996 General-purpose metric screw threads Gauges and gauging
- EN 12085: Geometrical Product Specification (GPS). Surface texture: profile method. Motif parameters.
- EN ISO 14253-1: Geometrical Product Specifications (GPS). Inspection by measurement of work pieces and measuring equipment. Part 1: Decision rules for proving conformance or non-conformance with specifications.
- EN ISO 14253-2: Geometrical Product Specifications (GPS). Inspection by measurement of work pieces and measuring equipment. Part 2: Guide to the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification.
- EN ISO 14660-1: Geometrical Product Specifications (GPS) - Geometrical features- Part 1: General terms and definitions.
- EN ISO 3650:2000: Geometrical Product Specification (GPS). Length standards. Gauge Blocks.
- EN ISO 5458: Geometrical Product Specifications (GPS) - Geometrical Tolerancing - Positional tolerancing.
- ISO 17123. Field Procedure for determining accuracy of Surveying Instruments.
- EN ISO/IEC 17025: Conformity assessment. General requirements for the competence of testing and calibration laboratories.
- ASME B89.4.19 ASME B89.4.19 Performance Evaluation of Laser-Based Spherical Coordinate Measuring Systems.

The Supplier may also propose their own Standards and specifications providing they are consistent with or more stringent than those of EN, ISO, etc.

EN and ISO Standards referenced in this technical appendix shall be considered in their last revision at the time of the sign of the contract.

5 Inspection requirements

The engineering drawings and other documents of this Technical Specification (Appendix B1_08) define the fundamental design dimensions, tolerances and related requirements.

The following requirements shall apply to dimensional inspection activities during the manufacturing of ISS.

5.1 General requirements

[B1_09-RQ-004]

The Supplier shall produce an implementation plan for dimensional control activities that will justify how the manufacture is controlled from start to finish. Apart from the final factory acceptance dimensional control, control activities described shall also consider progressive dimensional inspections, measurement instruments calibration, control of distortions, records and reporting.

As a minimum the implementation plan shall include the following items:

- Reference Standards.

- Measurement, data acquisition, post processing and validation procedures.
- Frequency and stages of the dimensional control activity according to the requirements of this Technical Specification.
- Instrument calibrations (certificates issued by accredited laboratories) and test procedures.
- Dimensional inspection data management procedures.
- Reporting procedures.
- Control of non-conformities.
- Design change control procedures.
- Distortion prediction plan according to the manufacturing route, including all the fabrication steps.

[B1_09-RQ-005]

The Client shall review and approve the implementation plan and any documents referenced within it, prior to manufacturing commencement.

[B1_09-RQ-006]

General requirements stated in the ITER Dimensional Metrology Handbook (46FN9B v2.1) for A&M Class 1 activities shall be applied to all dimensional control activities within the scope of this Technical Specification.

[B1_09-RQ-007]

Dimensional control practices and processes control shall follow the requirements in the ITER Dimensional Metrology Handbook (46FN9B v2.1).

Those requirements shall be complemented with the following subsections.

5.2 Environmental conditions during dimensional control activities

The engineering drawings (Appendix B1_08) specify dimensions at the reference temperature of 20˚C. The environmental conditions for dimensional inspection activities will depend very much on the location in which the activity is to be carried out.

[B1_09-RQ-008]

The dimensional control procedure shall avoid any temperature and/or load induced displacements of reference points. Thus, the Supplier shall make an assessment of the impact of thermal expansion/contraction on the dimensional control and specify measures to be put in place as necessary to compensate.

[B1_09-RQ-009]

Consideration shall be given to the thermal inertia of the components being measured, where necessary allowing sufficient soak time in the measurement environment to ensure thermal stabilisation.

[B1_09-RQ-010]

For critical items temperature measurements (better than ± 1°C) shall be recorded throughout the measurement of both the component and the environment, logged against time and saved with the measurement file.

[B1_09-RQ-011]

For large components, multiple measurements shall be required to enable the detection of thermal gradients.

[B1_09-RQ-012]

The following conditions during dimensional inspection activities shall be avoided:

- Vibrations or unstable ground.
- Interruptions due to parallel activities.
- Noise and dust.

5.3 Frequency and stages of Dimensional Inspection

The dimensional inspection shall be carried out at all crucial stages of the manufacturing process to guarantee adherence to final tolerances and to set as early as possible corrective measures.

[B1_09-RQ-013]

The frequency and details of intermediate surveys shall be defined by the Supplier and accepted by the Client.

[B1_09-RQ-014]

The Client may witness the dimensional inspections after key steps in the manufacturing sequence.

5.4 Factory acceptance dimensional control requirements

[B1_09-RQ-015]

Factory acceptance dimensional inspection shall be carried out after completion of ISS.

Apart from previous requirements applicable to dimensional inspections during production, the following particular requirements shall also be applicable to the dimensional control for factory acceptance.

[B1_09-RQ-016]

This control shall be conducted in a controlled environment with a maximum temperature variation of ±2°C.

[B1_09-RQ-017]

Key dimensions shall be measured at the reference temperature of 20°C or corrected to this temperature; therefore temperature stability during the measurement process is critical.

Raw data measurements and corrected values shall be recorded and made available to the Client. This temperature stability requirement applies at least one day before the start of the dimensional control inspection to take into account thermal inertia.

[B1_09-RQ-018]

The temperature shall be checked by direct measurements on thickest parts of the ISS at different heights in the factory (at the minimum on the top, middle and bottom).

[B1_09-RQ-019]

The accuracy of the measurements shall be better than ±1°C. Temperature measurements shall be recorded throughout the measurement task, logged against time and saved with the measurement file.

[B1_09-RQ-020]

The conditions of support and restraint of the ISS for the acceptance tests shall be agreed between the Client and the Supplier.

[B1_09-RQ-021]

To avoid the contamination of surfaces, the operator/inspector shall wear protection gloves made from textile material, during the dimensional inspection after finish operations.

[B1_09-RQ-022]

The Supplier shall submit to the Client for approval the details of the supporting conditions and finite element calculations identifying the deformation of the ISS under self-weight (as defined in appendix B1_11 of this Technical Specification) during acceptance tests.

Tolerance requirements are given in Appendix B1_08 (CAD Models, engineering drawings and tolerance requirements). They refer to nominal geometry of the ISS at 20°C without taking into account mechanical deformation under self-weight.

[B1_09-RQ-023]

Measurements shall use coordinate systems as specified in the tolerance drawings and measuring points and associated fiducials shall be agreed with the Client.

[B1_09-RQ-024]

For measurement surveys utilising multiple instrument stations, bundle adjustment algorithms shall be utilised to ensure error propagation, via multiple best-fit alignments, does not occur.

5.5 Corrective Measures

[B1_09-RQ-025]

The use of corrective measures involving machining, welding or plastic deformation shall be submitted to the Client for approval and backed by documents justifying any measures used.

[B1_09-RQ-026]

Deviations from factory acceptance requirements shall be covered by non-conformance reports submitted to the Client for approval.

6 Dimensional control methods

ISS have huge rolled welded structures subjected to rather tight dimensional (tolerances) requirements. For this reason during the fabrication of ISS different methods of dimensional examination are required.

Dimensional inspections could be carried out by traditional linear measuring systems (meter, calibre, micrometre, thickness gauge) or by 3D dimensional inspection equipment (CMM, laser tracker, laser scanner, photogrammetric).

[B1_09-RQ-027]

The methods used to carry out dimensional control activities shall follow a procedure issued by the Supplier and subjected to the Client’s approval.

[B1_09-RQ-028]

The instrument or measurement method selected for final acceptance dimensional control shall fit for the purpose for which it is being used and shall be subjected to the Client’s approval.

6.1 Traditional linear measuring systems

The tools belonging to traditional linear equipment are meter, calliper, micrometre, thickness gauge, etc.

[B1_09-RQ-029]

They normally will not satisfy the requirements stated in section 7 of this technical Appendix and therefore their use shall be permitted only for low-criticality dimensional controls (production support only) unless it can be demonstrated that they are calibrated and their uncertainty for the measurement is acceptable.

6.2 Coordinate Measurement Machine (CMM)

[B1_09-RQ-030]

Measurement examinations with CMM system will be carried out in a room with controlled environment according to the requirements in section 5.3 of the Standard ISO/IEC 17025 Conformity assessment. General requirements for the competence of testing and calibration laboratories.

6.3 Laser Tracker

[B1_09-RQ-031]

Laser tracker measuring systems shall be calibrated as per equipment Supplier's recommendations.

[B1_09-RQ-032]

Regular field checks previously defined in de implementation plan shall be carried out and documented.

6.4 Photogrammetric

For medium size and complex mechanical parts the photogrammetric can be used in order to perform faster dimensional control than the same control performed by point-by-point technique of laser tracker.

[B1_09-RQ-033]

Photogrammetric will be accepted provided that the measure accuracy and uncertainty is previously determined and that it is demonstrated the achieved values are acceptable for the dimensional control being performed.

6.5 Laser Scanner

For very large size and complex mechanical parts the laser scanner can be used in order to perform faster dimensional control than the same control performed by point-by-point technique of laser tracker.

[B1_09-RQ-034]

Laser scanner will be accepted provided that the measure accuracy and uncertainty is previously determined and that it is demonstrated the achieved values are acceptable for the dimensional control being performed.

7 Instruments calibration

[B1_09-RQ-035]

All equipment used for dimensional control shall be qualified in accordance with EN rules and shall hold calibration certificates (released by an accredited laboratory or traceable to) at the time of use.

[B1_09-RQ-036]

Instruments measurement uncertainties shall be calculated for all reported measurements at a confidential level of 2σ. As a general rule, the uncertainty values must not exceed 20% of the tolerances applicable to the feature being measured, or ± 0.5 mm which is lower.

[B1_09-RQ-037]

The equipment Supplier shall furnish user's manuals for each equipment and tool object; the minimum requirements for the different possible inspection equipment are defined here below.

[B1_09-RQ-038]

The Supplier shall have available on site, well in advance, all the equipment and tools required for executing inspections. Only high quality tools suitable for the assembly of the different components comprised in the contract scope shall be used.

[B1_09-RQ-039]

The Supplier shall incorporate as many tools as necessary during the execution of the works, and consider the provision and maintenance of as many tools and means as required in order to carry out the work in a timescale compatible with the execution of the work.

[B1_09-RQ-040]

The Supplier shall provide all necessary equipment to carry out the inspection tasks meeting all applicable safety requirements.

[B1_09-RQ-041]

The Client reserves the right to inspect these components and check the fulfilment of the stipulations in order to accept or reject them.

[B1_09-RQ-042]

The Supplier shall abstain from using components rejected by the Client immediately and replace them with new ones.

7.1 Validation and certification of the measurement system on site

[B1_09-RQ-043]

The three dimensional measuring equipment shall be calibrated in accordance with one of these Standards:

- ISO/TS 14253-2 Geometrical product specifications (GPS) - Inspection by measurement of work pieces and measuring equipment - Part 2: Guide to the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification.
- ASME B89.4.19 ASME B89.4.19 Performance Evaluation of Laser-Based Spherical Coordinate Measuring Systems.

An in-house calibration system shall ensure that all measuring and test equipment used in a company is calibrated regularly against its own reference Standards.

[B1_09-RQ-044]

The company reference Standards shall have traceability of measurement by being calibrated at a national accredited laboratory (similar to EAL (European cooperation for Accreditation of Laboratories) or any recognised National Metrology Institute applicable in the country of manufacture.

[B1_09-RQ-045]

The in-house calibration shall be evidenced by a factory calibration certificate, a calibration label, or some other suitable method. The calibration data must be retained for a prescribed period of time.

[B1_09-RQ-046]

The validation of the measurement system for hardware/optical tools shall be made by the Manufacturer and shall be traceable by any EAL accredited laboratory or a recognised National Metrology Institute.

[B1_09-RQ-047]

The certification of the measuring system shall be performed by physical test of different "measure notes", reproducing the typicality of the item to be measured. All targeting mounts or tooling, that contributes to the measurements process shall be controlled within the Supplier's calibration system and shall be uniquely identified.

7.2 Certification of the measurement system on an accredited laboratory

Accredited laboratories are often at the top of a firm's internal calibration hierarchy. Their task is then to compare, at appropriate intervals, the firm's own working Standards (factory standards) with reference Standards which are calibrated by an AEL National Metrology Institute or an accredited laboratory with a suitable best measurement capability.

[B1_09-RQ-048]

If an accredited laboratory is to be engaged to carry out a particular calibration by the Supplier, the Supplier shall ensure that the measurement uncertainty achieved is appropriate for the intended use of the calibrated instrument.

[B1_09-RQ-049]

The laboratory shall use methods and procedures for the calibration of measuring equipment, reference measurement Standards (including reference materials) and test equipment used in calibration and testing laboratories that comply with the requirements of ISO/IEC 17025.

[B1_09-RQ-050]

In its procedures for estimating the uncertainty of the calibration process, the laboratory shall take into account the cumulative effect of the uncertainties of measurement of each successive stage in the chain of calibrations for each measurement Standard and item of equipment calibrated.

[B1_09-RQ-051]

The calibration results shall be documented in a calibration certificate.

7.3 The Calibration certificate

[B1_09-RQ-052]

The Calibration certificate shall include at least the following information:

- The title "Certificate of Calibration".
- The name and the address of the laboratory and the place where the measurements were took place, if it is different than that of the laboratory premises.
- An unique identification of the calibration certificate (e.g. the issue number) and into each page an identification element, in order to ensure that the page is recognized as part of the calibration certificate, and also a clear identification of the end of the certificate.
- The name and the address of the Client.
- The identification of the method and the instrumentation used (type of instrument and serial number).
- The description, the status and the identity of the calibrated item.
- The receipt date of the item when it is critical for the validity and the application of the results and the date of calibration.
- Information about the plan and sampling procedures used by the laboratory or other organizations.

- The calibration results and where are necessary the units.
- The name, the position and the signature of the person(s) who are in charge to grant the calibration certificate.
- Where it is relevant, a statement that the results are related only with the calibrated items.
- The conditions (eg. environmental) under which the calibration was carried out.
- The uncertainty of measurement or/and a statement of compliance with any relevant metrological specification (the confidence levels should accompany the uncertainty of the measurement).
- A statement indicating how traceability to national Standards has been achieved.
- For calibration certificates which are within the Scope of Accreditation of the laboratory, the accreditation certificate issue number and the logo of the Accreditation Body.
- A statement that the certificate shall not be reproduced other than in full and the written approval of the Lab.
- The seal of the Lab.

8 Personnel qualification

[B1_09-RQ-053]

The equipment Supplier shall adequately train personnel, which will perform dimensional control by CMM, photogrammetric or laser tracker/scanner, covering as a minimum the following aspects:

- The use of equipment.
- Software management.
- Report issuing
- Safety.

[B1_09-RQ-054]

Concerning this, the Supplier shall provide certificates of training to each operator involved in dimensional inspections activities using aforementioned equipment.

9 Dimensional control reports and documentation to be prepared by the Supplier

[B1_09-RQ-055]

"As-built" drawings/3D models/electronic data shall be supplied in a format according to requirements in appendix B1_02 of this Technical Specification or in other format previously agreed with the Client to demonstrate compliance with the design.

[B1_09-RQ-056]

All inspection/dimensional control and alignment activities shall be reported in accordance to the ITER Dimensional Metrology Handbook (46FN9B v2.1).