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Technical Specifications (In-Cash Procurement)

Technical specifications for the procurement of the IVC Flowmeters

This document serves for the supply of the ITER In-Vessel Coils Flowmeters.
The IVC Flowmeters are used to monitor the water cooling mass flow within the IVC cooling loops and constitute the investment protection system for the coils.

Technical Specification

Supply of the IVC Flowmeters

Abstract:

This document defines the technical requirements for the supply of the IVC Flowmeters and forms an integral part of the Contract.

Table of Contents

1 Subject

This technical specifications document is an integral part of the supply contract for the IVC Flowmeters system.

1.1 Responsibilities

The responsibilities between the parties are summarised in Table 1 (below) and is further detailed in the following sections.

Table 1. Summary of the Responsibilities between the IO and the Supplier.

Activity	IO	Supplier
Phase 1 Pre-Production		
- IVC Flowmeter final detailed design proposal	A	R
- Pre-Production Tests	A	R
- Delivery of qualified prototype(s)	A	R
- Manufacturing Readiness Review (MRR)	A	R
Phase 2 Production and Delivery		
- IVC Flowmeters manufacturing (final products)	A	R
- Factory Acceptance Test	A	R
- Packing and Delivery to the ITER Site (DRR)	A	R
- Final acceptance at ITER Site (SAT)	R	A

R = Responsible for organizing, performing and for the content
A = Review/Comment/Accept/Approve

1.2 Contract Execution

1.2.1 Outline of Contract Implementation

The supply contract is split into two phases:

- **Phase I** is dedicated to the pre-production activities aimed at verifying the qualification of the proposed IVC Flowmeter design, assembly and installation sequence for the intended use;
- **Phase II** is dedicated to the final production and delivery of all products.

Important:

If the Supplier is not able to propose a product already qualified for similar, if not identical, use (i.e. not completely fitting the technical requirements and the field of application), the Pre-Production Phase shall include a full qualification test campaign of the prototype(s). The qualification campaign shall mandatorily comprise detailed functional and technological tests that shall be defined by the Supplier and proposed to the IO for approval at the moment of the Kick-Off Meeting (KOM). The scope of the tests is to demonstrate that the proposed product is fully qualified for the intended use as described in this document.

1.2.1.1 Phase I Pre-Production

During this phase, the Supplier is required to demonstrate that the prototype of IVC Flowmeter is fully qualified for the intended use and complies with all the technical requirements listed in this document.

The completion of this phase is achieved with a Manufacturing Readiness Review (MRR).

Activities for Phase I can be summarized as follows:

a) Production of detailed manufacturing drawings;
b) Development of assembly and installation procedures (including maintenance for replacement of single parts);
c) Manufacturing of IVC Flowmeter prototype(s);
d) Pre-Production Tests (prototypes(s) and equipment);
e) Manufacturing Readiness Review (MRR).

It is up to the Supplier to identify the amount of prototypes required to successfully qualify the components and processes.

All prototypes shall be delivered to IO at the end of Phase I.

At the end of Phase I, the Supplier must prepare all the documentation needed for the Manufacturing Readiness Review (MRR).

1.2.1.2 Phase II Production and Delivery

Phase II of the contract is dedicated to the final manufacturing and delivery of all IVC Flowmeters, including necessary extension cables, connectors and electronic units. All manufactured components shall be tested at the Supplier's factory (FAT) and shipped to the IO for acceptance tests (SAT) and storage before installation.

During Phase II, the Supplier is required to produce, test and deliver 24 IVC Flowmeters with the necessary cables, connectors and electronic units.

The final products shall be delivered to the IO in full. The delivery shall be preceded by a Delivery Readiness Review (DRR).

Before the DRR, the IO may request to delay the shipment of the final products up to 6 months.

1.2.2 <u>Time Schedule</u>

Events	**Due dates**
Contract signature	Ts
Kick-Off Meeting	Ts+1 month = T0
MRR (closure of Phase I)	T0+6 months
Final Delivery of products to the IO (closure of Phase II)	T0+18 months

The Supplier shall produce a detailed Schedule showing all phases of the Contract. This detailed Schedule shall be submitted to the IO for approval/acceptance, before starting any work in relation to the Contract.

The Supplier shall issue in the IDM an update of the detailed Schedule every first day of each month starting at T0+1 month and until the last month of contract, before the final delivery of all products.

2 Scope of the supply

2.1 General

The present supply is dedicated to the delivery of final products compliant with the technical specifications of the IVC Flowmeters.
The Supplier shall deliver to IO the Equipment described in this document.

As indicated in the Outline of Contract Implementation, the following components and quantity shall be delivered to the IO by the Supplier depending on the ongoing phase of the contract:

- Phase I

Equipment	Quantity
IVC Flowmeter prototype (i.e. set of sensors, stainless steel enclosure, pigtails and junction box)	1

- Phase II

Equipment		Quantity
IVC Flowmeter (i.e. set of sensors, stainless steel enclosure, pigtails and junction box)		24
Electronic unit (transmitter)		11[1]
Extension cables		(spools)
	L1 = 100 m	4
	L2 = 150 m	8
	L3 = 175 m	4
	L4 = 200 m	6
	L5 = 225 m	2
	L6 = 250 m	6
	L7 = 275 m	4
	L8 = 325 m	2
	L9 = 350 m	2
	L10 = 375 m	2

[1] This number considers the minimal architecture configuration as required in Section 4.4.5 but it may be subject to modifications according to the Supplier's proposal and IO approval.

2.2 Components' description

ITER is a joint international research and development project aiming to demonstrate the scientific and technological feasibility of fusion power for peaceful purposes. The seven members of the ITER Organization (IO) are: The European Union (represented by EURATOM), Japan, People's Republic of China, India, the Republic of Korea, the Russian Federation and the USA. The ITER Organization is located in Saint Paul lez Durance – France. Further information is available on the ITER website: http://www.iter.org.

In-Vessel Coils (IVC) are normal-conducting coils located behind the Blanket Shield Modules inside the Vacuum Vessel. The system is composed by two set of coils, VS and ELM.

27 Edge Localized Modes (ELM) coils are equally distributed along the vessel walls, with three coils per sector, namely Upper, Equatorial and Lower ELM. Each coil comprises 6 turns and is used to reduce the impulsive heat loads on the plasma facing components due to Edge Localized Modes. 2 Vertical Stabilization (VS) coils are located at the top and bottom location of the vessel and provide fast vertical stabilization of the plasma. Each VS coil comprises 4 individual turns, with independent feeders and cooling water path.

Being water-cooled, the IVC needs to have online monitoring capacity of the cooling water flow and for that reason mass flow sensors (IVC Flowmeters) shall be installed.

Each Flowmeter is installed in the ITER Tokamak building (Bldg 11), in areas where ionizing radiation is present from the ITER D-T plasma and also from tritiated water flowing in the pipes (N^{16} and N^{17} isotopes). The cumulated dose expected at the end of ITER lifetime is in the order of magnitude of 10 MGy and above.

The IVC Flowmeters are ultrasonic mass flow sensors, directly fastened onto the cooling water pipes that serve the IVC system (DN40 Sch.10S). Each IVC Flowmeter comprises the sensors (in reflection arrangement), a stainless steel enclosure (or cap) used for protection and installation and a junction box to allow easier maintenance in case of replacement. The ultrasonic transducers are cabled to the junction box. Each sensor is provided with an embedded cable (e.g. pig tails). An extension cable then connects the junction box with the electronic unit.

An overview of the IVC Flowmeters is given in Fig. 1 and Fig. 2.

All IVC Flowmeters are connected to electronic units (transmitters) used for signal conditioning and measurement delivery. The electronic unit is typically place hundreds of meters away from the sensors (in Bldg B74-diagnostic building) inside cubicles dedicated to signal conditioning and control – see Figure 3.

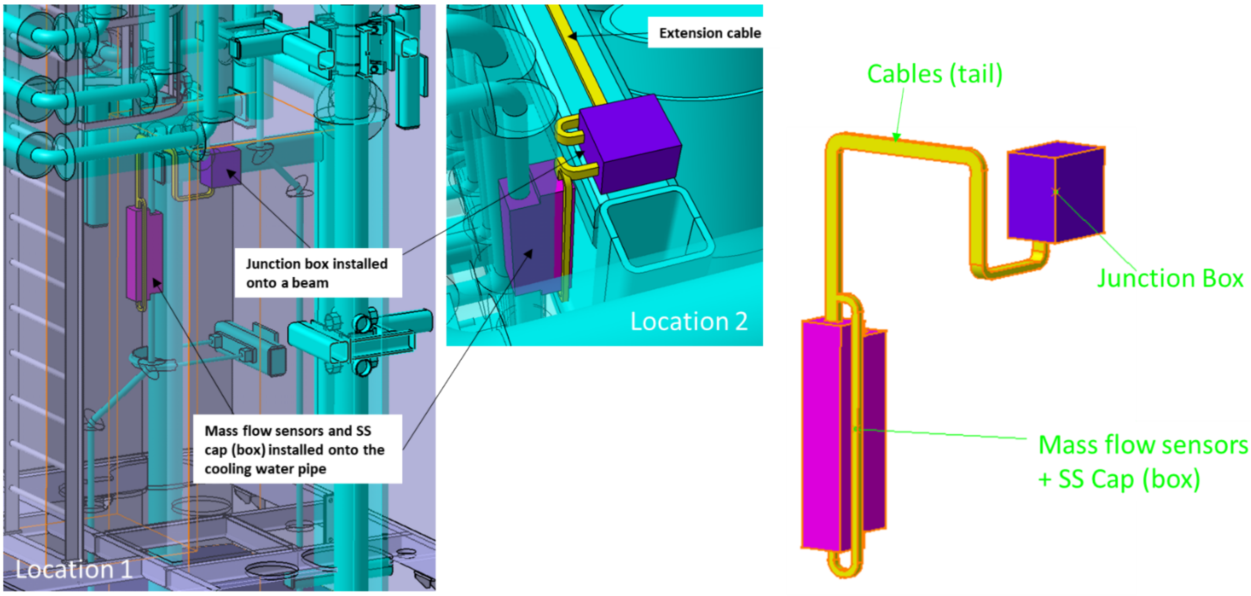

Figure 1. Overview of IVC Flowmeter: conceptual 3D model.

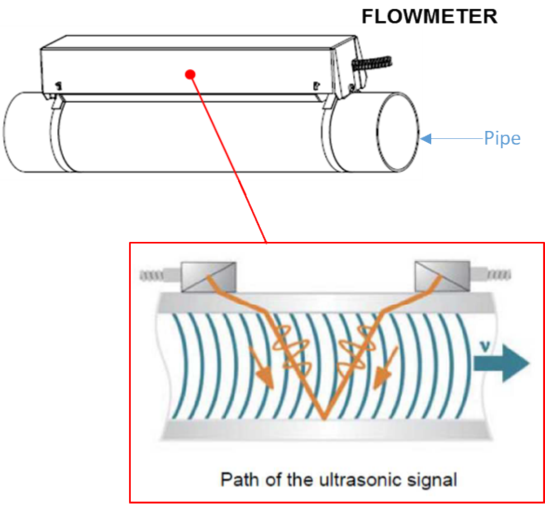

Figure 2. Overview of IVC Flowmeter: example of pipe "clamp-on" configuration (top) and sensors "reflection arrangement" (bottom).

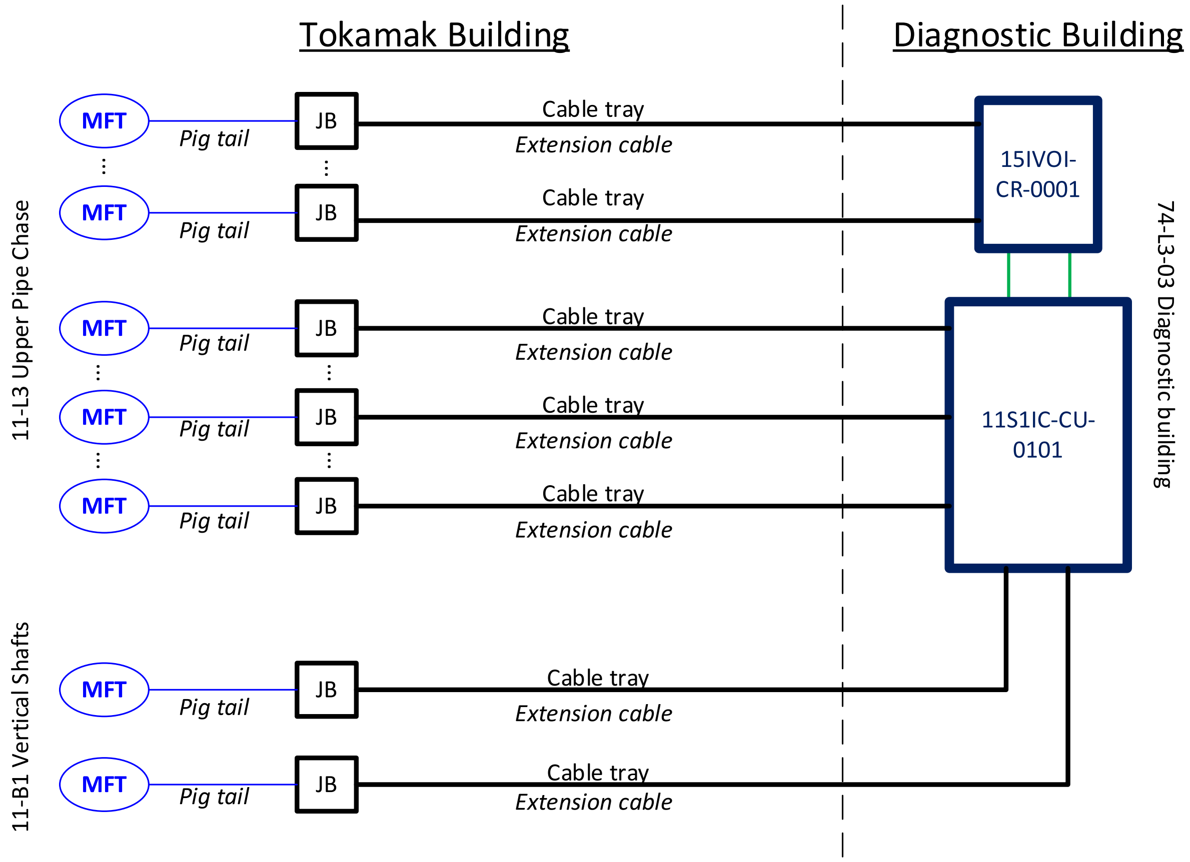

Figure 3. Overview of IVC Flowmeters (MFT) connection to Cubicles placed in Diagnostic Building B74. This schematic is provided as a visual example and shall not be considered as exhaustive.

2.3 Components not included in the Contract

Instrumentation cubicles, cable trays and corresponding power supplies are not included in the scope of this Contract.

2.4 Design and Related Activities

The Supplier shall provide a proposal of IVC Flowmeter. The choice of the design shall be justified during the MRR with appropriate technical documentation and/or presentations.

2.5 Manufacturing of the Equipment

2.5.1 Phase I

#	Main Activity	Sub Activities
1	Manufacturing of IVC Flowmeter system prototype(s)	a. Delivery and review of Manufacturing Drawings b. Delivery and review of Material Certificates c. Delivery and review of assembly and installation procedures d. Delivery and review of Pre-Production Test procedures

		e. Visual check of prototype (s) f. Pre-Production Tests execution g. Delivery of prototype(s) h. MRR

2.5.2 Phase II

#		Main Activity	Sub Activities
1		Manufacturing of final products	
	1.1	Manufacturing of IVC Flowmeters	a. Finalization of Manufacturing Drawings b. Manufacturing of parts c. Visual inspection
	1.2	Manufacturing of auxiliary parts and components (extension cables, electronic units etc…)	a. Finalization of Manufacturing Drawings b. Manufacturing of parts c. Visual inspection
	1.3	Factory Acceptance Tests	a. FAT(s) execution b. FAT Report c. Packing of final products
2		Delivery of Final Products	d. DRR e. Delivery of final products

2.6 Supply of Documentation

The Supplier shall provide IO with the documents and data defined in Chapter 8 of this Technical Specification (List of Deliverables and due dates).
The specific documents and data to be provided to the IO are defined in the following sub-section.

2.6.1 Documentation to be provided during the execution of the Contract

During all contract phases, the Supplier shall provide to the IO certain documents as a proof and record of the work done. The list of these documents is presented in Table 2 below.

Document description	**Phase I**	**Phase II**
Quality Plan	X	
Risk and Opportunity schedule	X	
Detailed Contract Schedule	X	X
Manufacturing Inspection Plan (MIP)	X	X
Pre-Production Plan	X	
Manufacturing drawings	X	X
Materials certificates	X	X
Pre-Production tests procedure(s)	X	

Pre-Production tests report(s)	X	
Assembly and Installation procedure(s)/diagram(s)	X	
User manual (including calibration and maintenance guidelines)	X	
Factory Acceptance Test Procedures		X
Factory Acceptance Test reports		X
Wiring diagrams		X
Bill of Materials (BoM)	X	X
SIL-2 Certification	X	X
Compliance Matrix	X	X
Packing and Shipping procedure	X	
Storage and Preservation procedure	X	
Maintenance and Calibration requirements		X
Components labelling document		X
Delivery Report	X	X
Manufacturing Dossier		X
Supplier Release Notes	X	X

Table 2: Documents list to be provided by the Supplier.

3 Technical Interfaces

Interface document	***IDM reference***	***Requirement***
IS-15.IV-26-001 Interface Sheet between Primary Heat Transfer PBS 26.PH/CV/DR/DY and In-Vessel Coils PBS 15.IV	*ITER_D_3YGF2G*	*1. The Junction Boxes as well as the Flowmeters installed on the pipes do not provide any load to PBS-26 equipment, apart from the deadweight.* *2. Each Flowmeter is provided with a Junction Box (for maintenance reasons). Junction Boxes are made of stainless steel parts only and cables are inserted in metallic conduits thus not providing any fire load or fire propagation mean.* *3. Each Junction Box is fastened to the PBS-26 support beams by means of a steel tie. The beams from PBS-26 shall be used also as shared support to allow the routing of the cable trays that reach the PBS-15.IV Junction Boxes.*

IS-11-44-002 Interface between Cable Tray System (PBS 44) and Magnets System (PBS 11) for IVC cables	*ITER_D_QVCQHC*	*The cumulated weight of the cables routed in cable trays shall not exceed the weights specified in the IO Cables Catalogue.* *→for IVC cables is 170 kg/km.*

4 Technical Requirements

In addition to the requirements specified in this Technical Specification, the requirements stated in the SRD and listed below apply:

SRD Section	Requirements applicable to the supply
[15Ivs144-R]	A QA program, including an implementation plan and adequate quality control and acceptance procedures, shall be established in accordance with the ITER Quality Assurance Program (QAP)
[15IVs217]	Materials which are subject to neutron irradiation shall be selected taking into account their possible activation during ITER operation. The requirements on the chemical composition of the materials, as specified in the ITER Material Properties Handbook shall be applicable.
[15IVs98]	Instrumentation cables shall meet the fire resistance requirements as specified in the ITER Cable Catalogue. Electric cables and other materials that run through a fire sector shall not contribute to the spread of fire (C1 cables, or cables that are protected by a flame-retardant material for a radiologically-controlled building).
[15IVs283]	Spares shall be procured for all IVC components.
[15IVs251-R;Defined Requirement]	Halogenated materials (such as insulating materials) shall be forbidden in areas that are served by the de-tritiation systems. Exceptions must be approved by the tritium systems and safety section responsible officers. The only material component affected is the insulation inside the Feedthroughs and Insulating breaks where Torlon is selected. According to the Toxic Gas Emission test the release of Hydrochloric or Hydrofluoric acid is in the ppm range during smoldering and flaming.
[15IVs907-R;Defined Requirement]	The concentration of Co in structural steels shall not exceed 0.05 %weight.
[15IVs884]	The IVCS shall be baked with circulating hot water at 240°C (-5°C/+0°C) through the IBED-PHTS.
[15IVs871]	Given the location of the IVC components without having the possibility of RH, all IVCs and feeders shall be designed “for life” without requiring scheduled maintenance. The instrumentation (thermocouples and mass flow sensors) as well as the IBs are designed allowing inspections and replacements (see Section 4.2 for details).

[15IVs932-R;Defined Requirement]	The concentration of Nb in structural steels shall not exceed 0.01 %weight.
[15IVs933-R]	Magnetic materials with a relative permeability that is greater than 1.03 shall not be used within the cryostat boundary without formal project approval.

4.1 Material Requirements

All materials shall comply with the specifications listed in this document. Equivalent materials may be proposed, but must be approved by the IO in writing before use.

All materials shall be accompanied by relevant technical certificate to prove compliancy with the requirements listed in this document. The Supplier shall certify each material in accordance with EN 10204 – type 2.1.

All materials shall be halogen-free and be supported by material certificates and certificates of conformity, where appropriate, to be provided to the IO before commencing any manufacturing process. Moreover, base materials specification shall be provided by the Supplier and approved by the IO. Full traceability of the materials is requested.

4.1.1 Radiation hardness

All equipment installed in the Tokamak Building (B11) shall be qualified for nuclear application. The expected cumulated dose at the end of ITER lifetime is ~10 MGy.

The Supplier shall provide adequate technical documentation to prove the required qualification.

4.1.2 Fire protection

All equipment casing (e.g. junction box, sensors enclosure etc…) shall be made of austenitic stainless steel (corrosion resistant) for fire protection reasons.

No cable shall propagate fire through the cable trays.

4.1.3 Coupling layer

The mass flow sensors, being ultrasonic, shall be provided with a coupling layer (or matching layer) to be placed at the contact surface with the stainless steel pipes where the IVC Flowmeters are mounted on.

The proposed coupling layer shall be qualified for continuous operations at 240°C and for nuclear applications (radiation environment). Radiation hardness requirements as indicated in Section 4.1.1 apply to the coupling layer as well.

The Supplier shall provide adequate technical documentation to prove the required qualification.

4.2 Applicable Codes and Standards

Materials		*Applicable Codes or Standards*
	Material Conformity	EN 10204 (type 2.1)

	Cables	NFC 32070 C1 or IEC 60332-1 and IEC 60332-3 (Fire retardancy), IEC 61034 (Low smoke), IEC 60754-1 (Zero halogen), IEC 60754-2 (Non toxicity) Or, as alternative, Construction Product Regulation (CPR): Euroclass Cca-s1b-d1-a1 and IEC 60754-1

Functional integrity		***Applicable Standards***
	Safety Integrity Level	IEC 61508 for SIL-2
	EMC	ITER Electrical Design Handbook Electromagnetic Compatibility (EMC) [2]

4.3 System Classification

The main ITER classifications for the IVC Flowmeters are listed in the following Table 3.

Component	PIC/Safety Class	Quality Class	ESPN Class	Seismic Class	Vacuum Class	Tritium Class	RH Class
IVC Flowmeters	Non PIC	QC-1	n/a	SC-2	n/a	n/a	Non RH

Table 3 – System classification.

4.4 Manufacturing Requirements

All operations to be carried out by the Supplier shall be listed in the MIPs which shall be submitted to the IO for approval.

At the end of Pre-Production phase (Phase I), all results shall be summarized in the Pre-Production Test Report.

All delivered goods shall be CE marked.

4.4.1 Equipment dimensions and integration

IVC Flowmeters

The equipment to be manufactured for the IVC Flowmeters shall fit within the (maximum) overall dimensions provided below in Figure 4. Variations to the overall dimensions can be proposed by the Supplier but must be subject to the IO approval before any implementation.

On top of the dimensions, a maximum weight shall be considered as well by the Supplier:

- Mass flow sensors assembly (Flowmeter) shall weight no more than 10 kg;
- Junction box shall weight no more than 1.5 kg.

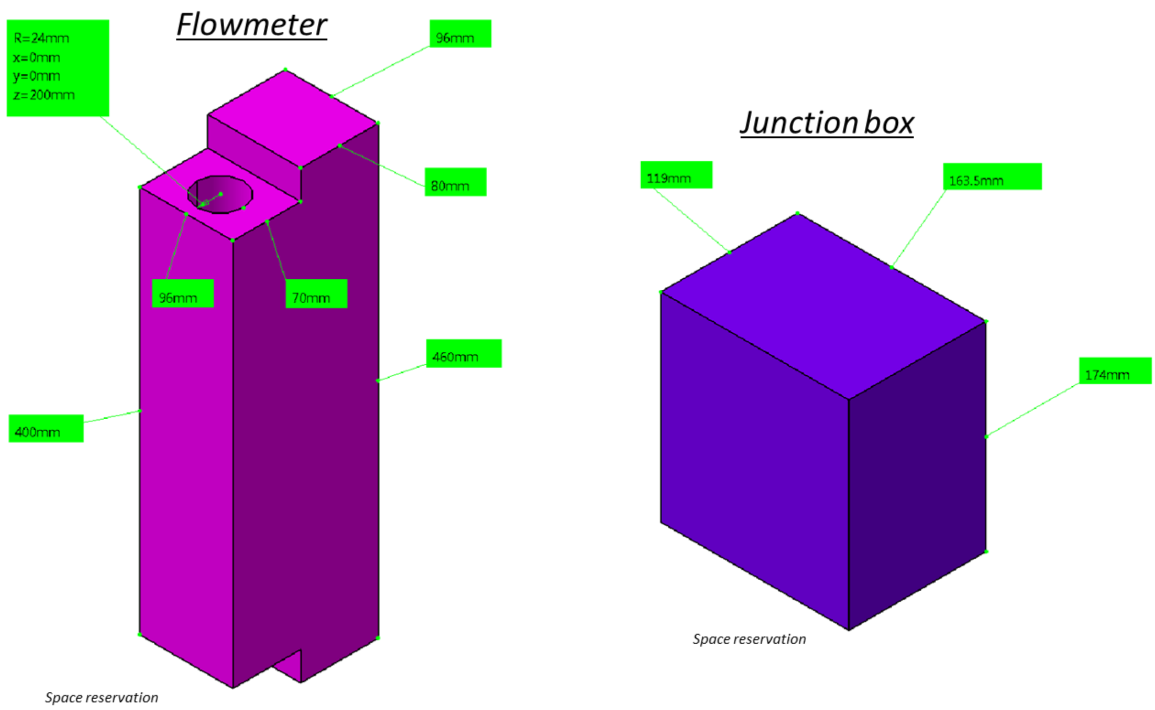

Figure 4. Overall dimensions of the mass flow sensor assembly (Flowmeter) and the Junction box.

The mass flow sensors (with their casing) are to be installed around DN40 stainless steel pipes – see Section 2.2 – without using welding, brazing or gluing processes. The attachment between flowmeters and pipes shall use fastening systems (e.g. steel ties, bolted clamps etc…).

The junction box is installed on metallic beams, placed in the right vicinity of the mass flow sensors (1 meter range). The junction box attachment shall use no welding, brazing or gluing processes but a fastening system instead (e.g. steel ties, bolted clamps etc…).

Mass flow sensors (with their casing) are to be installed in vertical position, along the cooling water pipe where they are fastened. Junction boxes are to be installed both in horizontal and vertical position, depending on the location in the Tokamak Building and the beam orientation. Figures below show some visual examples.

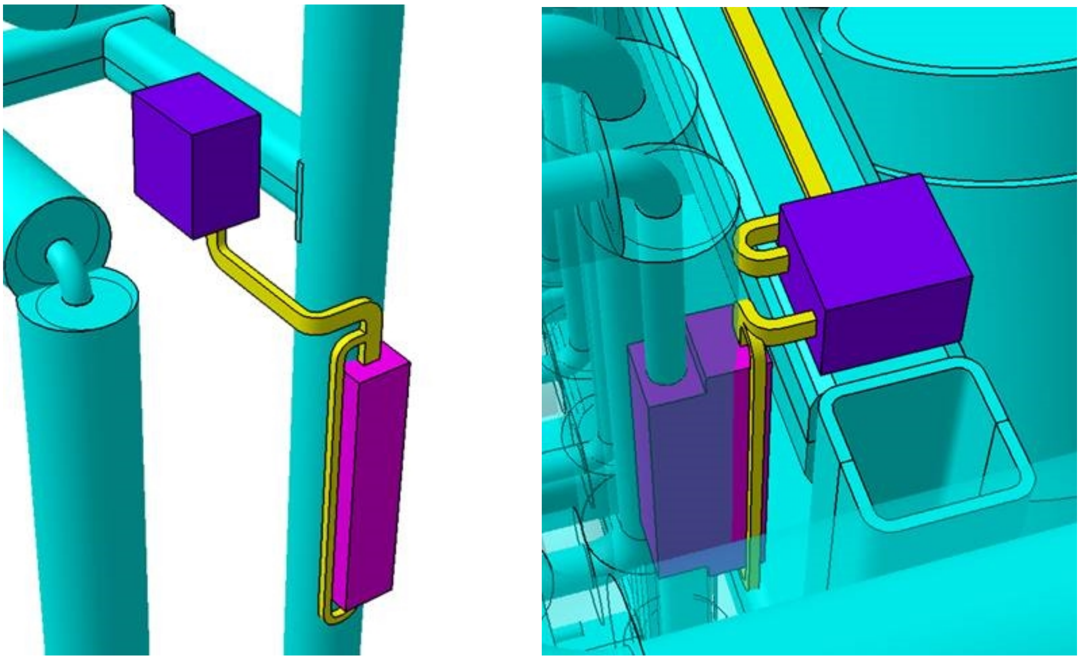

Figure 5. Visual example of Flowmeters installation: junction box may be installed in both vertical and horizontal position (orientation).

<u>Electronic units (transmitters)</u>

The electronic units, for each flowmeter, are to be installed in cabinets (cubicles) which have been already defined by the IO. Each electronic unit must fit into the assigned cabinet (cubicle) and be provided with the necessary features for integration and installation. The electronic units will be distributed into two separate cubicles, for space allocation reasons:

One (1) Wall Mounted Cubicle hosts the electronic unit(s) for 14 flowmeters (i.e. 14 independent mass flow measurement) and one (1) Floor Standing Cubicle hosts the electronic unit(s) for 6 flowmeters (i.e. 6 independent mass flow measurements).

The degree of protection is IP55 (according to IEC 60529).

Cabling interface and mounting fixtures shall be compliant with the requirements of [3].

Figure 6. Internal layout of wall mounted cubicle (SCC) and floor standing cubicle. Physical dimensions of the first are 1000 mm (H) x 800 mm (W) x 300 mm (D) – 19" chassis 21U – and of the latter are 2200 mm (H) x 800 mm (W) x 800 mm (D) – 19" chassis 47U.

The minimum required architectural configuration for each electronic unit (or transmitter) is to host and be able to manage independently at least 2 flowmeters (i.e. 2 mass flow measurements) for space optimization reasons. Any other configuration from the Supplier can be accepted if made compatible to the dimensions and to the integration of the cubicles but shall be anyway approved by the IO prior to any implementation.

The Supplier shall consider that the IVC Flowmeters electronic units (transmitters) will have to fit in a limited space within the cubicles dimensions, as other auxiliary parts will be installed in the same cubicles (e.g. network switches, power distribution units etc…). As initial requirement, the Supplier shall consider the following available space (rack units) in the cubicles:

Cubicle type (amount)	Signals amount	Available space for transmitters
Wall Mounted Cubicle (1)	6 Flowmeters	10 rack units available
Floor Standing Cubicle (1)	14 Flowmeters	22 rack units available

All equipment of the same type (sensor, cable, electronic unit etc…) shall be interchangeable, in order to allow replacement in case of corrective maintenance and allow flexibility on installation independently from the assigned location.

4.4.2 Equipment immunity and emission

For the manufacturing of all equipment, the ITER Electrical Design Handbook Electromagnetic Compatibility (EMC) [2] – chapter §6 and §7 – applies and in particular:

- All electronics equipment (non-SIC) shall conform with IEC 61000-6-2, IEC 61000-4-8 and IEC 61000-4-16;
- If an equipment does not fully comply with the specified standards, the Supplier shall provide the actual immunity level and the corresponding performance criterion (for approval by the IO), plus an explanation of the fundamental technical issue that prevents these tests from being passed;
- The mass flow sensors and junction boxes are located in areas where the static magnetic field may reach up to 120 mT and thus shall be compliant with this field or a specific test has to be prepared to certify the correct operation of the equipment following [4];
- The emission limits are based on MIL STD 461F, method CE 101-2, and IEC 61000-6-4. If an equipment does not meet the complete standard required, the Supplier shall provide the measurement of the emission levels (conducted and radiated), for approval by the IO.

4.4.3 Mass flow sensors

The description of the IVC Flowmeters design is provided in Section 2.2.

The mass flow sensors shall be manufactured according to the following principles:

- Each ultrasonic sensor shall be provided with radiation-hard cables to be connected to the junction box and a dedicated coupling layer (or matching layer);
- Cables from the mass flow sensors to the junction box shall have a length of 1 meter;
- The ultrasonic sensors shall work in ‘reflection arrangement’, i.e. aligned and mounted on the same side of the pipe where the flowmeter is installed;
- Each couple of sensors shall be enclosed in a stainless steel structure to allow for pipe ‘clamp-on’ installation and to ensure protection from external impacts;

- Mechanical integrity shall be maintained after a seismic event SL-1[2]. Such a seismic event is expected to impose the following combination of accelerations:

X, outward direction	Y, toroidal direction	Z, upward direction
10 m/s^2	1 m/s^2	10 m/s^2

Note: the above mentioned are Zero-Period Accelerations, cut out at 34 Hz.

4.4.4 Extension Cables and Connectors

Extension cables and connectors shall be manufactured and delivered to be compatible for the connection between each junction box and the assigned electronic unit (transmitter).

Each cable (spool) shall be manufactured considering the lengths provided in §2.

It is preferable to opt for cables without specific connectors so to leave more flexibility in view of cable pulling and installation in the cable trays (e.g. cutting). In case connectors are unavoidable, these shall allow easy dismantling to adjust the cable length during installation.

The following manufacturing standards shall be applied for cables:

- NFC 32070 C1 or IEC 60332-1 and IEC 60332-3 for fire retardancy requirements,
- IEC 61034 for low smoke requirements,
- IEC 60754-1 for zero halogen requirements,
- IEC 60754-2 for non-toxicity requirements.

As alternative, the following standard can be applied in lieu of the above:

- Construction Product Regulation (CPR): Euroclass Cca-s1b-d1-a1 and IEC 60754-1.

Cables are installed indoor, by pulling on industrial grade metallic cable trays or in metallic conduits, with cable ends exposed to surrounding environment (+10°C /+30°C and 40% RH).

4.4.5 Electronic Unit (transmitter)

The electronic unit(s) (transmitter) shall be manufactured in accordance with the applicable international standards and criteria mentioned in this document. In particular, it shall comply with the requirements of the IEC 61508 for SIL-2 level.

The electronic/unit(s) (transmitter) shall be provided with the following features:

- Adjustable output signal range 0-20 mA and 4-20 mA[3];
- Diagnostics and remote access to calibration information;
- Write protection (password, keyed etc.) to restrict access to calibration parameters, in order to prevent unintended changes that could make a device incapable to perform its function.

Each electronic unit (transmitter) output shall be compatible for the connection to Siemens SIMATIC S7 SM336 (HART) module.

The electronic unit(s) (transmitter) shall be compatible with being supplied in 230 V AC 50 Hz.

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[2] SL-1 corresponds to an event with a probability in the order of 10^{-2} per year and represents an investment protection earthquake level.

[3] The Supplier may propose just one of the two output signal options, depending on the proposed final configuration.

4.5 *Measurement requirements*

The IVC Flowmeters system shall be able to carry out the require measurement considering the following conditions:

Fluid characteristics:	Demineralized water (high Reynolds number) Internal pressure 40 – 44 bar gauge Temperature max. 240°C
Measurement range:	0 - 10 m/s
Operating range:	0 - 5 m/s
Accuracy:	< +/- 10%
Acquisition rate:	> 10 Hz
DC Magnetic flux:	Mass flow transducers: B ≤150 mT Electronic unit: B ≤ 15 mT
Radiation level:	~ 10 MGy (gamma) [4]
Temperature level:	35 – 240 °C
Ambient pressure:	Standard atmospheric pressure

4.6 *Maintenance requirements*

The IVC flowmeters shall be designed to maintain their full functionality over the entire ITER lifetime, i.e. ~20 years, considering pre-fusion power operations and fusion power operations. No planned corrective maintenance shall be foreseen.

It is possible to consider a planned preventive maintenance at the end of the ITER pre-fusion power operations (PFPO-2), thus before starting fusion power operations (FPO) where gamma radiation will be present. Such planned preventive maintenance shall mainly cover the sensors' coupling layer: this can be considered as replaceable at the end of the ITER pre-fusion power operations campaign and before entering the fusion power operations campaign (FPO). During PFPO, the main ageing factor is supposed to be the machine baking temperature, i.e. 240°C continuous operation. Ageing of the coupling layer due to radiation can be considered starting from FPO and for a duration of at least 14 years.

In principle, ultrasonic sensors, junction boxes, mounting structure, electronics and cables shall not be involved in a possible planned preventive maintenance.

5 Delivery

5.1 Requirements for Labelling, Cleaning, Packaging, Handling, Shipment and Storage

5.1.1 Labelling and Traceability

All components and the main subcomponents shall be clearly marked in a permanent way and in a visible place with the IO official numbering system according to the document "*ITER*

[4] Cumulated over ITER fusion power operations (> 14 years operation).

Numbering System for Components and Parts" [5]. The marking must include a unique serial number (at the discretion of the Supplier) and the IO may require adding an ITER ID Code composed by maximum 15 digits. The details of the digits will be defined by IO together with the Supplier and a reference table must be provided with the correspondence between the two codes. The Supplier must identify a suitable area for accommodating both markings (Supplier SN and ITER PNI[5]).
No dye-penetrant or marker pens shall be used.

5.1.2 Cleaning

Final cleaning shall ensure effective cleaning without damage to the surface finish, material properties or metallurgical structure of the materials.

5.1.3 Packaging and Handling

Any special IO or regulatory transportation requirements shall be documented and provided to the Supplier prior to shipment.
All components requiring re-assembly at the ITER Site shall be clearly labelled and tagged.
The supplier shall design and supply appropriate packaging, adequate to prevent damage during shipping lifting and handling operations. Electronic accelerometers shall be used and fitted to ensure that limits have not been exceeded. These electronics accelerometers shall have the capability to record shocks and indicate the point in time (date/hour) when the shock has happened. Accelerometers shall be fixed onto each box and shall be capable of recording the acceleration along three perpendicular directions.
Shock absorbing material shall be used.
Each shipment shall be accompanied by a Delivery Report shall be prepared by the Supplier, stating as a minimum:

- The packing date;
- The full address of the place of delivery and the name of the person responsible to receive the package, as well as of the Supplier's name and full address;
- Bill of Materials
- Gross and net weight
- Dimension of the package
- Security Measures
- Release Note [6];
- Packing List;
- Material Safety Sheet;
- Package lifting and handling instructions
- The declaration of integrity of the package;
- The declaration of integrity of the components;
- Any additional relevant information on the status of the components.

The Delivery Report shall be signed by a representative of the IO and its Supplier. The signature by the IO of the Delivery Report prior to shipment represents a Hold Point (HP).

[5] PNI will be provided by the IO during the relevant contract phase and upon request by the Supplier.

The Manufacturing Dossier is part of the List of Deliverables in Chapter 8. An example of Manufacturing Dossier is listed below:

- As-Built Drawings, Documents, and Data (with signatures)
- Supplier Release Note
- Quality Plan
- Testing Procedures, Specifications and Reports
- Material Control Reports, incl. Certificates, Inspections, Concessions etc..,
- Manufacturing Documentation, incl. Manufacturing procedures, Non-Destructive Testing (NDT) Procedures, Process specifications etc..,
- Records of approved Non-Conformances (NCR) and Deviation Requests (DR)
- Certificates of conformance
- Control Reports (Visual Examination, Certificates of Cleanliness, Geometric measurements etc...)
- Codes and Standards conformity certificates
- Completed Manufacturing & Inspection Plans
- Manuals and Instructions for the handling, assembly and maintenance of all SSCs, Tools and Equipment within the supply

5.1.4 Shipment, Transportation and Delivery to the ITER Site

The components shall exclusively be delivered to the ITER Site using the ITER Global Logistic Provider (DAHER) under the responsibility of the Supplier.
Before the shipment, a Release Note shall be prepared in accordance with [6] and approved by the IO.
Upon receipt of the package, the IO shall open the package and make a visual inspection of its content to check:

- The integrity of the package, including identifying visible damage;
- The number and type of components contained in the shipment;
- The enclosed documentation;
- The reading of the accelerometers or other sensors;
- The integrity of the components.

In the case of anomalies the IO shall make any additional relevant remark on the inspection.
The IO will inspect the electronics accelerometers and other sensors mounted on the boxes. If these accelerometers record shocks above 5g, a thorough inspection of the components shall be performed. A decision on acceptance of the delivery of the components will be made by the IO.
If the components are in an acceptable condition, the IO will sign the Delivery Report. The signature of the Delivery Reports is an IO Hold Point.
The original of the Delivery Report shall be kept by the IO and a copy of it shall be kept by the Supplier.

6 Tests and Inspections

All testing operations will be listed in the MIPs. The Supplier and SubSuppliers shall supply procedures regarding all testing operations, for approval by the IO. A summary of the applicable tests and inspections per contract phase is provided below:

Contract phase	Applicable tests and inspections	Responsibility
Phase I	• Visual inspection (§6.1) • Pre-Production tests (§6.2)	Supplier
	• Site acceptance tests (§6.4)	IO
Phase II	• Visual inspection (§6.1) • Factory acceptance tests (§6.3)	Supplier
	• Site acceptance tests (§6.4)	IO

6.1 Visual Inspections of finished components

All external surfaces and accessible internal surfaces of each finished machined component shall be inspected by a visual examination in accordance with ASME Section V Article 9. The results shall be reported on a sketch showing the locations, size, and distribution of the acceptable imperfections, and their photographs if any.

6.2 Pre-Production Tests

During Phase I, the manufactured prototype(s) shall undergo the following Pre-Production tests.

The final number of prototypes to be subject to each Pre-Production test shall be formalized in the Supplier's technical offer.

6.2.1 Dynamic Flow Factory Test

The test is aimed at qualifying the fastening system and the measurement accuracy of the IVC Flowmeter prototype(s) with respect to a calibrated reference. The Supplier shall consider realistic operating conditions for such test and propose to IO, for approval, a dedicated test procedure and test configuration.

The following test parameters shall be considered[6]:

- Fluid: water;
- Fluid velocity > 2 m/s;
- Fluid temperature ≥ 200°C (240°C preferable);
- Test setup: shall include a DN40 Sch.10S pipe, where the prototype is mounted on.
- Test duration (cumulated): minimum 70 hours, at steady fluid flow and temperature.

During the test, the fluid velocity shall be measured with the IVC Flowmeter prototype(s), after proper calibration, and the accuracy shall be demonstrated to be in line with the requirements of this document – see §4.5.

6.2.2 Immunity Tests

The Supplier must be able to demonstrate that its manufactured equipment is immune to certain faulty events, discharges, magnetic fields etc..., in accordance to the IEC standards list below.

[6] This list is to be considered as a minimum requirement and shall not be considered as exhaustive.

If the Supplier is not able to demonstrate it with appropriate certifications, dedicated immunity tests shall be performed.

The following Immunity Tests are applicable and must performed or relevant documentation must be provided:

Test description	Ref. standard	Test parameters
Immunity test against electrostatic discharges (ESD)	IEC 61000-4-2	Air Discharge ±8 kV Contact Discharge ±4 kV
Immunity test against radiated electromagnetic fields (E-Field)	IEC 61000-4-3	- 1 V/m, 2.0-2.7 GHz, 80% AM (1kHz) - 3 V/m, 1.4-2.0 GHz, 80% AM (1kHz) - 10 V/m, 80M to 1 GHz, 80% AM (1kHz)
Immunity test against electrical fast transient/bursts on supply, signal, control and earth ports	IEC 61000-4-4	Test Level 3 as indicated in the relevant IEC.
Surge immunity	IEC 61000-4-5	- ±1.0 kV (I/O Leads) - ± 2 kV(CM), ± 1 kV(DM) (AC Power Leads) - ± 0.5 kV(CM&DM) (DC Power Leads)
Immunity test against conducted disturbances	IEC 61000-4-6	10V for continuous; 100V for short duration.
Immunity test against fluctuating magnetic fields	IEC 61000-4-8	Continuous duration: 2.4 mT/s (H=6 A/m) Short duration (3 sec): 8 mT/s (H=20 A/m)
Immunity test against voltage dips	IEC 61000-4-11	0% Residual – 1 cycle; 40% Residual – 10 cycles; 70% Residual – 25 cycles;
Immunity test against interruptions		0% Residual – 250 cycles
Immunity test against common mode disturbances	IEC 61000-4-16	10V for continuous duration; 100V for short duration.
Immunity test against static magnetic field	ITER_D_98JL4W [4]	According to Table 5.1-1 of [4]: 1.4**B* mT / 2**B* mT [7]

The Supplier shall carry out the Immunity Tests according to the IEC international standard mentioned above and provide the relevant test reports.

[7] *B* is the static magnet induction strength as indicated in §4.5 of this document.

6.3 Factory Acceptance Tests (FAT)

At Phase II, the Supplier shall perform factory testing (FAT) before shipping the final products to the IO. For each milestone, the Supplier shall provide necessary support to test the component/system to demonstrate that the required performance meet the criteria.
Each FAT shall be substantiated by a FAT Report to be submitted to IO for approval.

Each final product shall undergo the following FATs.

6.3.1 Visual inspection

Each manufactured part shall be visually examined to verify that no visible damage is present. In particular, each part shall be free from laps, laminations, seams, visible cracks, tears, grooves, slivers, pits, and other imperfections detrimental to the part itself. The visual inspection shall be carried out in a proper and clean environment, equipped with suitable illumination for a visual inspection. Any identified damage shall be marked on a representative drawing of the concerned part and submitted to the IO for further review and analysis (high-quality photos of the damaged part shall be provided as well).

The Supplier can decide to adopt an international standard reference for carrying out the visual inspection (e.g. ISO, etc…). This shall be declared prior to the start of any inspection.

6.3.2 Electrical tests

Each manufactured cable (spool) shall be subject to the following electrical tests:

- Continuity test;
- Insulation resistance test (or linear hipot test).

The test shall aim at verifying the status and the electrical integrity of the cable structure (i.e. open/closed circuit, absence of insulation flaws etc…).

The test parameters (voltage, configuration etc…) shall be defined by the Supplier according to their internal procedures and cables design rules. A dedicated test procedure shall be submitted to the IO for approval prior to any activity.

6.4 Site Acceptance Tests (SAT)

Once the prototype(s) or the final products have been delivered to the ITER site, the IO is responsible for performing Site Acceptance Tests (SAT):

- Each delivered package will be inspected to verify its integrity and ensure no great visible damage is inflicted to the delivered products;
- Check of (electronic) accelerometers upon delivery at IO site;
- Visual inspection of each delivered product;
- Electrical tests on cables (spools).

Delivered products will be accepted only if they pass the SATs. In case any non-conformity is identified by the IO during SATs, the related issue(s) and corrective action(s) will be managed through the IO NCR database.

The Supplier shall bear the risk of loss or damages to the components during the execution of this Contract up to delivery and after inspection against any failure of the components that may happen during transport. Any risk of loss or damage shall be transferred from the Supplier to the IO after SATs hold point is cleared.

6.5 *Acceptance criteria*

Test	Acceptance Criteria	Appl. standard
Visual inspection of finished parts	Each part shall be free from laps, laminations, seams, visible cracks, tears, grooves, slivers, pits, and other imperfections detrimental to the part itself.	-
Dynamic Flow Factory Test	Accuracy of the measurement compliant with requirements of §4.5	-
Immunity tests	Full specification maintained during and after the test (Criterion A).	IEC 61000-4-3 IEC 61000-4-6 IEC 61000-4-8 IEC 61000-4-16
		ITER_D_98JL4W [4]
	Temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention (Criterion B).	IEC 61000-4-2 IEC 61000-4-4 IEC 61000-4-5 IEC 61000-4-11 (only for voltage dips 0% Residual)
	Temporary loss of function or degradation of performance, the correction of which requires the intervention of the operator (Criterion C).	IEC 61000-4-11 (all other test parameters)
Continuity Test	No open-circuit measurement is detected	-
Insulation resistance test	No voltage breakdown	-

6.6 *Final Acceptance*

The components shall be handed over to the IO when they have been delivered in accordance with this Technical Specification and all related documentation have been accepted by the IO, have satisfactorily passed the tests and a Certificate of Final Acceptance has been issued (Final Acceptance). The Certificate of Final Acceptance shall be signed by both the IO and the Supplier, after the definitive acceptance of each component and its related documentation.

Ownership of the components shall be transferred from the Supplier to the IO upon Final Acceptance at the ITER Site. The transfer of ownership to the IO shall not relieve the Supplier of its obligations under this Contract in case of non-conformities of the components for the duration of the warranty period.

7 Contract Management

7.1 Control Points

To ensure a close oversight of the entire activities foreseen in the present technical specification, a system of Control Points will be implemented by the IO in order to keep track of the work advance in accordance with the approved Manufacturing and Inspection Plans (MIP).

The control points shall be integrated into the agreed schedule and defined as the following:

- A Notification Point (NP) is a milestone where the Supplier is required to notify the IO that it has completed a specific task or a specific deliverable and is proceeding to the next task or to the next action on the specific deliverable. A NP is meant to enable the IO personnel to follow the progress of the Contract and possibly to witness a critical manufacturing step at the Supplier's premises. The Notification shall be sent by the Supplier to the IO at least 10 working days prior to the scheduled manufacturing step. The IO shall decide whether or not they want to attend. A NP shall not affect the production flow of the Supplier that shall continue the work even without a reply from the IO.
- A Hold Point (HP) is a milestone where the Supplier is required to notify the IO, that it has completed a specific task or a specific deliverable and must stop the associated processes until a HP Clearance is issued. The HP Clearance shall be issued on the basis of clearly identified Quality Control and data and Acceptance test results to be provided to the IO at the time of the request. The IO shall have a maximum of 5 working days to review the Suppliers data and to notify the Supplier of its decision. In case of clearance the Supplier shall resume its activity. In case of rejection, the Supplier shall develop a recovery plan that shall be submitted and reviewed by the IO within 10 working days of submission.
- A Witness Point (W) is a milestone which identifies an operation to be witnessed. Adequate notice shall be given to the IO, in order to allow the IO to participate to the operation.

The preliminary list of Control Points is defined below for all the contract phases, listing the minimum required controls. Additional Control Points may be identified following review of the MIPs.

NP	HP	W
	Manufacturing drawings	
Materials certificates		
Prototype(s) manufacturing		
		Pre-Production tests
	Pre-Production Tests reports	
Delivery to IO		
	MRR	MRR

Table 3: Summary of Control Points for Phase I.

NP	HP	W
Materials certificates		
Start of production		
	FAT	FAT
	DRR	
	SAT	

Table 4: Summary of Control Points for Phase II.

7.2 Data Management

The data generated during the execution of the present Contract shall be handled electronically and entered into the ITER IDM and ITER Manufacturing Database (MDB), depending of the type of data. The structure of this database shall be defined by the IO. The Supplier shall use this database to store information related to the Contract. All data entered in the database will be kept strictly confidential by the IO and, under no circumstances, shall be communicated or made accessible to other Suppliers or the DAs. Data consistency checks shall be implemented to facilitate IO oversight.

Relevant data shall be made available by the Supplier to the IO through IDM each time a control point is requested, or a deviation request, a non-conformance report, or any other document which is part of the Contract deliverables is issued by the Supplier, in accordance with the document "*IO / In-Cash Contractor Documentation Exchange and Storage Working Instruction*" [7]. This requirement does not apply for other documents and data files, which are, for example, managed through specialized CAD software (e.g. CATIA) and so undergo other requirements specified in separate documents.

Specific trainings on how to navigate in the abovementioned databases and manage the corresponding documentation will be organized by the IO for the Supplier upon need.

7.3 Reviews

7.3.1 Manufacturing Readiness Review

At the end of Phase I, the Supplier must prepare all the documentation needed for the Manufacturing Readiness Review (MRR), which shall be focused on the final procedures and on the final Pre-Production results. The review shall be held at the IO headquarters or at the Supplier's premises. The organization of the MRR is under the responsibility of the Supplier but the IO shall review the agenda and the review panel. The objects of the MRR are:

- Final manufacturing drawings;
- Implemented manufacturing procedure;
- Implemented Pre-Production program;
- Results of prototype(s) Pre-Production campaign;
- Final approval of drawings and procedures to start production phase;
- Acceptance of all documents as specified in section 2.6;
- Time schedule of production phase;
- Quality control program to be implemented during production phase.

Safety Reviews will be organised at each stage of production, as required by the IO.

Working instructions for the preparation of the MRR are included in [8].

7.3.2 Delivery Readiness Review

All components and parts that are delivered to the ITER site shall undergo Delivery Readiness Review (DRR). A DRR shall be executed for each shipment planned to IO.

The Supplier is responsible for preparing and providing the following documents:

- Contractor Release Note
- Delivery Report
- Packing List

The IO will provide the Supplier with the Equipment Storage & Preservation Requirements prior to shipment.

Working instructions for the preparation of the DRR are included in [9].

7.4 Compliance Matrix

The Supplier shall demonstrate its compliancy with the technical requirements presented in this document. In order to do this, a so-called "Compliance Matrix" shall be submitted to the IO at the end of each contract phase.

The Compliance Matrix is pre-filled in by the IO (see Appendix 2), listing and summarizing all the technical requirements required per phase and their justification type (inspection, test, factory acceptance…): the Supplier shall complete the Matrix by specifying the status of the requirements (acquired, partially acquired, not yet acquired…) and the corresponding justification document/deliverable(s).

The Compliance Matrix shall be sent by the Supplier to the IO for final review and approval at the end of each contract phase.

7.5 Monitoring and Access Rights

The Supplier shall submit periodic reports to the IO, with a frequency depending on the progress of the works. Progress meetings shall be conducted at the IO or Supplier premises, as required by the IO.

The Supplier shall organise progress meetings and upload related documents and meeting minutes to the IDM for the progress, encountered blockage and resolve methods review. Progress meetings shall be conducted by in-person at the IO or Supplier premises or by regular video conference. The frequency of meeting shall be biweekly or monthly, depending on the progress of the works. Unscheduled meeting can be organized if required by the IO or the Supplier.

Moreover, the IO reserves the right to take photographs of the ITER equipment during the contract life.

8 List of Deliverables and due dates

Payments shall be done according to the deadlines reported in following table. Payment will be done by the IO only after delivery and acceptance of all the relevant documentation, equipment and prototypes procured or manufactured under each phase. Sub-deliverables could be re-arranged following the MIP.

#	Deliverables Phase I - Pre-Production	Due dates
0	Kick-off Meeting (KOM)	T0
1	Quality Plan. Risk and Opportunity Schedule, Detailed Project Schedule, MIP and Prototype Manufacturing Drawings	T0 + 2 months
2	Pre-Production tests report	T0 + 5 months
3	Delivery of all Prototypes and MRR	T0 + 6 months

Table 5: List of deliverables and due dates for Phase I.

#	Deliverables Phase II – Production and Delivery	Due dates
4	Final MIP and Final Manufacturing Drawings	T0 + 8 months
5	Delivery of final products (including FAT and DRR Hold Points clearance)	T0 + 18 months

Table 6: List of deliverables and due dates for Phase II.

9 Quality Assurance

The Supplier conducting the presented activities shall have an ITER approved QA Program or an ISO 9001 accredited quality system. The general requirements are detailed in *ITER Procurement Quality Requirement*s [10].

Prior to commencement of the task, a Quality Plan (QP) must be submitted to the IO for approval giving evidence of the above and describing the organization for this task, the skill of workers involved in the study, any anticipated sub-Suppliers and giving details of who will be the independent checker of the activities (see *Procurement Requirements for Producing a Quality Plan* [11]).

Prior to commencement of any manufacturing, a Manufacturing Inspection Plan (MIP) [12] must be approved by ITER who will mark up any planned interventions.

Deviations and Nonconformities shall follow the procedure detailed in *Procedure for the management of Deviation Request* [1] and *Procedure for management of Nonconformities* [13].

Prior to delivery of any manufactured items to the IO Site, a Release Note shall be signed in accordance with ITER requirements regarding *Suppliers Release Notes* [6].

Documentation developed as the result of the tasks here included shall be retained by the performer of the task for a minimum of 5 years and then may be discarded at the direction of the IO.

10 Safety requirements

N/A

11 Applicable Documents

Ref. #	Document Title	IDM reference	Version

[1]	*Procedure for the management of Deviation Request*	ITER_D_2LZJHB	5.5
[2]	*EDH Part 4: Electromagnetic Compatibility (EMC)*	ITER_D_4B523E	3.0
[3]	*I&C Cubicle Internal Configuration*	ITER_D_PQM7M8	1.0
[4]	*Test method for ITER equipment for static (d.c.) magnetic fields*	ITER_D_98JL4W	3.3
[5]	*ITER Numbering System for Components and Parts*	ITER_D_28QDBS	5.0
[6]	*Requirements for Producing a Contractors Release Note*	ITER_D_22F52F	5.0
[7]	*IO / In-Cash Contractor Documentation Exchange and Storage Working Instruction*	ITER_D_G8UMB3	4.1
[8]	*Working Instruction for Manufacturing Readiness Review*	ITER_D_44SZYP	3.1
[9]	*Working Instruction for the Delivery Readiness Review (DRR)*	ITER_D_X3NEGB	2.0
[10]	*ITER Procurement Quality Requirements*	ITER_D_22MFG4	5.1
[11]	*Procurement Requirements for Producing a Quality Plan*	ITER_D_22MFMW	4.0
[12]	*Requirements for Producing an Inspection Plan*	ITER_D_22MDZD	3.7
[13]	*Procedure for management of Nonconformities*	ITER_D_22F53X	7.1

12 Acronyms

CAD	Computer Aided Design
DRR	Delivery Readiness Review
EMC	Electromagnetic Compatibility
FAT	Factory Acceptance Test
HP	Hold Point
IDM	ITER Document Management
IO	ITER Organization
IS	Interface Sheet
IVC	In-Vessel Coils
MIP	Manufacturing and Inspection Plan
MRR	Manufacturing Readiness Review
NP	Notification Point
PBS	Plant Breakdown Structure
PIA	Protection Important Activity
PIC	Protection Important Component
PNI	Part Number of ITER

QA	Quality Assurance
QP	Quality Plan
SAT	Site Acceptance Test
SIC	Safety Important Class
SSC	System, Structure and Component
VT	Visual Testing
W	Witness Point

List of Appendices

- Appendix 1: Compliance Matrix (Template)