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Technical Requirements Specification

55.C7.C0/D0 - Gyrotron Technical Specification

This tech spec is for lauching a market survery.

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55.C7.C0/D0 - Gyrotron Technical Specification (57HR72)			
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v0.0	In Work	06 Apr 2021	
v1.0	Revision Required	05 Sep 2025	First version.
v1.1	Approved	30 Sep 2025	Updated according to the received comments.

Table of Contents

1 Preamble

This Technical Specification is to be read in combination with the General Management Specification for Service and Supply (GM3S) [1] that constitutes a full part of the technical requirements.

In case of conflict, the content of the Technical Specification supersedes the content of [1].

2 Purpose

The purpose of this document is to outline the technical specifications for the procurement of the Radiofrequency (RF) Gyrotrons and associated auxiliaries, for the ITER Collective Thomson Scattering (CTS) project.

3 Acronyms & Definitions

3.1 Acronyms

The following acronyms are the main ones relevant to this document.

Abbreviation	Description
BPS	Body Power Supply
CEL	Conventional Exceptional Loads
CMM	Configuration Management Model
COTS	Commercial Off-The-Shelf
CRO	Contract Responsible Officer
CRR	Construction Readiness Review
CTS	Collective Thomson Scattering
CWP	Construction Work Package
DRR	Delivery Readiness Review
ECH	Electron Cyclotron Heating
ECRH	Electron Cyclotron Resonance Heating
EDH	Electrical Design Handbook
EM	Electromagnetic
EMC	Electromagnetic Compatibility
ESP	Équipements Sous Pression (see also PE)
ESPN	Équipements Sous Pression Nucléaire (see also NPE)
EWP	Engineering Work Package
FAT	Factory Acceptance Tests
FDR	Final Design Review
FPS	Filament Power Supply
GM3S	General Management Specification for Service and Supply
HEL	Heavy Exceptional Loads
HMI	Human-Machine Interface
HV	High-Voltage
IDM	ITER Document Management system

IO	ITER Organization
IRSN	Institut de Radioprotection et de Sûreté Nucléaire
IWP	Installation Work Package
KOM	Kick-Off Meeting
LPT	Liquid Penetrant Testing
MHVPS	Main High-Voltage Power Supply
MIG	Magnetron Injection Gun
MIP	Manufacturing and Inspection Plan
MOU	Matching Optics Unit
MRR	Manufacturing Readiness Review
MTO	Material Take Off
NCR	Non-Conformance Report
NEG	Non-Evaporable Getter
NPE	Nuclear Pressure Equipment (see also ESPN)
NSC	Non-Seismic Classified
OC	OverCurrent
OHS	Occupational Health and Safety
OV	OverVoltage
PCDH	Plant Controller Design Handbook
PE	Pressure Equipment (see also ESP)
PIC	Protection Important Component
PRO	Procurement Responsible Officer
QOMC	Quasi-Optical Mode Converter
REMS	Radiological and Environmental Monitoring System
RF	Radio Frequency
SAT	Site Acceptance Tests
SDR	System Design Review
SIC	Safety Important Component
SQEP	Suitably Qualified and Experienced Personnel
StIR	Structural Integrity Report
SVS	Service Vacuum System
SWL	Safe Working Load
TBD	To Be Defined
TL	Transmission Line
VQC	Vacuum Quality Class
VW	Vacuum Window
WG	Waveguide
WLL	Working Load Limit

3.2 Definitions

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

Gyrotron: within these specifications, the term "Gyrotron" is intended to refer to an ensemble of connected sub-systems that concur to produce the coherent radiation at approximately the CTS frequency (60 GHz) starting from the electron beam, e.g. the Magnetron Injection Gun (MIG), the Interaction Region or Cavity, the Quasi-Optical Mode Converter (QOMC), the Vacuum Window (VW), and the Collector.

Gyrotron Magnets: within these specifications, the term "Gyrotron Magnets" is intended to refer to the ensemble of coils producing the magnetic field for the gyrotron, e.g. the Super-Conducting Magnet (SCM) producing the static magnetic field (SMF) inside the cavity, the magnet system for the collector, the magnet system for the MIG, etc. By extension, this term also includes the active and/or passive countermeasures for external interfering fields.

Gyrotron Services: within these specifications, the term "Gyrotron Services" is intended to refer to the ensemble of components and sub-assemblies providing services to the Gyrotron, e.g. electrical power supply systems, connectors, tanks, etc.

Microwave Source Package: within these specifications, the term "Microwave Source Package" is intended to refer to the ensemble of "Gyrotron", "Gyrotron Magnets", and "Gyrotron Services".

Factory Acceptance Tests: within these specifications, the term "Factory Acceptance Tests" is intended to refer to the ensemble of tests, for which the procedure has been pre-emptively prepared by the Contractor and approved by IO, necessary to be done at the factory premises and successfully passed on all or part of the manufactured components under the scope of these specifications.

Commissioning: within these specifications, the term "Commissioning" is intended to refer to the ensemble of tests, for which the procedure has been pre-emptively prepared by the Contractor (jointly with IO) and approved by IO, necessary to be done at IO premises and successfully passed on all or part of the manufactured components under the scope of these specifications, after successful installation of the components in their final location and in preparation of the Site Acceptance Tests.

Site Acceptance Tests: within these specifications, the term "Site Acceptance Tests" is intended to refer to the ensemble of tests or checks, for which the procedure or list has been pre-emptively prepared and approved by IO, necessary to be done at IO premises and successfully passed on all or part of the manufactured components under the scope of these specifications, after successful commissioning in IO, to accept the manufactured components.

Installation: within these specifications, the term "Installation" is intended to refer to the ensemble of activities, for which the procedure has been pre-emptively prepared by the Contractor and approved by IO, to be done at IO premises to install the manufactured components in their final location.

Spare Parts: within these specifications, the term "Spare Parts" is intended to refer to the ensemble of components of any type (electrical, mechanical, etc.) which are to be kept in IO in

case of corrective maintenance or replacement needed on the delivered components within the first 3 years of full-time operation. The list of needed components is to be prepared by the Contractor and approved by IO.

4 Applicable Documents & Codes and standards

4.1 Applicable Documents

This is the responsibility of the Contractor to identify and request for any documents that were not transmitted by IO, including the below list of reference documents.

Number and Title	IDM Doc ID	Version
[1] General Management Specification for Service and Supply (GM3S)	82MXQK	1.4
[2] Quality Classification Determination	24VQES	6.0
[3] ITER Vacuum Handbook	2EZ9UM	2.5
[4] ITER Seismic Nuclear Safety Approach	2DRVPE	1.6
[5] Plant Control Design Handbook	27LH2V	7.1
[6] Codes and Standards for ITER Mechanical Components	25EW4K	5.0
[7] RF Sources Load Specification	UMACZK	2.3
[8] Procedure for Analyses and Calculations	22MAL7	6.8
[9] Instructions for the Storage of Analysis Models	U34WF3	2.0
[10] Instructions for Structural Analyses	35BVV3	4.1
[11] Instructions for Seismic Analyses	VT29D6	2.0
[12] EDH Guide A: Electrical Installations for SSEN Client Systems	2EB9VT	2.7
[13] EDH Guide C: Electrical Installations for EPS Client Systems	2F6BBN	2.5
[14] EDH Part 3: Codes & Standards	2E8DLM	1.3
[15] EDH Part 4: Electromagnetic Compatibility (EMC)	4B523E	3.0
[16] EDH Part 5: Earthing and Lightning Protection	4B7ZDG	3.0
[17] ITER Vacuum Handbook Attachment 1 - Welding	2FMM4B	1.5
[18] ITER Vacuum Handbook Attachment 2 – Cleanliness Requirements Relating to the Assembly of Vacuum Equipment	MBXPP3	1.7
[19] General Management Specification for Executing Entities at the ITER Site	YX55YY	2.3
[20] Design Review Procedure	2832CF	7.0
[21] MQP L3 Working Instruction for Manufacturing Readiness Review	44SZYP	5.1
[22] Working Instruction for the Delivery Readiness Review	X3NEGB	3.0
[23] Procedure for Management of Nonconformities	22F53X	9.1
[24] Safety Guidance Note: Electromagnetic Fields Exposure	R35EGX	2.4
[25] ITER Site Signage & Graphics Standards	4ALJEU	2.5
[26] ICNIRP GUIDELINES, https://www.icnirp.org	N/A	N/A
[27] Assessment of Order of 29 September 2017 approving Nuclear Safety Authority Decision 2017- DC-0591 of 13 June 2017 on the minimum technical design requirements to be met by workplaces in which electrical equipment that emit X-rays is used	WDYTR6	1.1

Table 1. List of reference documents.

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

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

4.2 Applicable Codes and Standards

This is the responsibility of the Contractor to procure the relevant Codes and Standards applicable to that scope of work.

Ref	Title	Version
CS1	NF C15-100	Latest
CS2	NF C13-200	Latest
CS3	NF C18-510	Latest
CS4	European Directive 2006/95/EC	-
CS5	European directive 2004/108/EC	-
CS6	European directive 1999/5/EC	-
CS7	European Directive 96/53/CEE	-
CS8	IEC 61000-6-2	Latest
CS9	IEC 61000-4-16	Latest
CS10	IEC 61000-6-4	Latest
CS11	MIL STD 461F	Latest
CS12	ISO 17025	Latest
CS13	ISO 4287:2000	Latest
CS14	Eurocode 8	Latest
CS15	European Pressure Equipment Directive 2014/68/EU	-
CS16	Arrêté du 17 janvier 1989 fixant les mesures de prévention des risques d'incendie présentés par l'épandage et l'inflammation des diélectriques liquides inflammables utilisés dans les matériels électriques - Légifrance (legifrance.gouv.fr)	Latest

Table 2. List of codes & standards.

Item	Title	Type of Work	Location of Work
1	Gyrotron	SUPPLY	CONTRACTOR
2	Gyrotron Coils	SUPPLY	CONTRACTOR
3	Gyrotron Services	SUPPLY	CONTRACTOR
4	Spare Parts	SUPPLY	CONTRACTOR
5	Final Design	SERVICE	CONTRACTOR
6	Manuf. & Install. Readiness	SERVICE	CONTRACTOR
7	FAT	SERVICE	CONTRACTOR
8	Installation	SERVICE	IO
9	Commissioning	SERVICE	IO
10	Participation to SAT	SERVICE	IO
11	User's Document Package	SUPPLY	CONTRACTOR
12	Assistance to User's Package	SERVICE	CONTRACTOR

Table 3. Scope of supply/service.

5 Scope of Work

This section defines the specific scope of work, in addition to the contract execution requirement as defined in [1]. The contract includes the scope of work outlined in Table 3, together with the type of work and the location where the work shall be executed.

The scope of work shall be achieved in four phases, which normally happen in chronological order for the same component but can be initiated in parallel for different components. There may also be partial overlays between phases (e.g. a component for which design is not needed can already be started in Phase 2).

Table 4 shows the phases of the contract. Each phase is broken down into several steps, which can also happen in chronological order, with possible partial overlays (e.g. in case of batched manufacturing).

Phase	Title	Steps
1	Technical inputs for finalisation of the design	1.1. Hardware Design
		1.2. Procurement of technical documents for finalisation of the design
		1.3. Update of technical documents for finalisation of the design
2	Manufacturing	2.1. Manufacturing Readiness Preparation
		2.2. MRR
		2.3. MRR Chits Closure
		2.4. Manufacturing
		2.5. Installation Readiness
		2.6. FAT
		2.7. Shipping & Delivery
3	Installation	3.1. Visual Inspection
		3.2. CRR
		3.3. On-site Assembly
		3.4. Installation verification and closure
4	Commissioning	4.1. Commissioning readiness
		4.2. Commissioning
		4.3. SAT and Acceptance

Table 4. Contract breakdown in phases, and activities forming each phase.

In the following, a description of each step is performed, phase by phase.

Within Phase 1 (**Technical inputs for finalisation of the design**), the Contractor shall develop the technical inputs for finalisation of the design of the components under the scope of supply of the contract. All the steps under this phase refer to the scope item 5 in Table 3. The steps are:

- **Hardware Design**: the Contractor shall perform the final design of the components under the supply scope of the contract. The output of this step is a final technical description of the components designed.
- **Procurement of technical documents for finalisation of the design**: the Contractor shall **procure** technical documents for finalisation of the design, which will be taken and used by IO for the Final Design Review (organized by IO). The output of this step is the successful completion and approval of all relevant documentation.

- **Update of technical documents for finalisation of the design**: the Contractor shall **update relevant technical documents** following the feedback from IO received during the IO-led FDR, providing supporting evidence (e.g. analysis, justifications, tests, calculations). The output of this step is the successful completion and approval of all relevant docu—**this step constitutes a Hold Point for the contract.**

Within Phase 2 (**Manufacturing**), the Contractor shall manufacture components under the scope of supply of the contract. All the steps under this phase refer to the scope items 1 – 4 and 6 – 7 in Table 3. The steps are:

2.1. **Manufacturing Readiness Preparation**: this step is applicable for those components requiring a Manufacturing Readiness Review (MRR). The Contractor shall prepare the Manufacturing Readiness Review (MRR), by assessing manufacturability of all concerned components, producing drawings, test procedures, and possible deviation requests to be agreed with IO. A complete Manufacturing and Inspection Plan (MIP) shall be submitted by the Contractor as part of the MRR document package. The output of this step is the MRR document package approval. Specification of the content of the MRR document package is done in §14.

2.2. **MRR**: the Contractor shall present the manufacturing readiness of all components under the scope of supply of the contract through a MRR (organized by the Contractor), according to IO procedural requirements (see §6.10). The output of this step is the successful completion of the MRR meeting.

2.3. **MRR Chit Closure**: the Contractor shall resolve the chits (i.e. objections to the manufacturing) raised during the MRR, providing supporting evidence in order to successfully close the MRR and be able to start manufacturing the components. The output of this step is the formal closure of the MRR. For those items requiring MRR, **this step constitutes a Hold Point for the contract.**

2.4. **Manufacturing**: the Contractor shall proceed to manufacture the totality of the components under the supply scope of the contract, as per the information on quantities and types given in the below Sections. Within this step, the activities described in the approved MIP, previously produced, shall be followed, justified and adequately documented. The output of this step is the notification of readiness for Factory Acceptance Tests (FATs).

2.5. **Installation Readiness**: the Contractor shall develop, with input from IO, a set of procedures for the installation of the components to be supplied at the IO premises. The output of this step is the approval of the installation procedures. This step can be partially or totally overlapped with the previous and/or following one, according to manufacturing step evolution.

2.6. **FAT**: the Contractor shall proceed to execute the FATs according to the approved procedure agreed upon MRR. The tests shall be documented and results uploaded in IDM. The output of this step is the approval of the FAT test results. Please note that although this step is listed as chronologically happening after Manufacturing is concluded, partial FATs for subsets of manufactured items can be organized (e.g. for a subset that is completed first) while other subsets are still in manufacturing. **This step constitute a hold point (HP) for the contract**.

2.7. **Shipping and Delivery**: the Contractor shall organize the Delivery Readiness Review (DRR) according to the related instructions (see §6.10) before performing the shipping. Shipping can happen for subsets or types of connector harnesses, as agreed with IO. The output of this step is the delivery to IO.

Within Phase 3 (**Installation**), the Contractor shall install components under the scope of supply of the contract, at the IO premises, following the agreed procedures. All the steps under this phase refer to the scope items 6 and 8 in Table 3. The steps are:

3.1. **Visual Inspection**: the components under the scope of supply of the contract, once delivered at the IO premises, will be inspected by IO. The Contractor shall be available to respond to any IO inquiry following or during the visual inspection. The Contractor shall also resolve any Non-Conformance Report (NCR) submitted by IO. The output of this step is successful visual inspection report(s), with resolved NCRs (if any).

3.2. **CRR**: the Contractor shall perform a **document**-based Construction Readiness Review, submitting final installation documents for approval, and answering IO inquiries and comments, if any. The output of this step is the approval of all installation documents.

3.3. **On-Site Assembly**: the Contractor shall **install** the components under the scope of supply of the contract, at the IO premises, following the installation procedures previously produced and the IO installation requirements (see §6.8). The output of this step is the installation of the last component of the supply (or supply batch).

3.4. **Installation verification and closure**: the Contractor shall participate in the final walkdown performed at IO, to address any open point using punch items and successfully close them. The output of this step is the closure of the installation.

Within Phase 4 (**Commissioning**), the Contractor shall perform the on-site commissioning of the components under the scope of supply of the contract, at the IO premises. All the steps under this phase refer to the scope items 9 – 10 in Table 3. The steps are:

4.1. **Commissioning Readiness**: the Contractor shall review the commissioning procedures previously produced, and assess the readiness (in terms of pre-requisites, equipment, conditions, and availability/accessibility) for commissioning, together with IO. The output of this step is the authorisation to proceed with commissioning.

4.2. **Commissioning**: the Contractor shall commission the installed components under the scope of supply of the contract, at the IO premises, following IO commissioning requirements (see §6.8) and the agreed commissioning procedures. This step also includes debugging and conditioning tests needed for the components. The Contractor shall resolve any NCR that may appear. The output of this step is the successful completion of the commissioning, and closure of all NCRs (if any).

4.3. **SAT and Acceptance**: any test required after commissioning will be executed at IO, and the commissioning results checked. The Contractor shall be available to answer IO inquiries and resolve any possible NCR. The output of this step is the Final Acceptance of the components under the scope of supply of the contract, at the IO premises.

5.1 Scope of Supply

This Section describes the components under the scope of supply of the contract. All these components are to be delivered at IO.

5.1.1 Description

With reference to Table 3, and especially to items 1 – 3 (see related definitions, when applicable, in §3.2), the scope of supply of the contract consists of the supply of 2 sets of "Gyrotrons", 2 sets of "Gyrotron Magnets", and 2 sets of "Gyrotron Services".

Each of the items 1 – 3 and 11 in Table 3 is in itself a list of components.

The components and sets belonging to the item called "Gyrotron" (indicated with suffix "A") are listed in Table 5. The components and sets belonging to the item called "Gyrotron Magnets" (indicated with suffix "B") are listed in Table 6. The components and sets belonging to the item called "Gyrotron Services" (indicated with suffix "C") are listed in Table 7. In all tables, quantities are identified.

Item	Title	Quantity
A.1	Gyrotron tube including: MIG, Interaction region, QOMC, Collector, X-ray shielding, Vacuum chamber, Vacuum window, necessary viewing ports	1 set
A.2	Dummy Load (relief window)	1 set if required
A.3	Bellows (between MOU and Gyrotron output)	1 set
A.4	Matching Optics Unit (MOU)	1 set
A.5	Alignment system for MOU mirrors	1 set
A.6	Any additional component deemed necessary to be added	TBD
A.7	Any additional component/improvement that would increase lifetime and/or performance (e.g. efficiency)	TBD

Table 5. Scope of supply for <u>each</u> of the item "Gyrotron" of Table 3 in the scope of supply of the contract.

Item	Title	Quantity
B.1	Liquid-He Super-Conductive Magnet (SCM) equipped with diagnostics sensors as required	1 set
B.2	Magnet system for collector sweeping	1 set
B.3	Magnetic coil set for MIG	1 set
B.4	Passive and/or active magnetic shielding set as required	1 set
B.5	Any additional component deemed necessary to be added.	TBD
B.6	Any additional component/improvement that would increase lifetime and/or performance (e.g. efficiency)	TBD

Table 6. Scope of supply for each of the item "Gyrotron Magnets" of Table 3 in the scope of supply of the contract.

A particular mention regarding the diagnostics instrumentation (i.e. sensors) listed in Table 7 must be done. Indeed, the Contractor shall pre-emptively perform a risk analysis, identifying the needs of diagnostics (e.g. temperature sensors) in terms of type, location, and quantities. The types outlined in Table 7 are intended to be the minimum which is expected to be there.

Additionally, the Contractor shall perform a second separate analysis, focused on the operation and maintenance aspects, which shall identify the need of any additional instrumentation to be implemented (e.g. additional temperature sensor(s) in the MIG area).

Item	Title	Quantity
C.1	Temperature Sensors for collector and cavity	As required
C.2	Temperature Sensors for MOU	As required
C.3	Arc detector for gyrotron window	As required
C.4	Oil tank with: 1. dielectric fluid 2. external female HV connector 3. internal HV circuitry 4. fixing structure to the gyrotron	1 set
C.5	Pump for oil tank, equipped with following sensors for oil tank: 1. flow-rate sensor 2. level sensor 3. temperature sensors 4. hydrometer	As required
C.6	Compressor/refrigerator for SCM	1 set
C.7	SCM electronics for local control	1 set
C.8	Protection circuitry for all Gyrotron components	As required
C.9	Mechanical support structure set	1 set
C.10	Arc-detector sensor head	As required
C.11	Specific instrumentation for magnetic field alignment	As required
C.12	Any additional component deemed necessary to be added	TBD

Table 7. Scope of supply for <u>each</u> of the item "Gyrotron Services" of Table 3 in the scope of supply of the contract. The mention "As required" is to be intended as "quantity required as per risk analysis output". Also note that additional sensors might be required as per §5.1.1.

Given the unavoidable interface that the Microwave Source Package (see definition in §3.2) will have with auxiliary and external systems like the cooling manifold, the control system for integration in ITER control network and similar, the scope of supply of the contract also includes 2 sets of "User's Document Package" (see Table 3).

The "User's Document Package" is a set of documents which the Contractor shall prepare and supply to IO. This document package shall be prepared in a way to enable the interfacing system (e.g. control system, cooling manifold) to design a compatible system to successfully interface with the Microwave Source Package. Therefore, all necessary information shall be disclosed in this document package. Any request for clarification/integration to the submitted information shall be addressed and solved by the Contractor.

Table 8 lists the set of documents belonging to the "User's Document Package" item. A brief description of each document is following:

- The "Operational Manual" shall be a document that enables the user to successfully operate the Microwave Source Package (i.e. the gyrotron with its magnetic systems and services). It lists the functionalities of the components, procedures for operating them in the foreseen operational modes, and operational limitations. It shall also contain the procedures for calibrations. It shall be a self-contained document.
- The "Maintenance and Troubleshooting Manual" shall be a document that lists, explains and details all maintenance procedures (e.g. periodic, corrective, preventive etc.) required to correctly maintain the Microwave Source Package. It shall be a self-contained document.

Item	Title	Quantity
D.1	Operational Manual*	1
D.2	Maintenance and Troubleshooting Manual*	1
D.3	Datasheets in electronic forms**	1
D.4	Any software code (source) developed	TBD
D.5	Technical Requirement document for the Cooling Manifold	1
D.6	Technical Requirement document for the Control System	1
D.7	Technical Requirement document for Power Supplies	1
D.8	Technical Requirement document for Cabling	1
D.9	Technical Requirement document for Other Interfaces	1
D.9	Any additional document deemed necessary to be added.	TBD

*Applicable to the entire supply scope.
**Applicable to COTS components.

Table 8. Scope of supply for <u>each</u> of the item "User's Document Package" of Table 3 in the scope of the contract.

- The "Datasheets in electronic forms" shall be an electronic document package containing the datasheets of all COTS components included in the scope of supply or used for part of such components.
- "Any software code developed" shall include the source code of any script, post-processing, or elaboration code developed in the framework of the supply. The format under which this code shall be supplied shall be decided by IO.
- The "Technical Requirement document" family, encompassing 5 documents, is a document family containing all necessary interfacing information for the interfacing systems.
- The "Technical Requirement document for the Control System" shall contain all the control and protection functions to be implemented by the control system. The detailed requirements shall also be included, e.g. operating modes and sequences, specific waveforms, reaction times. All the signals (analogue or digital, for example coming from sensors and/or interlocks) made available for the control system, the related characteristics, any applicable or compatible transfer protocol shall also be provided. This document shall therefore enable the independent, complete and parallel development of the control system.
- The "Technical Requirement document for the Cabling" shall contain all specifications needed for cables, in terms of cable type (e.g. individually shielded twisted pair, coaxial, etc.), cable and wire quantity, segregation, grounding information, etc. This document shall therefore enable the independent, complete and parallel development of the cabling system.
- The "Technical Requirement document for the Power Supplies" shall contain all specifications needed to power supply the components under the supply scope of the contract. Examples are the power supply specifications for the magnet system used for collector sweeping, or for the sensors and interlocks, or for compressor/refrigerator, etc.
- The "Technical Requirement document for the Cooling Manifold" shall contain all specifications needed to perform the design of the cooling manifold needed for the Microwave Source Package under the scope of the contract, e.g. needed flow rate,

pressure, interface flange, valves specifications etc. The “Technical Requirement document for Other Interfaces” shall contain all specifications needed for the correct interface with other external systems.

With reference to Table 3, and especially to item 4, the scope of supply of the contract also includes 1 set of “Spare Parts”. The definition of this supply scope is already given in §3.2. The identification of the actual needed components to be supplied as part of this scope is done exhaustively at FDR level and is limited in value to 5% of the total integrated value of the sets of “Gyrotrons”, “Gyrotron Magnets”, and “Gyrotron Services” in the scope of the contract.

5.1.2 Exclusions

The following sub-systems are out of the supply scope of the contract:

- Control System (hardware and software)
- Cooling Manifold
- Cabling
- Power Supplies.

Indeed, these systems are developed through other sources. However, the scope of supply of the contract contains appropriate documentation to allow suitable interfacing (see previous section).

5.2 Scope of Services

This Section describes the items under the scope of service of the contract. The scope of services is described by referring to Table 3 and map the services to the phases/steps described in Table 4.

The scope of services identified in item 5 of Table 3 is described as Phase 1 (steps 1.1 – 1.3) in Table 4 and adequately described at the beginning of §5. Design justification through analysis is an optional scope. The scope of services identified in items 6 – 7 of Table 3 is described as Phase 2 (steps 2.1 – 2.3 and 2.5 – 2.6) in Table 4 and adequately described at the beginning of §5. The scope of services identified in item 8 of Table 3 is described as Phase 3 (steps 3.2 – 3.4) in Table 4 and adequately described at the beginning of §5. The scope of services identified in items 9 – 10 of Table 3 is described as Phase 4 (steps 4.1-4.3) in Table 4 and adequately described at the beginning of §5.

5.3 Duration

The maximum expected duration for the contract is 9 years, with an optional extension of 2 additional years. IO shall have full and exclusive rights to activate, or not, the extension option.

6 Technical Requirements

This section defines the ensemble of technical requirements related to the scope of work previously defined as in the scope of the contract.

Many of the requirements set forth in this section require reference to a schematic representation of the working principle of a Gyrotron RF source, and a visualization of the scope presented previously. Figure 1 on the next page shows the general working principle of a Gyrotron, and several of the components previously presented as part of the Microwave Source Package.

<table>
<tr><th>Item</th><th>Description</th><th>Quality</th><th>Safety</th><th>Seismic</th><th>Vacuum</th><th>PE/ESP</th></tr>
<tr><td>A.1</td><td>Gyrotron tube</td><td rowspan="7">QC3</td><td rowspan="10">Non-SIC</td><td rowspan="10">NSC</td><td rowspan="3">G</td><td rowspan="4">Y</td></tr>
<tr><td>A.2</td><td>Dummy Loads</td></tr>
<tr><td>A.3</td><td>Bellows</td></tr>
<tr><td>B.1</td><td>SCM</td><td rowspan="2">VQC 3A</td></tr>
<tr><td>A.1</td><td>Vacuum Boundaries*</td></tr>
<tr><td>A.4</td><td>MOU</td></tr>
<tr><td>A.5</td><td>Alignment system for MOU mirrors</td><td rowspan="4">N/A</td><td rowspan="2">N</td></tr>
<tr><td>B.2 – B.4</td><td>Gyrotron Magnets</td><td rowspan="3">QC4</td></tr>
<tr><td>C.1 – C.5, C7 – C.11</td><td>Gyrotron Services</td></tr>
<tr><td>C.6</td><td>SCM Compressor</td><td>Y</td></tr>
</table>

* These include the vacuum window (Part of A.1 in Table 5) and any other component forming a vacuum boundary, except the gyrotron tube itself.

Table 9. System classification. The first column is based on the nomenclature in Tables 4 to 6.

6.1 System Classification

The components under the supply scope of the contract are classified in classes, according to quality, safety, seismic, vacuum, and pressure aspects. The system classification is shown in Table 9. Following FDR, it might be that some items could change quality classification, according to the design evolution. The classification is based on criteria contained in [2] for quality classification, [3] for vacuum classification, [4] for seismic classification. The classification under certain classes entails requirements to be fulfilled, which are developed in the following sections.

6.2 Design and Performance Requirements

Table 10 shows the main design and performance requirements associated with the Microwave Source Package under the scope of these specifications. The Contractor shall design a Microwave Source Package that fulfils all of the listed requirements.

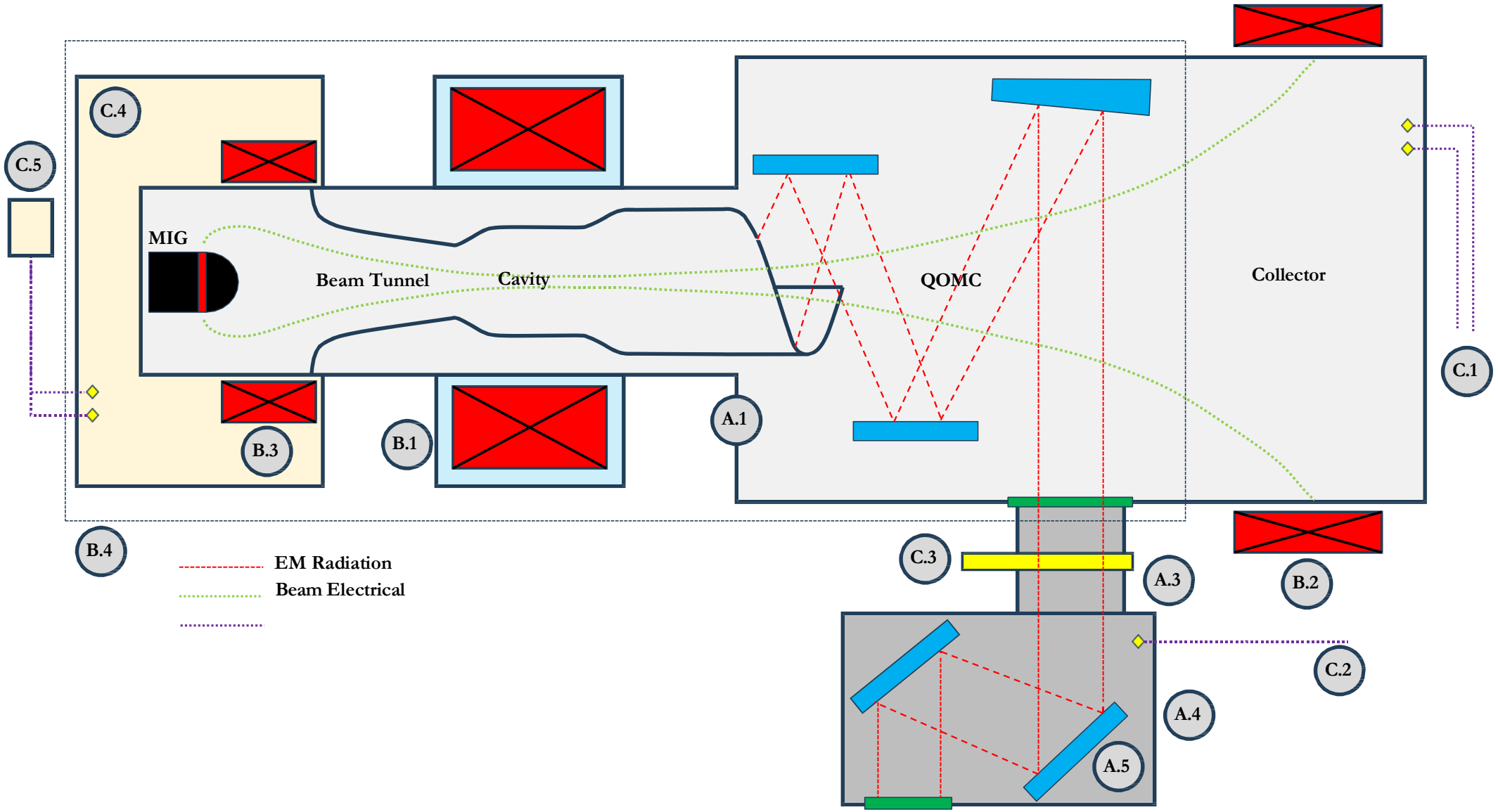

Figure 1. Schematic (non-exhaustive and not to scale) representation of a Gyrotron. The small circles indicate some of the items in Table 2, Table 3, Table 4.

Item	Description	Requirement
1	Gyrotron Type	Depressed Collector, with efficiency $> 50\%$
2	Nominal Output Power	≥ 1.2 MW
3	Nominal Frequency	60 ± 0.1 GHz
4	Pulse Length	≥ 3600 s
5	Side bands power (60 ± 5 GHz)	110 dB below the power at the centre frequency (60 GHz)
6	Reliability	$\geq 95\%$
7	Short-pulse Efficiency	$\geq 45\%$
8	Long-pulse Efficiency	$\geq 50\%$
9	HE_{11} Mode purity	$> 97.5\%$
10	Modulation	100% power depth from $0 - 500$ Hz, rising time ≤ 0.2 ms
11	Cathode Voltage*	≥ -55 kV
12	Body Voltage*	≤ 35 kV
13	Beam Current*	≤ 55 A
14	Environment Magnetic Field[1] before compensation/shielding	0.3 mT Radial Magnetic Flux Density 0.12 mT Vertical Magnetic Flux Density

* These parameters can be adapted/relaxed by the Contractor if they pose restrictions to the design of the Gyrotron as per the requirements.

Table 10. Main design and performance requirements for the Microwave Source Package.

Explanation of the meaning of each requirement is given in this section, as follows:

- **Nominal Output Power**: this value shall be the minimum value of RF power measured at the end of a 1 m long corrugated waveguide (hereafter called "test waveguide") connected to the MOU output flange (see Figure 2)[2]. The power measurement method can be calorimetric.
- **Nominal Frequency**: this value shall be the frequency of the electromagnetic radiation outputted by the Microwave Source Package, measured at the output flange of the MOU. The requirement also contains the required measurement uncertainty. The frequency measurement can be done with a synthesizer or other method, provided that the uncertainty is compatible with the requirement.
- **Pulse Length**: this value shall be the minimum duration to achieve for a continuous-wave long pulse scenario.
- **Side bands power**: this value shall be the maximum power level in the side bands (± 5 GHz around the centre frequency) with respect to the power at the centre frequency.

[1] The calculations to estimate the stray magnetic field at the location of the CTS Gyrotrons are attached to this Technical Specifications.

[2] The test waveguide is out of scope of these technical specifications. It will be free-issued by IO to the Contractor for the sake of FAT and tests. The Contractor shall ship back the test waveguide alongside with the components under the supply scope of the contract. If the contractor already possesses a suitable corrugated waveguide, no shipment shall be done by IO.

- **Reliability**: this parameter shall be defined as the percentage of successful pulses with respect to the ensemble of attempted pulses. It shall be valid for short and long pulses. For the sake of this definition, a successful pulse is defined as a pulse of specified duration T, where the nominal output power (see previous requirements) is delivered for at least an integrated duration of $0.95T$[3]. The minimum number of pulses (attempted) for the establishment of the reliability shall be 20.
- **Short-pulse efficiency**: this value shall be the efficiency value for those pulse durations not exceeding 100 seconds. In general, the efficiency of the Microwave Source Package under the scope of the present technical specifications shall be intended as the electronic efficiency, which considers losses as well, as follows:

$$\eta_{el} = \frac{P_{RF}}{P_{in}} = \frac{P_{out} + P_{Loss}}{V_c \cdot I_b} \quad (1)$$

  where P_{RF} is the power which is extracted from the beam and delivered to the RF field, P_{out} is the output power, P_{loss} is the power loss (including resistive and dielectric losses) on the Microwave Source Package components, V_C is the cathode voltage, I_b is the beam current. The power measurement method can be calorimetric.
- **Long-pulse efficiency**: this value shall be the efficiency value for those pulse durations exceeding 100 seconds. For the first 100 seconds of such long pulses, a lower efficiency value may be accepted, provided that it fulfils the requirement for short-pulse efficiency (previous). The power measurement method can be calorimetric.
- **HE_{11} Mode purity**: this percentage value shall represent the degree of mode purity of the EM radiation in output to the test waveguide. Indeed, given the possibility of mode competition and overmoding, this requirement assures that 97.5% of the EM field power is coupled into the HE_{11} mode in the test waveguide. The measurement and processing methods for determining the mode purity value shall be based on measurements and pre-emptively agreed with IO.
- **Modulation**: this requirement shall define the capability to perform a full power depth modulation (i.e. ON-OFF switching) with a modulation frequency up to the specified value.
- **Cathode Voltage**: this value shall be maximum voltage applied at the cathode electrode for the nominal power output. The value shall be updated for compatibility with the power upgradeability.
- **Body Voltage**: this value shall be the maximum voltage applied at the body electrode. It entails the fact that the Gyrotron shall operate using a depressed collector. This value is for the nominal power output. The value shall be updated for compatibility with the power upgradeability.

[3] Such definition of successful pulse generates the following conditions:
- In case of an arc occurred during the pulse duration T, causing the emergency shut-down, the pulse can still be considered successful, provided that the Microwave Source Package is able to recover safe ON conditions and eventually deliver the nominal output power level for at least a duration of $0.95T$.
- In case of an external interlock (i.e. not coming from the Microwave Source Package), e.g. an external power supply protection, triggering the emergency shut-down, the pulse may be discarded and may not be counted for the establishment of the reliability value. However, if the Microwave Source Package was able to recover safe ON conditions and eventually deliver the nominal output power level for at least a duration of $0.95T$, the pulse may be counted as a successful pulse towards the establishment of the reliability value.

- **Beam Current**: this value shall be maximum beam current value for the nominal power output. The value shall be updated for compatibility with the power upgradeability.
- **Environment Magnetic Field**: this requirement specifies the maximum value (intended to be along radial and vertical axes) of ambient magnetic field which shall be experienced by the Microwave Source Package and that shall not undermine the operation of the latter within specifications.

If compliance with requirement 14 (Table 10) cannot be assured, the Contractor shall specify what is the maximum magnetic field (in terms of radial and vertical components, in mT) that can be experienced by the Microwave Source Package while satisfactorily operating within all other technical requirements' boundaries.

6.3 Interface Requirements

The Microwave Source Package under the scope of these technical specifications interfaces with several systems or sub-systems which are not in the scope of the contract. Therefore, this section outlines the requirements that the Microwave Source Package shall fulfil in order to assure compatibility with the interfacing systems and services.

6.3.1 Interface with CTS Control System

The CTS control system manages signals and interlocks coming from the CTS sub-systems (gyrotrons, transmission lines, waveguides etc.) and implements the control logic according to ITER rules [5].

To assure full compatibility of the Microwave Source Package under the scope of the contract, and the Control System being developed through other sources, requirements are hereafter specified.

The arc detector shall be a fibre-optic-based sensor.

The Gyrotron shall be equipped with a window between its output and the MOU input, suitable for the installation of the arc detector installed at least on the MOU.

The SCM shall incorporate suitable communication protocols to allow interfacing with the main Control System, according to [5].

The development of the Control System will undergo a specific FDR. The Contractor shall review the applicable documentation of the Control System FDR, with the aim of checking the correct implementation of the requirements. The Contractor's requirements input (through the supply of item D.6 of Table 8) will be considered to finalise the design of the Control System.

Before the SAT, IO will perform a preliminary acceptance test of the Control System alone, where the Contractor shall participate in defining required test procedure, and reviewing related test results, with the aim of checking and assuring full compatibility with the Microwave Source Package. If all tests are successful, the Contractor shall therefore accept the Control System as it is to be integrated with the Microwave Source Package for operation. The SAT shall therefore be performed with the accepted Control System.

Any technical requirement that the manufactured Microwave Source package should have towards a Control System (e.g. interface type, signal type, connection type, cabling etc.) being developed outside the scope of the contract, shall be included in the required documentation of Table 8.

6.3.2 Interface with Service Vacuum System

The SVS (IO service) provides interfacing services for pumping, venting and purging.

To assure full compatibility of the Microwave Source Package under the scope of the contract, and the SVS being developed through other sources, requirements are hereafter specified.

In order to allow pumping of the MOU, the latter shall be equipped with a pumping flange DN160 CF suitable for connection of ion/NEG pumping system.

Any technical requirement that the manufactured Microwave Source package should have towards a Service Vacuum System (e.g. vacuum level etc.) being developed outside the scope of the contract, shall be included in the required documentation of Table 8.

6.3.3 Interface with RF Transmission Lines

The RF output power from the Microwave Source Package (more particularly, at the output of the MOU) will be coupled to a waveguide system carrying the power to the front-end launcher, about 200 m away. This waveguide system, located between the RF sources and the launcher, is referred to as the Launcher Transmission Line (LTL).

To assure full compatibility of the Microwave Source Package under the scope of the contract, and the LTL being developed through other sources, requirements are hereafter specified.

The MOU mirrors shall be capable of aligning the output RF beam to the LTL axis with a resultant offset tolerance of ≤ 1.0 mm and a resultant angular tolerance of $\pm 0.1°$.

During normal operation, the displacements of the MOU output flange shall be limited to ± 5 mm either perpendicular or parallel to the LTL axis.

The polarization of the TEM_{00} mode at the output of the MOU shall be in the horizontal direction.

The MOU output flange shall be designed according to interface drawings to be provided by IO.

6.3.4 Interface with Cooling Manifold and Cooling Water Systems

The Cooling Manifold and Cooling Water Systems are providing cooling power to the Microwave Source Package.

To assure full compatibility of the Microwave Source Package under the scope of the contract, and the Cooling System being developed through other sources, requirements are hereafter specified.

The gyrotron collector shall be equipped with ANSI B16.5 RF Class #150 DN100 flange for cooling interface.

Other cooling interfaces shall be equipped with ANSI B16.5 RF Class #150 flanges (diameter to be specified, in the range between DN10 to DN100).

All components (including the SCM compressors) shall be compliant with demineralized water.

The Microwave Source Package shall be compliant with the cooling water system data outlined in Table 11.

Parameter		Units	Value	
			Gyrotron	Compressor
Water Quality	Electrical Conductivity	μS/cm	≤ 1	
	pH @ 25º C	-	$6.5 - 7.5$	
	Chloride concentration	ppb	< 10	
	DO concentration	ppb	< 20	
	Iron concentration	ppb	< 10	
Supply	Min. Allowable Pressure	Mpa-g	0.85	0.5
	Max. Allowable Pressure	Mpa-g	1	0.68
	Min. Temperature	ºC	25	4
	Max. Temperature	ºC	31	28
	Min. Flow Rate	kg/s	28	0.12
	Max. Flow Rate	kg/s	32	0.17
Return	Min. Allowable Pressure	Mpa-g	0.12	0.2
	Max. Allowable Pressure	Mpa-g	0.2	N/A
Return Low Pressure	Min. Allowable Pressure	Mpa-g	0.03	N/A
	Max. Allowable Pressure	Mpa-g	0.1	N/A
	Nominal Flow Rate	kg/s	TBD	N/A
Nominal Loads		MW	1.23	0.0072

Table 11. Cooling System Parameters.

The potential interfacing flange with the cooling system shall allow decoupling of mechanical loads acting on the Microwave Source Package from the ones acting on the cooling manifold itself. This may be achieved e.g. by adopting flanges suitable for flexible pipes or bellows.

Any technical requirement that the manufactured Microwave Source package should have towards a Cooling System (e.g. flow, temperature requirements, water chemistry etc.) being developed outside the scope of the contract, shall be included in the required documentation of Table 8.

6.3.5 Interface with Power Supplies

The interface under the scope of this sub-section deals with the high-voltage power supply needed for the Microwave Source Package (i.e. MHVPS, BPS), and the other service power supplies (FPS, MIG coil set, SCM compressor/refrigerator, magnets for collector sweeping, ion pumps), which are not in the scope of the contract.

To assure full compatibility of the Microwave Source Package under the scope of the contract, and the Power Supplies being developed through other sources, requirements are hereafter specified.

The Microwave Source Package shall be equipped with receptacles at the level of the oil tank to allow connections to MHVPS, BPS and FPS as required.

The receptacle for the high-voltage connections (MHVPS and BPS) shall be a HIVOLT R41009/D receptacle suitable for a HIVOLT HV-Connector R10 100kV (Straight) with clamping sleeve.

As specified for the Control System (§6.3.1), the Contractor shall review the service power supplies FDR documents and acceptance tests to accept them for operation and SAT (see §6.3.1 and footnote 3).

Any technical requirement that the manufactured Microwave Source package should have towards Power Supplies (e.g. interface type in case of diode- or triode-type gun, final voltage and current levels, ripples, connection type, overshoot/undershoot, settling times etc.) being developed outside the scope of the contract, shall be included in the required documentation of Table 8.

6.3.6 Interface with Building

The Microwave Source Package shall keep continuous consistency with the reference Configuration Management Models (CMMs), which will be determined as part of the FDR.

6.3.7 Interface with Radiological and Environmental Monitoring System

IO Radiological and Environmental Monitoring System (REMS) shall provide the equipment (e.g. portable and personal dosimeters) used to measure the X-ray emissions in the installation and during test, commissioning, operation and maintenance.

IO REMS will provide dosimeters integrators which will be installed close to each gyrotrons to record the X-rays doses. IO REMS also records the personals doses. To assure full compatibility of the Microwave Source Package under the scope of the contract, and the REMS being developed through other sources, requirements are hereafter specified.

In the framework of the supply scope identified in Table 8, the Contractor shall identify (especially related to the maintenance and troubleshooting procedures):

- Number of workers involved in any procedure.
- Number of portable X-rays monitors needed for all the activities in the procedures.

The Microwave Source Package shall be compatible with the installation of a dosimeter integrator, in the number of 1 needed for each Microwave Source Package (see Figure 2). The supplier of the integrators is IRSN, and their supply is not in the scope of the contract.

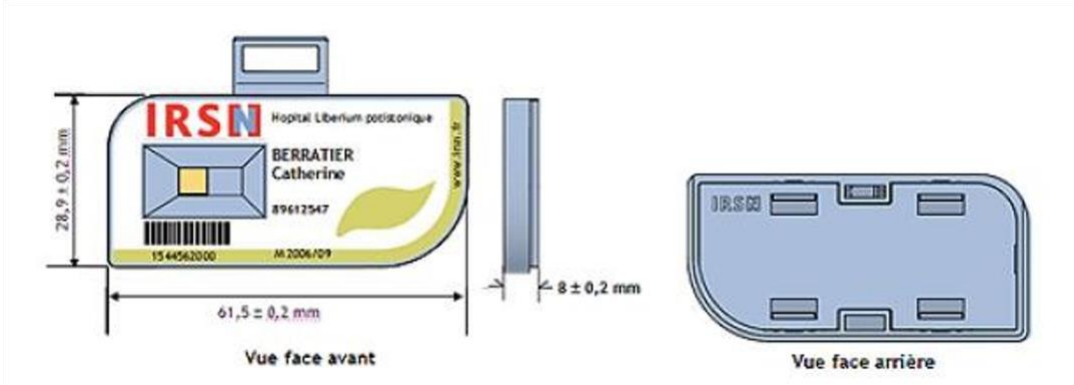

Figure 2. Dosimeter integrator from IRSN.

6.4 Mechanical Requirements

6.4.1 Mechanical

The mechanical and structural design of the Microwave Source Package shall be performed in accordance with [6].

The structural design of the Microwave Source Package shall be performed so that its components shall withstand the loads specified in [7] with the associated damage limits.

The structural design of the Microwave Source Package shall include an assessment of potential damages and failures due to seismic events categorized under SL-2 [7]. The combination of loads including earthquakes and any other loading event shall lead to no significant leakage (from oil tank and/or cooling) from the Microwave Source Package into the room where it is installed.

According to [7], the Microwave Source Package shall be structurally designed to be able to restart and operate after a SL-1 seismic event without special maintenance or test needed.

Where possible and practical, the Microwave Source Package shall be designed to prevent damage to its high-value components during seismic events, as a matter of investment protection.

Evidence of the fulfilment of the structural design criteria shall be given by the Contractor through the preparation, submission to IO, and approval by IO of a Structural Integrity Report (StIR) based on the loads and limits identified in [7].

6.4.2 Analysis

The Analysis work is specified to be an optional part of the contract. If this option is activated, the following requirements shall be fulfilled.

The Contractor shall perform seismic analysis (as part of the StIR) to demonstrate that the structural integrity of the Microwave Source Package is maintained for seismic levels defined in the Eurocode 8. This guarantees that occupational safety is ensured as per Eurocode 8 criteria [8].

The Contractor shall perform seismic analysis to demonstrate that the Microwave Source Package does not jeopardize the building structural integrity in case of a SL-2 event.

Seismic analysis shall be linear dynamic or equivalent static, depending on the methodology chosen by the Contractor.

All analyses, regardless of the type, shall follow the instructions in [8].

All analysis models, macros, etc. shall be stored on the IO Analysis Model Database in accordance with [9].

For this specific analysis task, the calculations should be performed following the Instructions for Structural Analyses [10] and the Instructions for Seismic Analyses [11].

The Contractor shall be responsible for implementation and coordination of all activities required to complete the task. This includes ensuring that Suitably Qualified and Experienced Personnel (SQEP) resources complete tasks within the proposed timescales.

The ITER Organization shall be responsible for technical input for all identified scope. This

includes the delivery of loads and boundary conditions input data.

The chosen analysis methodology shall be approved by the ITER Organization prior to commencement of the work.

The calculations should be performed using ANSYS. The use of different software may be proposed by the Contractor (e.g. anchor validation software) but will in any case require authorization in writing by IO, prior to the commencement of any analysis task.

The Contractor shall submit a draft version of analysis reports or/and models. The IO will review the draft version of the deliverables and respond within a specified period after receipt, providing a commented version of the deliverables. The Contractor shall perform all the necessary modifications or iterations to the reports and submit a revised version by the due dates specified by the IO.

IO shall be able to reproduce all reported results. To that end, the requirements in [9] shall be followed, with the following being provided with every report:

- All calculation and finite element models used for generating the reported data.
- The models shall come with all the boundary conditions (BCs), loads, and element and material properties applied, making the model ready to run. Alternatively, pre-processing subroutines or macros that apply these BCs, etc. shall be supplied, along with clear instructions for which macros need to be run in order to reproduce the reported results. In other words, the number of manual operations required to rerun the analyses shall be reduced to the strict minimum. Any manual operation that is required to rerun the analyses shall be described either in the analysis report or in a document attached to the model.
- All pre- and post-processing subroutines, macros, batch scripts, spreadsheets, etc. used in the preparation of the work.
- If macros and subroutines are used, they shall be well commented. All text shall be written in English, including names (parameters, models, files…), comments (scripts, source code…), etc. Macros and subroutines shall be documented to a sufficient extent that a user proficient in the relevant programming language can easily understand the purpose of each macro, and how different macros link to each other.
- FE models shall be attached to geometry, unless otherwise agreed in writing by IO. If macros are used for the generation of the model, these form part of the deliverables.

6.4.3 Materials

The source of material properties for design and analysis shall be either the applicable structural code or the ITER Material Properties Handbook. In case of conflict, the latter has priority. The Contractor will be provided access to the Material Properties Handbook in due course.

Materials for the components classified VQC-3A shall not damage the ITER detritiation system as per [3].

Materials for the components classified VQC-3A shall not contain halogenated materials.

With the possible exception of potential passive magnetic shielding, the use of ferromagnetic materials in proximity of the Gyrotron shall be avoided in an exclusion zone of 5 meters

(diameter).

Commercial materials shall conform to the applicable standard (ASTM, JIS, DIN etc.) for the definition of their grade, physical, chemical and electrical properties and related testing.

According to the classification, and if applicable, materials without a suitable certification from the supplier shall be tested by the Contractor to determine the relevant properties.

The Contractor shall provide a materials list at MRR preceding manufacturing, including specific requirements which will be mutually agreed with IO. The list may include the following:

- Brief description of the material and of its manufacturing process.
- Applicable standards.
- Delivery conditions (e.g., required heat treatments, cold work).
- Chemical composition.
- Required minimum, average thermal and mechanical properties at various temperatures, including the testing protocol and standards, mentioning whether the properties refer to the “as delivered” material or to the “as manufactured” material or both.
- Specific requirement on the maximum scatter band of the material properties.
- Required certificates and characterisation reports.
- Complete traceability of the materials including welding material.

Materials shall be selected to prevent the spread of fire between the fire sectors.

6.5 Electrical Requirements

The reference document for electrical requirements shall be the ITER Electrical Design Handbook (EDH) [12]-[16]. The requirements set forth in [12]-[16] and its appendices shall therefore be satisfied.

The design of the components under the scope of these specifications shall comply with the French electrical standards NF C15-100 (for low voltage equipment) and NF C13-200 (for medium and high voltage equipment), and the Arrêté du 17 janvier 1989 fixant les mesures de prévention des risques d'incendie présentés par l'épandage et l'inflammation des diélectriques liquides inflammables utilisés dans les matériels électriques - Légifrance (legifrance.gouv.fr).

Additionally, any electrical component under the scope of these specifications shall comply with the European Directive 2006/95/EC.

All electrical components shall be CE marked.

The design, manufacturing and testing of the EC system high power RF components shall refer to the relevant standards published by the International Electrotechnical Commission (IEC) and in particular to the European directive 2004/108/EC and the European directive 1999/5/EC.

Any power supplies under the scope of these specifications shall only use dry transformers to minimize fire loads in the buildings.

Electrical equipment (e.g. power supplies) shall comply with the applicable standards and be tested on the basis of their functional specifications.

EMC immunity tests shall be carried out on electronic equipment according to IEC 61000-6-2, IEC 61000-4-16 (level 3, performance criterion A).

EMC emission tests shall be carried out on electronic equipment according to IEC 61000-6-4, MIL STD 461F, method CE 101-2 (see also [15], Sections 7.2-7.5 for applicable limits related to low-voltage and high-voltage equipment that shall be respected).

Proper earthing studs shall be provided where possible.

All tests shall be carried out by independent test laboratories that have been assessed and accredited by a government-appointed National Accreditation Body as complying both with the current version of ISO 17025 and the test standards listed in these specifications.

6.6 Vacuum Requirements

The reference document for vacuum requirements shall be the ITER Vacuum Handbook [3]. The requirements set forth in [3] and its appendices shall therefore be satisfied.

6.6.1 General

According to Table 8, components classified as "G" (for Guidelines) under vacuum classification are not belonging to a specific VQC according to [3]. However, these components shall meet the requirements for UHV technology commonly found in the vacuum industry.

In particular, these components shall:

- Be cleaned, manufactured and tested to meet UHV standards found and accepted in the vacuum industry.
- Exhibit leak tightness to a rate not exceeding 10^{-10} Pa m^3/s.
- Have a maximum outgassing rate of 10^{-9} mbar l/s/cm^2 after 10 hours from initiating pump-down from atmospheric pressure.
- Be wrapped and protected so as to maintain vacuum cleanliness and prevent damage.
- Be handled in accordance with good vacuum practices.

Components classified as VQC-3A shall exhibit leak tightness to a rate not exceeding 10^{-9} Pa m^3/s air equivalent.

Components classified as VQC-3A shall have a maximum outgassing rate of 10^{-8} Pa m^3/s/m^2 after cleaning or baking.

For VQC-3A components, the maximum average surface roughness (Ra) of metallic components shall be 12.5 µm. The surface roughness is defined in accordance with ISO 4287:2000, and the measurement technique shall be electric stylus.

For VQC-3A components, the design of any vacuum component shall avoid trapped volumes in vacuum spaces which could result in virtual leaks. Communicating passages should be made between any potential trapped volume and the pumped volume.

Designs for in-vacuum bearings and sliding joints for VQC-3A components shall be subject to prior acceptance at the design stage. These should be eliminated by design wherever practical, for example by the use of flexure pivots.

Prior to manufacture the Contractor shall have an accepted leak test plan detailing the timing and type of tests to be performed during manufacture. The procedure shall describe how the leak test will be performed and include configuration diagrams and full details of the equipment to be used.

Acceptance leak tests on VQC-3A components which include joints of dissimilar materials[4] shall be subject to a minimum of three thermal cycles from ambient to the maximum possible operating temperature prior to leak testing. The time taken for any component to reach the specified bake temperature from ambient shall be less than 100 hours.

Additional requirements including (but not limited to) measurement procedures (e.g. leak testing or outgassing rate measurement), witnesses and acceptance are set forth in [3] and its appendices and shall be fulfilled.

6.6.2 Welding

All welds of vacuum boundaries shall be subject to documentation, qualification, approval and testing according to [17].

For VQC-3A components (classified so as per Table 6), the welds on the boundary shall be full-penetration welds.

Welds shall be made in such a way that they can be leak tested at the time of completion. Where leak detection is not practical at the time of completion, a test plan including provision for repair of the welds shall be submitted by the Contractor during the design stage for acceptance by IO.

Welds that cannot be inspected are not permitted for VQC-3A components.

The selected welding technique for vacuum applications (e.g. electron beam, laser or TIG welding) shall produce a clean, pore free weld with minimal oxidation. Autogenous welding shall be used where practical.

For VQC-3A components, volumetric examination of 10% of production welds shall be performed with the wall thickness limits specified in [17] (see Table 7-1), unless a method of pre-production proof sampling is agreed by the ITER IO.

For VQC-3A components, the use of liquid penetrant testing (LPT) or magnetic particle techniques shall not in general be permitted for the inspection of welds or in the inspection of weld preparations. This is because such substances may block leaks temporarily and can be difficult to remove satisfactorily.

Production welds used on all vacuum systems shall be left clean and bright but there is no vacuum requirement to machine the weld zone to match the surface finish of the parent material.

All weld regions shall be free from scale, voids, blowholes, etc., and there shall be no visible evidence of inclusions.

The design of welded joints shall be such as to avoid the risk of trapped volumes.

The size and magnitude of weld leaks found shall be reported to the IO and no weld repairs shall be carried out without prior agreement.

[4] Metallic joints shall be considered to be of dissimilar materials if the difference in linear thermal expansion coefficients over the operating temperature range of the materials comprising the joint is greater than or equal to 20%. Joints between non-metallic materials shall be considered as dissimilar.

6.6.3 Windows

Windows shall be subject to visual examination and dielectric loss tangent measurement.

6.6.4 Cleaning and Handling

A detailed Clean Work Plan shall be submitted to the IO for prior acceptance before any cleaning operations are undertaken at the Contractor's site. The plan shall specify how cleanliness will be maintained throughout the manufacturing process. It shall state when specific cleaning procedures will be applied and all of the controls which will be in place to maintain cleanliness, including handling.

Parts and sub-components shall be degreased using solvents or alkaline detergents, rinsed with demineralised water, and dried in hot gas or an oven to accepted procedures. The use of halogenated solvents is forbidden at any stage.

Abrasive techniques to clean or to attempt to improve the appearance of the surfaces of vacuum components shall be kept to an absolute minimum and are preferably avoided. The use of files, harsh abrasives, sand, shot or dry bead blasting, polishing pastes and the like is prohibited under normal circumstances and may not be used without prior agreement.

After final cleaning, the handling of vacuum equipment shall be strictly controlled to preserve cleanliness.

The post-cleaning handling of VQC-3A and G components shall happen in areas where regular housekeeping is performed, and by trained personnel using clean powder free latex or nitrile outer gloves.

The mandatory requirements relating to cleanliness during assembly of vacuum equipment are detailed in [18].

Surfaces which are to be exposed to vacuum shall only be marked or identified if necessary and shall be marked by scribing with a clean sharp point, laser scribing or electromagnetic dot peen method.

Seal faces shall not be marked in any way.

6.7 Manufacturing Requirements

Manufacturing tolerances shall be consistent with achieving the overall installation tolerances, considering inaccuracies resulting from installation and tolerances of mating components.

The MOU shall be capable of including enough flexibility for alignment with TL to be consistent with the mode purity requirement set forth in §6.2.

In order to simplify and reduce the cost of designing, integrating, operating and maintaining the plant systems, the Contractor shall use as much COTS components as possible.

6.8 Installation and Commissioning Requirements

The requirements that the Contractor shall fulfil in preparation for and in execution of the installation are set forth in §5, in particular, points 2.5, 3.1 – 3.4.

The requirements that the Contractor shall fulfil in preparation for and in execution of the commissioning of the Microwave Source Package are set forth in §5, in particular, points

4.1 – 4.2.

In addition to those, specific requirements related to installation and commissioning are hereafter identified.

In preparation for the installation, the Contractor shall be the main acting entity in the preparation of the documents needed to populate the Engineering Work Packages (EWPs) for the description of the activities to be performed during installation. The Contractor shall also collaborate in the review of the Construction Work Packages (CWPs), generated after the EWPs, and execution of the Installation Work Packages (IWPs), organized after the CWPs, as required.

For the installation, debugging and commissioning tests, IO will make available to the Contractor specific equipment such as dummy load, transmission lines or some measurement devices.

However, the Contractor shall design and procure any special equipment and tooling required for the installation, debugging and commissioning of the Microwave Source Packages at the ITER site.

The Contractor shall also determine the need of any specific equipment and tooling required for the maintenance of the Microwave Source Packages under the scope of these specifications. The information shall be submitted to IO as part of the output expected in Table 5. The procurement of the needed items shall be mutually agreed.

The different parts of the Microwave Source Package shall be compatible with the handling facilities (overhead crane characteristics are detailed in Table 12), the accessibility requirements, and the space allocated in the ITER buildings hosting the Microwave Source Package.

In the frame of works to be performed at the ITER site (installation, commissioning and SAT), the Contractor shall follow the General Management Specification for Executing Entities at the ITER Site [19]. This document (also referred to in [1]) contains the ITER specific rules concerning safety regulations applicable to works of third parties at ITER, access to and activities on the site, occupational health and safety on the site and special health and safety matters.

Maximum Crane hook height	6.25 m high (from concrete floor)
Safe Working Load (SWL)	5 t
Working Load Limit (WLL)	5 t
Span	21.928 m
Main hoist speed	0.8 & 5 m/min (15 if load < 20 % of WLL)
Cross travel speed	5 & 20 m/min
Long travel speed	8 & 32 m/min

Table 12. Main parameters of the overhead crane available in the ITER building hosting the Microwave Source Package.

6.9 Test Requirements

The test requirements are applicable to the FAT (point 2.6 of Table 4), SAT (point 4.3 of Table 4) and any test needed for any sub-component before or during the manufacturing (e.g. verification of EMC compliance, leak tests, etc.).

The FAT (point 2.6 of Table 4) shall be conducted at the Contractor's premises, and shall include at least the following steps for each of the manufactured Microwave Source Package:

1. Measurement of oscillation frequency.

2. Measurement of Gyrotron power output.
3. Validation of short- and long-pulse efficiency values.
4. Validation of reliability value.
5. Achievement of required full-power modulation.
6. Validation of mode purity requirements.
7. Validation of safety X-ray limits.
8. Validation of safety stray RF radiation limits.
9. Achievement of required magnetic field shielding, if needed.
10. Other ancillary tests (e.g. emergency cut-off test).

The success criteria of each of the described steps is closely related to the requirements set out in Table 7, and shall be formalized in a FAT procedure that shall be prepared by the Contractor.

The SAT (point 4.3 of Table 4) shall be conducted at the ITER site. The SAT procedure shall be elaborated by IO.

Vacuum testing and measurement requirements are set forth in §6.4.

Electrical testing and measurement requirements are set forth in §6.5.

6.10 Procedural Requirements

For the preparation of System Design Reviews (SDRs), the Contractor shall adhere to the design review procedures developed at IO.

For the preparation of the FDR the Contractor shall fulfil the requirements set forth in [20].

For the preparation of the MRR, the Contractor shall adhere to the related instructions set forth in [21]. The MRR shall cover:

- Material: manufacturing environmental conditions meet product technical requirements; production materials used for ITER project are correctly procured, qualified, inspected and stored; appropriate procedure/system for assuring material identification and traceability; all products designed for manufacturing shall be designated with type reference codes, i.e. PNI.
- Personnel: Contractor’s personnel who work for ITER project have been trained and evidence that IO requirements are understood is available.
- Machines and Tools: machines, jigs, measuring and testing equipment used for IO are qualified and valid for usage; specific manufacturing processes have been qualified.
- Manufacturing methods: documents relevant to ITER project are approved or accepted by IO as may be applicable, e.g. quality plan, Manufacturing and Inspection Plan (MIP), procedures, etc.
- Transportation.
- Requirements: a specific matrix is built for the component to manufacture with all the requirements (design and manufacturing ones, as well as shipping, transportation, packing) and the evidences of their fulfilment.

MRR input data package shall include documents like the following (as a guideline, some documents can be grouped, or additional documents may be present as deemed necessary – specification of input document list is given in §14):

- Manufacturing and Inspection Plan.
- Quality plan.
- Manufacturing Schedule.
- Drawings.
- MRR Plan.
- Notification.
- Agenda.
- Presentation.
- Minutes of MRR meeting (record of what has happened during the meeting).
- Panel Report (comments and decisions).

In addition, the list of documents of the input data package shall be provided. Applicable documents, namely for instance procedure documents, welding documents, Codes, & Standards, tooling related documents, certificate of personnel should be submitted as attachments of Manufacturing Plans.

Given the classification of the components listed in Table 9, the MRR shall follow the simplified procedure. In this case, the MRR Responsible party (Contractor) shall issue an MRR Plan containing the list of documents of the input data package and a detailed checklist of elements to be checked. As for the SDR, the chit system may also be simplified, allowing for actions to be recorded in the panel report and to be resolved before the MRR can be officially closed.

IO shall review the elements described in the MRR Plan and issue final MRR report to give 'go-ahead' or stop decision.

For the preparation of the DRR, the Contractor shall adhere to the related instructions set forth in [22].

Requests for deviations from any of the requirements set forth in these technical specifications, as well as IO design and/or procedural requirements, shall require a Deviation Request to be submitted by the Contractor to IO. The Deviation Request shall explain the reasons and justifications for the deviation, together with any possible impact. The approval of the Deviation Request is at the discretion of IO only.

Non-Compliance to any of the requirements set forth in these technical specifications shall require a Non-Conformity Report to be submitted by the Contractor to IO, where full explanation of the scope, extent, reason, possible remedial/preventive action(s) and root-cause analysis of the non-compliance shall be explained. The Contractor shall adhere to the related procedure [23].

6.11 Logistics Requirements

The contractor shall be responsible for the transport of the procured equipment to the ITER site in Saint-Paul-lez-Durance, France, including the packaging for the transport and the handling and storage during the transport.

The contractor shall issue, at least 10 months before the transportation to the ITER site, the "Specifications for Handling and Transportation" of all the procured components. These Specifications shall include, at least, the dimension and weight of each transported package and the detailed instructions for properly handling and transporting each package.

To this aim, the contractor shall include in each package any stress sensor and provision to make possible an effective and easy monitoring of the package conditions and to ensure that the package itself and anything included is substantially sound.

The packaging must provide adequate mechanical and environmental resistance to road and/or ship transport. The packaging must provide adequate attachments for loading and unloading by crane or equivalent lifting/moving tools and for its stable fixation on trucks and ships.

The sub-components forming the Microwave Source Package and their parts shall be packaged and loaded for overland transport respecting the size and weight limits indicated in the European Directive 96/53/CEE dated 25 July 1996. It is assumed that standard limits will be respected. If any deviation is foreseen, this shall be agreed with IO at least 18 months before the transport to Saint-Paul-lez-Durance, France. As far as possible it should be avoided abnormal (exceptional) transport.

The limitations in size and weight of the components to be transported to the ITER site, in Saint-Paul-lez-Durance, France, due to the itinerary, are listed in Table 13.

The CEL type of transport is for Conventional Exceptional Loads (CEL) that can be transported on normal roads but with special escort. If the dimensions or weight of the component exceeds the limits for CEL items, the contractor will inform IO at the tender proposal in order to apply the special provisions for the Heavy Exceptional Loads (HELs).

Type of Transport	Indicative Characteristics of ITER components			
	Max length [m]	Max width [m]	Max height [m]	Max weight [t]
Normal	5	2.5	2.5	41
CEL	19	5	5	60
HEL	19	9	9.1	600

Table 13. Limitations in size and weight of the components to be transported.

The packaging of the components, ready for shipment, shall be inspected at the manufacturer premises to verify the respect of the requirements for transport. The inspection shall consist of a visual verification of the packaging and of a review of the formal and technical documentation for transport. The inspection and documentation verification shall be performed with the presence of representatives of the contractor and IO. An official note of the inspection shall be prepared and approved by the representatives.

The handling must be performed adopting procedures that minimize the risk of damages to the components. The storage must prevent any possibility of contact with any contaminant agent.

Road and ship transports have to be performed using the most appropriate carriers in order to

guarantee component safety and delivery on time.

The contractor shall provide all the documentation requested by the local authorities to deliver the components to France.

At the arrival in the ITER site, the packaging containing the components ready for unloading shall be checked. This check shall consist in:

- Visual verification of the packaging.
- Checking of shock recorders and/or acceleration sensors prepared to monitor shocks and vibrations during transport.
- Checking of all the requested administrative documentation.

An official note of the check ("Consignment note") shall be prepared and approved by representatives of the contractor and IO.

7 Schedule

The Contractor shall execute the scope of work associated to the contract in full respect of the overall schedule foreseen for the manufacturing preparation, manufacturing, installation and commissioning of the CTS gyrotrons.

Schedule	2026		2027		2028		2029		2030		2031		2032		2033		2034		2035	
Activity	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2	H1	H2
Tender																				
Development																				
Manufacturing Preparation																				
Manufacturing																				
Installation																				
Commissioning																				

Figure 3. Contract Schedule.

The schedule is depicted in Figure 3. The key milestones to identify are:

- Start of development beginning of 2027.
- End of development by end of 2030.
- Start of manufacturing preparation beginning of 2031.
- End of manufacturing preparation by end of 2031.
- Start of manufacturing beginning 2032.
- FAT and delivery of the gyrotrons by end of 2033.
- Installation of the gyrotrons beginning of 2034.
- Commissioning of the gyrotrons beginning mid-2034.
- Installation completed by mid-2035.
- Commissioning completed by end of 2035.

8 Location for Scope of Work Execution

The Contractor can perform the work at their own location, except for installation, SAT and commissioning activities, which are performed at the ITER site (see Table 3). In this case, [1] and [19] shall be respected.

9 IO Free issue items

Under this scope of work, Table 14 lists the equipment/parts to be delivered by the IO and corresponding delivery dates.

Ref	Equipment / Part Description	Part Nr.	Expected date
1	Test waveguide (if needed – see footnote 1)	1	In time for FAT

Table 14. Equipment/parts to be delivered by the IO.

10 List of deliverables

The list of deliverables and due dates for each of the task orders will be outlined in the technical specifications of the single task orders.

Contractor is requested to prepare their document schedule using the template available in Appendix II of [1] (click here to download).

No element of work or activity shall begin without the prior written notification by the ITER Organization in the form of a Task Order signed by both Parties.

The deliverables will depend on the type of a task, but they shall be well defined before the start of the Task order in question and shall be based on the expertise requested these Technical Specifications.

The examples of the deliverables can include, but are not limited to, the following items:

1. Reports or minutes of the kick-off meeting including list of all input information and requirements.
2. Progress reports containing:
    a. Summaries of meetings and decisions,
    b. Drafts of material to be used in final reports,
    c. Issues that have arisen in the course of the work, along with suggested approaches to addressing these issues.
3. Deliverables of Task orders in the form of:
    a. Report.
    b. Technical note.
    c. Calculation Note.
    d. Any other relevant engineering or manufacturing documents, e.g. a Manufacturing and Inspection Plan (MIP).
4. Reports or minutes of the meeting for completion of the task order containing:
    a. Deliverables acceptance statement.

b. Report on outstanding issues identified during Task Order execution, forward action plan.

c. Summary of the Task Order outcome.

5. Delivery on ITER site (or other agreed location) of components manufactured under the contract.

11 Quality Assurance requirements

The Quality class under the contract is according to Table 6, thus §7 of [1] applies in line with the defined Quality Class.

12 Safety requirements

12.1 Pressure Equipment

The scope under the contract includes PE/NPE components, thus §5.3 of [1] applies.

12.2 Occupational Health and Safety

Occupational Health and Safety (OHS), that is related to the prevention or mitigation of all risks of injury or illnesses from workplace exposure other than nuclear risks, shall be considered by the Contractor in the design phase.

The Contractor shall install the Microwave Source Packages to ensure safe worker ingress and egress paths.

For high- and low-voltage electrical parts, the Contractor shall (in addition to the compliance with applicable standards during the design phase, see §6.5) implement suitable strategies to avoid exposure to electrical risks (e.g. implementing physical protection from HV components, or suitable access control and/or restrictions).

The Contractor shall implement proper signage where the magnetic field exceeds 0.5 mT (interference risk with active implanted devices such as pacemakers) and 3.0 mT (attraction and projectile risk) [24].

When active, magnetic field shall be monitored with a flashing light visible to the personnel in the vicinity of the RF source. The colour of the light shall be specified during the final design phase.

All identification, labelling and signage installed on the site shall comply with the ITER Site Signage & Graphics Standards [25].

The RF radiation coming from the Microwave Source Package shall comply with the French Safety limits that specify guaranteeing an Equivalent Power density for plane waves lower than 0.5 mW/cm^2, measured at a distance of 30 cm [26], [24].

In general, the exposure of workers to electromagnetic power shall follow the Safety Guidance in [24].

For X-rays, the Microwave Source Packages shall comply with the technical requirements required by the French Order dated 29 September 2017 and summarized in [27].

The shielding of any X-ray shall guarantee dose rates below 1 μSv/h measured at any point that

can be reached by operator in normal operating conditions. This is complemented by the Decision No 2017-DC-0591 of the ASN (devices emitting X-rays [27]).

X-ray emission will be checked during installation and periodic measurements will be performed under the IO safety division responsibility.

Specific design provisions shall be undertaken by the Contractor to avoid that solid, liquid and gaseous toxic products affect workers during normal operations and to avoid spread of these materials into rooms accessible to workers. These provisions must consider potential corrosive, inflammable and explosible issues associated with these toxic products.

Any toxic material contained in any component of the Microwave Source Package and any specific requirement for disposal shall be specified at the final design stage.

The operation manual shall include a set of operating instructions that define safe operation for personnel and equipment in the vicinity of the Microwave Source Package.

13 Specific General Management requirements

Requirements specified in §6 of [1] fully apply with the following complementation.

13.1 Meeting Schedule

The KOM can be either in-person or remote.

A progress review meeting is to be held on a bi-weekly basis between the Contractor representative and CRO with the appropriate support of relevant stakeholders.

13.2 CAD design requirements

The contract requires CAD activities, thus §6.2.2.2 of [1] applies.

14 MRR Document Package

Table 15. List of documents to be supplied as part of the MRR document package

Doc #	Document Title	Comments
1	MRR Document Production plan	
2	Manufacturing description	
3	Final Installation/Integration/Alignment Plan	1 or more documents as needed
4	Special process qualification plan	Per process being qualified (welding, hipping, coating, etc.)
5	System Final design drawings	To be presented at MRR
6	Documents related to engineering analyses	When needed, if changes on geometry are proposed
7	Analysis validation / Independent verification	If needed
8	Test Plan	If needed
9	FAT Plan	
10	Manufacturing and Inspection Plan (MIP) template	Agreed template to be used during manufacturing (including agreement with IO on PIAs and associated IO surveillance)
11	Certificates of specific product control	(inspection certificate type 3.1 or 3.2)

Doc #	Document Title	Comments
12	Marking procedure for material identification	
13	Marking procedure for equipment identification	
14	Special process qualification procedures	A document for all applicable process: Welding, joining, coating, corrugation, machining, gun-drilling, etc
15	List of Suitably Qualified and Experienced Personnel (SQEP matrix)	
16	Welding Data Package	See Note 1
17	Cleaning procedure	
18	Cleaning final report	
19	Preservation plan	
20	Manufacturing and Inspection Plan (MIP)	
21	Inspection Plan (MIP)	
22	Implementation plan for dimensional control	
23	Calibration procedures	
24	Instruments calibration certificates	As needed for all instruments (for dimensional control, NDT examinations, etc)
25	Testing plan	
26	Examination procedures	As needed for all examinations (e.g. visual inspection, surface roughness)
27	NDT procedures	As needed for all NDT (e.g. liquid penetrant radiographic, ultrasonic)
28	Testing procedures	As needed for all tests to be performed (functional tests, leak rate, thermal cycling, leak rate, pressure test, outgassing)
29	Testing records (including NDE, dimensional control, etc…)	As needed for all performed tests (functional tests, leak rate, thermal cycling, leak rate, pressure test, outgassing, etc)
30	Procedure for packing, handling and storage	Prior to packaging
31	Inspection Plan (MIP)	As needed for packing, handling, transportation, storage, etc
32	Contractors Release Note	
33	Transport Delivery Report	