CLASSIFICATION **Export Control**	iDOCS UID **US_D_22T3KD**	ICP Number **ITER_D_2T5ZYN**
EXTERNAL REFERENCE	VERSION CREATED ON / VERSION / STATUS **25 Jun 20 / 5.0 / Approved**	
PA DESIGN DOCUMENT TYPE **Component Technical Specifications**		

PA/TA NUMBER(s)
5.2.P2.US.01.0

Technical Specification for ECH TL Gyrotron Conditioning RF Load - EXPORT CONTROL

Abstract or description:

This Technical Specification defines the technical requirements for the ECH TL Gyrotron Conditioning RF Load to be used for daily conditioning of gyrotrons in the ITER ECH TL system. The ECH TL Gyrotron Conditioning RF Load consists of a water-cooled dummy load (including pre-load, if required), structural supports, cooling and vacuum connections, and fiber optic connections for use with an arc detection system.

Workflow Role	*Name*	*Action*
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Final
Configuration Baseline

	Freudenberg K. **Rasmussen D.** **Rossano G.**	**01 Jul 20:recommended** **29 Jun 20:recommended** **29 Jun 20:recommended**
Approver	**Vetter K.**	**01 Jul 20:approved**

Final
Configuration Baseline

Change Log			
Technical Specification for ECH TL Gyrotron Conditioning RF Load - EXPORT CONTROL (22T3KD)			
Version	***Latest Status***	***Issue Date***	***Description of Change***
v1.0	OBSOLETE (Signed)	03 Jul 14	
v2.0	OBSOLETE (Revision Required)	28 Jan 20	Updated requirements to be consistent with the sSRD, sLS, and final space reservation.
v2.1	OBSOLETE (Approved)	30 Jan 20	Updated document reference list to match order of use in document and updated table of contents. Change Vacuum Handbook version to v2.5. Added reference 3.1.7 for Machinery Directive. Changed reference 3.1.10 to the Corrugation detail drawing. Added requirements 4.2.11, 4.2.12 and 4.3.6. Deleted the original 8.1.1 requirement, and reworded other requirements in section 8. Added additional description to Appendix A to address waveguide interface to the space reservations
v3.0	OBSOLETE (Approved)	10 Mar 20	Updated version number on drawing reference 3.1.9.
v4.0	OBSOLETE (Signed)	03 Jun 20	Revision issued to make document Configuration Baseline - Final. Added Document Title to reference document 3.1.18. Corrected reference to Table 4-3 in section 4.10.1 (from Table 4-2). Corrected reference number in section 6.7.6 (changed to 3.1.18 from 3.1.4). Corrected reference number in section 8.2.1 (changed to 3.1.21 from 3.1.19). Corrected maximum allowable coolant pressure drop (changed to 0.5 MPa from 0.6 MPA). Corrected cooling water nominal supply pressure to 0.8 MPa (from 0.85 MPA) in section 4.10.5. Corrected cooling water nominal return pressure to 0.3 MPa (from 0.25 MPA) in section 4.10.6
v4.1	OBSOLETE (Approved)	04 Jun 20	Corrected numbering of figures in Appendix A to be Figures A-1 and A-2 (were Figures 1 and 2). Corrected numbering of table in Appendix B to be Table B-1 (was Table A-1).
v5.0	CURRENT (Approved)	25 Jun 20	Deleted requirement 4.11.1 giving the equation for calculating reliability as the required reliability is given in requirement 4.11.2. Based on the IO TRO input, changed the RF load reliability from 98% to 95% in requirement 4.11.2.

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1 INTRODUCTION

The ITER Electron Cyclotron Heating (ECH) Transmission Line (TL) system includes radio frequency (RF) Loads that provide a means of absorbing the output microwave power generated by a gyrotron. These RF Loads are used for daily gyrotron conditioning before plasma operations. During conditioning operations, an RF Load maintains vacuum while absorbing microwave power generated by the gyrotron.

2 SCOPE

This Technical Specification defines the technical requirements for the ECH TL Gyrotron Conditioning RF Load to be used for daily conditioning of gyrotrons in the ITER ECH TL system. The ECH TL Gyrotron Conditioning RF Load consists of a water-cooled dummy load (including pre-load, if required), structural supports, cooling and vacuum connections, and fiber optic connections for use with an arc detection system. Hence forth in this Technical Specification, the ECH TL Gyrotron Conditioning RF Load will be referred to as simply the RF Load.

3 DOCUMENTS

3.1 References

3.1.1 ECH&CD Transmission Line Component Quality Classification. ITER_D_35R67C v3.3

3.1.2 ESP, French Decree 2015-799 of 1st July 2015

3.1.3 ITER Vacuum Handbook, ITER_D_2EZ9UM v2.5

3.1.4 ITER Vacuum Handbook Appendix 4 Accepted Fluids, ITER_D_2ELN8N v1.14

3.1.5 Codes and Standards for ITER Mechanical Components, ITER_D_25EW4K v4.0

3.1.6 Procedure for the Selection and Modification of the Codes and Standards, ITER_D_46A9KC v2.2

3.1.7 Machinery Directive, Directive 2006/42/EC

3.1.8 ECH Vacuum Matching Optical Unit (MOU) Pumping System – Dummy Load Pumping Assembly Drawing, ITER_D_23DDKL, v4.0

3.1.9 ECH TL 50mm Waveguide Generic Connection Details Drawing, US_D_23L9Z4 V5.0

3.1.10 ECH TL 50mm Waveguide Corrugation Details, US_D_23FFMT, v4.0

3.1.11 Low Voltage Directive 2014/30/EU

3.1.12 Electromagnetic Compatibility Directive 2014/30/EU

3.1.13 IS-26.CC-52-001, ITER_D_34NQG7, v2.11

3.1.14 Load Specification of EC TL, ITER_D_6YF5H5 v3.0

3.1.15 ITER Vacuum Handbook, Appendix 3 Materials, ITER_D_27Y4QC v1.20

3.1.16 ASME Boiler and Pressure Vessel Code Section IX 2013.

3.1.17 ITER Vacuum Handbook Appendix 8 Flanges, ITER_D_2DJYQA v2.5

3.1.18 ASME B31.3-2014 Process Piping, Appendix X Rules for Expansion Joints

3.1.19 ITER Vacuum Handbook Appendix 13 Cleaning and Cleanliness, ITER_D_2ELUQH v1.2

3.1.20 ITER Vacuum Handbook Appendix 17 Guide to Outgassing Rates and Measurement, ITER_D_2EXDST v2.2

3.1.21 ITER Vacuum Handbook Appendix 12 Leak Testing, ITER_D_AKEFTF v1.0

3.2 Acronyms

CCWS Component Cooling Water System
ECH Electron Cyclotron Heating
QC Quality Classification
NC No Classification
NSC Non-Seismic Category
RF Radio Frequency
SIC Safety Important Classification
TL Transmission Line
VQC Vacuum Quality Classification
WT Wall Thickness

4 TECHNICAL REQUIREMENTS

4.1 Classification

4.1.1.1 The RF Load shall be designed to the classifications in Table 4-1.

Table 4-1. RF Load Classification

No.	Category	Classifications	Reference
1	Quality class	QC3	3.1.1
2	Safety important class	Non-SIC	3.1.1
3	Seismic classification	NSC	3.1.1
4	Vacuum classification	VQC3A	3.1.1
5	Tritium classification	NC	3.1.1
6	Pressure category	0	3.1.2
7	Fluid group	2	3.1.2
8	Fluid type	Water	3.1.2

4.2 Functional and Performance Requirements and Design Criteria

4.2.1 The RF Load shall be capable of operating with a maximum input power of 0.96 MW.

4.2.2 The RF Load shall be capable of operating at a maximum pulse length of 10 s with a 10% duty cycle.

4.2.3 The RF Load shall be capable of operating with a maximum average power of 0.15 MW.

4.2.4 The RF Load shall operate with 170.00 ± 0.3 GHz frequency power.

4.2.5 The RF Load shall reflect < 0.5% of the input power back into the transmission line.

4.2.6 The RF Load reflected power coupled to the HE_{11} mode shall be < 0.5% of the input power.

4.2.7 The RF Load shall be capable of operating with an input mode purity greater than 90% HE_{11} for pulse lengths > 1 s.

4.2.8 The RF Load shall be capable of operating with an input mode purity greater than 80% HE_{11} for pulse lengths ≤ 1 s.

4.2.9 The RF Load shall be designed for a total operating time of 60 hours at maximum power.

4.2.10 The RF Load shall be designed for 30,000 full power cycles of ≤ 100 ms and 30,000 full power cycles > 100 ms but ≤ 10 s.

4.2.11 The RF Load shall be compatible with a 1.0-MW beam modulated at full power (ON/OFF) in the range from 0 to 15 Hz, 100 Hz to 1 kHz, and partial power modulation (depth down to 50%) from 1 to 5 kHz.

4.2.12 The RF Load shall not emit microwave radiation exceeding 0.5 mW/cm^2 measured at 0.30 m.

4.3 General

4.3.1 The RF Load shall be designed to comply with the *ITER Vacuum Handbook* [Ref. 3.1.3].

4.3.2 Cutting fluids and solvents used shall be selected from Appendix 4, Accepted Fluids, of the *ITER Vacuum Handbook* [Ref. 3.1.4].

4.3.3 Ferro-fluidic feedthroughs shall not be used.

4.3.4 The design shall ensure that stray microwave leakage into the vacuum duct shall be less than 10 mW under normal operations.

4.3.5 The codes and standards for the design, assessment, and final validation of the TL components, supports, and auxiliaries are to be consistent with Table 1 of *Codes and Standards for ITER Mechanical Components* [Ref. 3.1.5].

Pressure Vessel	ASME Section VIII Div. 2
Piping	ASME B31.3
Supports	ANSI/AISC 360
	ANSI/AISC N690

Where the codes and standards outlined in [Ref. 3.1.5] do not directly apply, the technical specifications for the components shall be considered. In instances where an applicable code or standard is not defined or where an exception is desired, the *Procedure for the Selection and Modification of the Codes and Standards* [Ref. 3.1.6] shall be used to define the applicable code or standard.

4.3.6 In the event that powered hardware is used for the RF, the load must comply to the Machinery Directive 2006/42/EC [Ref. 3.1.7]

4.4 Dimensions, Weight, and Support

4.4.1 The RF Load body, including connections, supports, and pre-load, if required, shall fit within the volumes shown in APPENDIX A.

4.4.2 Total weight of the RF Load, water, piping, cubicles, instrumentation, controllers, structural framework, and intermediate steel work shall not exceed 500 kg.

4.4.3 Structural framework shall be provided to maintain the integrity of the RF Load during operation and handling conditions.

4.4.4 The RF Load shall have precision mechanical adjustment (relative to the axis of the input waveguide) of at least ± 25 mm vertically, transversely and axially to accommodate aligning the load input flange to the input waveguide.

4.4.5 The RF Load shall have precision mechanical adjustment (relative to the axis of the input waveguide) of at least ± 5° vertically, transversely and to accommodate aligning the load input flange to the input waveguide.

4.4.6 Lifting points, such as welded attachments or threaded holes, shall be provided to facilitate the movement of the load via crane and fork truck. Lifting point locations shall consider the orientation of the RF Load during shipping and during installation.

4.4.7 The dimensions of the overall RF Load and all additional items mentioned in Section 4.4.2, shall be built and configured to allow six RF Load sets to fit in the B15 South Wall Load Configuration. Dimensions for RF Load configuration shown by Figure A-1 in APPENDIX A.

4.4.8 The dimensions of the overall RF Load and all additional items mentioned in Section 4.4.2, shall be built and configured to allow six RF Load sets to fit in the B15 North Wall Load Configuration. Dimensions for RF Load configuration shown by Figure A-1 in APPENDIX A.

4.4.9 The dimensions of the overall RF Load and all additional items mentioned in Section 4.4.2, shall be built and configured to allow twelve RF Load sets to fit in the B15 Center Position Load Configuration. Dimensions for RF Load configuration shown by Figure A-1 in APPENDIX A.

4.5 Vacuum

4.5.1 There shall be no trapped volumes within the vacuum envelope of the RF Load.

4.5.2 The input vacuum connection to the RF Load shall be DN40 CF flange with thru bolt holes [Ref. 3.1.8].

4.5.3 The maximum internal pressure during operation shall be 1.5 Pa (absolute).

4.5.4 The conductance at the RF Load vacuum port flange is shall be ≥ 5 l/s.

4.5.5 The internal absorbing coating shall be TiO_2 or other ITER-approved material.

4.5.6 The maximum average surface roughness for vacuum surfaces shall be 12.5 µm Ra, except for TiO_2 coated surfaces.

4.5.7 All joints between vacuum and water must be welded.

4.5.8 All mechanical vacuum joints must use all metal seals.

4.6 Waveguide Input Connection

4.6.1 The waveguide input connection to the RF Load shall be compliant with the male waveguide connection design as shown in Ref. 3.1.9.

4.6.2 The input waveguide inner diameter (ID) shall be 50.00 ± 0.04 mm and shall be corrugated per Ref. 3.1.10.

4.6.3 The RF Load shall accommodate thermal expansion/contraction of the waveguide connected to the load of ± 2 mm.

4.6.4 Any miter bend required to connect the Company provided waveguide to the RF Load shall be part of the RF Load.

4.6.5 The waveguide connecting to the load shall enter the space reservation as shown by Figure A-1 in APPENDIX A. The interface point between the waveguide and the RF Load can be anywhere along the axis of the waveguide.

4.6.6 The vendor shall specify where the waveguide to RF Load interface is along the axis that is described in requirement Section 4.6.5.

4.7 Arc Detection

4.7.1 The RF Load shall be supplied with fiber optic vacuum feedthroughs for arc detection utilizing 2 mm fibers with F-SMA connectors.

4.7.2 The fiber optic connections must allow monitoring of the internal coatings in all bounce regions, and all reflecting mirrors.

4.7.3 A minimum of two fiber optic arc detection connections shall be provided.

4.8 Instrumentation and Controls

4.8.1 It is expected that for the 10-s max pulse length RF Load, with an average power of 100 kW, that a control system will not be required, but if the RF Load requires a control system for safe operations, this control system shall meet the following requirements:

4.8.1.1 The control system shall provide local and remote operations capability.

4.8.1.2 The control system shall provide an Emergency OFF interlock to protect the RF Load.

4.8.1.3 A mode switch shall be provided to change operating states between ON/Off/Local/Remote.

4.8.1.4 The local control system shall have the following hardwired remote interfaces:

- Dry contact closure to interlock the RF Source. A CLOSED contact shall be presented when RF operation is permitted.
- Remote ON/OFF control of the RF Load using a required 24 VDC signal
  - Remote operation will be permitted only when:
    - Remote operation is selected with a Mode Switch and
    - A 24 VDC signal is activated by supplied equipment.

4.8.1.5 The local control system shall have the following remote interfaces via software:

- PROFINET protocol shall be used for remote communications.
- The following remote functions shall be provided:
  - Remote ON/OFF to control the RF Load.
  - Status of the Mode Switch (ON/OFF/LOCAL/REMOTE).
  - Status of the RF Load interlocks.

4.8.2 All equipment associated with the RF Load shall accommodate up to 90 m cable lengths for cable tray routing.

4.9 Electrical Power Supply

4.9.1 The electrical requirements of the equipment shall conform to the relevant guidelines given in the Low Voltage Directive [Ref. 3.1.11] and the Electromagnetic Compatibility Directive [Ref. 3.1.12].

4.9.2 The RF Load AC power input voltages shall be compatible with line voltages between 100 – 240 V and frequencies of 50 – 60 Hz. Voltage and frequency shall be compatible for use in the United States and European Union.

4.9.3 The RF Load shall require not more than 1 kW of electrical power.

4.9.4 The displacement power factor shall be higher than 0.8.

4.9.5 The total harmonic distortion introduced to the steady state electrical network shall be less than 8%.

4.10 Erosion/Corrosion and Cooling

4.10.1 The cooling water circuits shall be designed for a 20-year operating life, including erosion/corrosion with the CCWS-2A water quality parameters in Table 4-3.

4.10.2 The cooling water input and output connections shall be of the DN65 bolted flange type.

4.10.3 The maximum coolant input pressure shall be 1.0 MPa.

4.10.4 The maximum allowable coolant pressure drop across the load shall be 0.5 MPa.

4.10.5 The nominal supply pressure shall be 0.8 MPa.

4.10.6 The nominal return pressure shall be 0.3 MPa.

4.10.7 The maximum coolant input temperature shall be 31°C.

4.10.8 The maximum coolant flow rate shall be 10 kg/s.

4.10.9 Cooling system fittings shall be 304L/316L stainless steel.

4.10.10 RF Load shall be equipped with vent connection at high point in cooling water circuits.

4.10.11 RF Load shall be equipped with drain connection at low point in cooling water circuits.

4.10.12 RF Load must be completely drainable in its installed orientation.

4.11 Reliability and Operating Conditions

4.11.1 The equipment shall be designed to operate for the expected 20-year lifetime of the ITER facility (plasma operation) at the conditions identified in Table 4-2 and with the CCWS-2A water quality parameters listed in Table 4-3.

4.11.2 The RF Load shall have a reliability, R(t), of 95% for the expected 20-year lifetime of ITER.

Table 4-2. Functional Performance Requirements for the RF Load

Parameter	**Requirement**
Operating Conditions	
ITER lifetime (commissioning plus plasma operation), year	20
Environmental Conditions	
Temperature (°C)	10 - 35
Absolute pressure (MPa)	0.1
Humidity (%)	≤ 85
Safety	
Maximum internal pressure (absolute) (MPa)	≤0.2

Table 4-3. CCWS-2A Water Quality Parameters

Parameter	**CCWS-2A**
pH @ 25°C	6.5– 9.5
Water conductivity @ 25°C, maximum, µS/cm	≤1.0
Dissolved oxygen concentration, maximum, µg/kg	≤20
Chloride, maximum, µg/kg	≤10
Iron, maximum, µg/kg	≤10

Copper, maximum, µg/kg	≤10
Sodium, µg/kg	≤10

Source: [Ref. 3.1.13]

4.12 Loads

Complete descriptions of the load combinations and the single load cases for the RF Load are given in Appendix B.

4.12.1 For each load category, the damage limits permitted at the component level shall be considered. The damage limits applicable to the component are provided in Table 4-4. (This section is consistent with §2.2 of *Load Specification of EC TL* [Ref. 3.1.14].)

Table 4-4. RF Load damage limits

Load category	Condition	Damage limits at component level
Cat. I	Normal/Design/Test	The component should maintain specified service function.
Cat. II	Upset	The component must withstand these loadings without significant damage requiring special inspection or repair.

4.12.2 The load combinations listed in Table 4-5 shall be considered in the design and analysis of the RF Load.

Table 4-5. RF Load load combinations

No.(1)	Operating conditions	Initiating event	Concatenated events	Cat.	# of events
	-	Assembly & pretension	-	I	Static
I.1	DW, Po, Atm, To, Tr (Normal Operation)	-	-	I	Static
II.10	DW, Po, Atm, To, Tr (Normal Operation)	SL-1	-	II	5

Notes:

1) Unless noted otherwise, loads shall be considered concomitant in time with the maximum values of the responses combined algebraically. This is a conservative assumption considering the dynamic nature of certain loads. A different combination method shall be justified.

5 MATERIALS

5.1.1 Acceptable materials for use in vacuum or for forming vacuum boundaries are listed in the materials portion of the Vacuum Handbook Annex [Ref. 3.1.15].

5.1.2 Materials shall comply with the requirements of the applicable codes and standards selected for design and construction.

5.1.3 The maximum Steady State Outgassing Rate for materials used in vacuum shall be 1 x 10^{-8} ($Pa \cdot m^3 \cdot s^{-1} \cdot m^{-2}$) at 20°C.

5.1.4 All materials used in the construction of the RF Load and associated equipment, including the supporting structure shall be non-magnetic.

5.1.5 The RF Load and associated equipment may not emit a magnetic field.

5.1.6 Mechanical vacuum seals shall be made of metal.

5.1.7 All wetted metallic surfaces shall be 316L/304L stainless steel or copper alloy.

5.1.8 Halogenated materials shall not be used within the Tokamak building or in vacuum components connected to the Tokamak building.

6 FABRICATION PROCESSES

6.1 Joining Processes

6.1.1 All joining processes shall be qualified according to the applicable design and construction code.

6.1.2 Permitted joining techniques for vacuum applications are shown in Table 6-1. Proposals for joining techniques not listed require prior approval.

6.1.3 The use of liquid dye penetrant or magnetic particle techniques are not permitted for the inspection of vacuum boundary joints or in the inspection of joint preparations.

Table 6-1. Joining methods

	VQC 3	
	A	B
Welded joints	✓	✓

Brazed/soldered joints	✓	✓
Diffusion bonding	✓	✓
HIP	✓	✓
Compression joints	✓	✓
Adhesive bonding	✝	✝
Explosion bonding	✓	✓

✓ Indicates an acceptable technique.
× Indicates an unacceptable technique.
✝ Application-specific acceptance required.

6.2 Welded Joints

6.2.1 All welds shall be qualified, produced, and inspected in accordance with ASME Section IX [Ref. 3.1.16] (or equivalent), or the applicable design and construction code.

6.2.2 On the boundary between vacuum and air or vacuum and water, full-penetration welds shall be used.

6.2.3 Welds forming a vacuum or water boundary shall be made in such a way that they can be leak tested at the time of completion.

6.2.4 Production welds used on all vacuum systems shall be left clean and bright.

6.2.5 All repair welds forming part of a vacuum boundary shall be qualified in accordance with ASME Section IX [Ref. 3.1.16] (or equivalent) or the relevant design and construction codes.

6.3 Brazed and Soldered Joints

6.3.1 Brazed joints shall be qualified, produced, and inspected in accordance with ASME Section IX [Ref. 3.1.16] (or equivalent), or the applicable design and construction code.

6.3.2 Brazing shall be carried out in a vacuum, hydrogen, or inert gas atmosphere. Where the use of brazing flux is unavoidable, a cleaning procedure shall be qualified.

6.3.3 Brazing shall not be used for any water to vacuum joint.

6.3.4 Soft soldering (<400°C with Sn, Zn, alloys of Pb, Cd, etc.) shall not be used for vacuum boundaries.

6.3.5 Vacuum exposed braze shall be clean, flush and free from voids, blowholes, and visible evidence of inclusions. The braze material shall fill the joint without excessive over-run.

6.3.6 Brazed joints that form part of a vacuum boundary shall be subject to 100% helium leak testing.

6.3.7 Brazed joints shall not be reflowed.

6.4 Diffusion Bonding

6.4.1 Diffusion bonding of joints is acceptable.

6.4.2 Diffusion bonded inter-layers shall comprise materials listed in [Ref. 3.1.15].

6.4.3 Diffusion bonded joints shall be qualified, produced, and inspected in accordance with ASME Section IX [Ref. 3.1.16] (or equivalent), or the applicable design and construction code.

6.5 Explosion Bonding

6.5.1 Explosion bonding of metals is acceptable.

6.5.2 Explosion bonded joints shall be qualified, produced, and inspected in accordance with ASME Section IX [Ref. 3.1.16] (or equivalent), or the applicable design and construction code.

6.6 Demountable Joints

6.6.1 Demountable vacuum joints (e.g., quick release couplings, compression joints, transition couplings, flange pairs) shall use all-metal seals.

6.6.2 Demountable joints shall not be used for water-to-vacuum boundaries.

6.6.3 Demountable vacuum joints for use on ITER vacuum systems are listed in [Ref. 3.1.17].

6.6.4 All demountable vacuum joints shall be subject to 100% helium leak testing.

6.6.5 All demountable joints must be accessible for maintenance and helium leak testing.

6.6.6 Seal faces shall not be electropolished. Seal faces must have the requisite surface finish and cutting lay or lap direction for the seal design.

6.7 Bolts, Fasteners, Bellows

6.7.1 All fasteners shall be metric.

6.7.2 Bolts for use in the formation of a vacuum boundary shall satisfy the mechanical properties to provide the calculated seal force requirements per the seal manufacturer's specification.

6.7.3 Threaded fasteners shall be treated to prevent seizing. Approved solid (dry) lubricants, aluminum bronze inserts, or coatings are preferred.

6.7.4 Lubricants shall be Solid (dry) lubricants or coatings. Permitted lubricating materials are listed in Appendix 4, Accepted Fluids, of the *ITER Vacuum Handbook* [Ref. 3.1.4].

6.7.5 The use of bellows or flexibles in water circuits inside vacuum systems is not allowed.

6.7.6 Formed circular bellows shall be designed to the ASME B31.3 Appendix X [Ref. 3.1.18] or equivalent design code.

6.7.7 Edge welded bellows shall comply with the requirements for welded joints.

7 CLEANING AND HANDLING

7.1.1 All components, including waveguide corrugations, shall be free of burrs, metal chips, fluids, and have rounded corners to reduce the chance of arching.

7.1.2 Parts and sub-components shall be cleaned and degreased, with a procedure consistent with [Ref. 3.1.19], to meet the maximum steady state outgassing rate in requirement Section 5 as measured per [Ref. 3.1.20].

7.1.3 The use of files, harsh abrasives, sand, shot, dry bead blasting, polishing pastes and the like is shall not be used on surfaces of vacuum components.

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

8 QUALITY ASSURANCE

8.1 Testing, and Inspection

8.1.1 Testing and inspection procedures shall comply with applicable design and construction codes.

8.1.2 Material certifications shall be compliant to EN 10204 (or equivalent).

8.1.3 For vacuum boundaries, volumetric examination of 10% of production welds shall be performed with the wall thickness limits specified in Table 8-1, unless a method of pre-production proof sampling is approved.

Table 8-1. Range of wall thickness and preferred volumetric examination method to be applied

Wall thickness (wt) (mm)	Preferred volumetric examination method
wt < 8	Radiography
8 < wt < 19	Radiography and ultrasonic
wt > 19[a]	Ultrasonic or radiography

[a] For wt > 19 mm, ultrasonic examination of welds is preferred if radiographic examination would require excessive exposure times.

8.2 Leak Test

8.2.1 Helium leak test procedures shall be consistent with Ref. 3.1.21.

8.2.2 All vacuum sealing welds shall be subject to helium leak testing.

8.2.3 Before vacuum leak testing, components shall be cleaned and dried.

8.2.4 Leak testing shall be performed after pressure or hydrostatic testing.

8.2.5 Welded vacuum joints, or other joints as listed in Table 6-1, shall go through 3 thermal cycles to operating temperature before leak testing.

8.2.6 The maximum acceptable leak rate for the load assembly is 10^{-9} Pa·m^3/s air equivalent.

8.2.7 For an acceptance helium leak test, the helium concentration around the test piece shall be at a minimum of 50% for the duration of the test.

8.2.8 Acceptance leak tests on components that include joints of dissimilar materials shall be subject to a minimum of three thermal cycles from ambient to the maximum possible operating temperature prior to leak testing.

8.2.9 The leak test shall be repeated after any repair or rework.

8.3 Calibration

8.3.1 Measurement and test equipment shall be calibrated, and calibrations shall be up to date.

9 PACKAGING, HANDLING AND SHIPPING

9.1 Packaging

9.1.1 The equipment shall be packaged, handled, and shipped to prevent mechanical or physical damage to it during transit in accordance with the Vacuum Handbook [Ref. 3.1.3].

9.1.2 Components shall be packed with adequate protection from thermal or mechanical stresses that may adversely affect the operation of the component.

9.1.3 All vacuum components shall be shipped dry (defined as <100 ppm water at ambient pressure and temperature), both internally and externally.

9.1.4 Volumes that have been pumped for helium leak testing shall be backfilled with dry nitrogen or dry air (<100 ppm H_2O) at a positive pressure of 0.1 MPa gage and sealed or valved off.

9.2 Transportability

9.2.1 The equipment shall be packaged in a manner that facilitates movement, loading, and unloading by fork truck or crane. Any lifting fixtures or related hardware required to move, load, unload or install the equipment shall be considered part of the equipment.

9.3 Nameplate and Product Marking

9.3.1 The equipment shall be permanently marked to include the following information:

- Manufacturer
- Model number
- Serial number
- CE marking (if required by applicable EU Directives)

9.3.2 Surfaces that are to be exposed to vacuum shall only be marked or identified if necessary and shall be marked only by scribing with a clean sharp point or by a laser scribing method. Seal faces shall not be marked in any way. Dyes, marker pens, paints, etc. shall not be used on surfaces that will be exposed to vacuum.

9.4 Storage

9.4.1 Equipment shall be protected from damage during storage. Provisions shall be identified and implemented to ensure that the equipment is thoroughly drained and dried of all water prior to transport to prevent damage due to freezing. Vacuum surfaces shall be protected by pressurizing the vacuum portion of the equipment with dry nitrogen.

APPENDIX A – RF LOAD SPACE RESERVATION AND WAVEGUIDE INTERFACE LOCATION

The space available for the RF Loads in the ITER RF building is defined by the three space reservation boxes shown in Figure A-1. In each space reservation, the waveguide entering the space is shown at 630 mm above the floor with its distance from the edge of the box. The waveguide enters the space reservation normal to the surface. The waveguide can be specified to end anywhere along this axis within the space reservation. The positioning of these load space reservations in the ITER RF building level 3 is shown in Figure A-2.

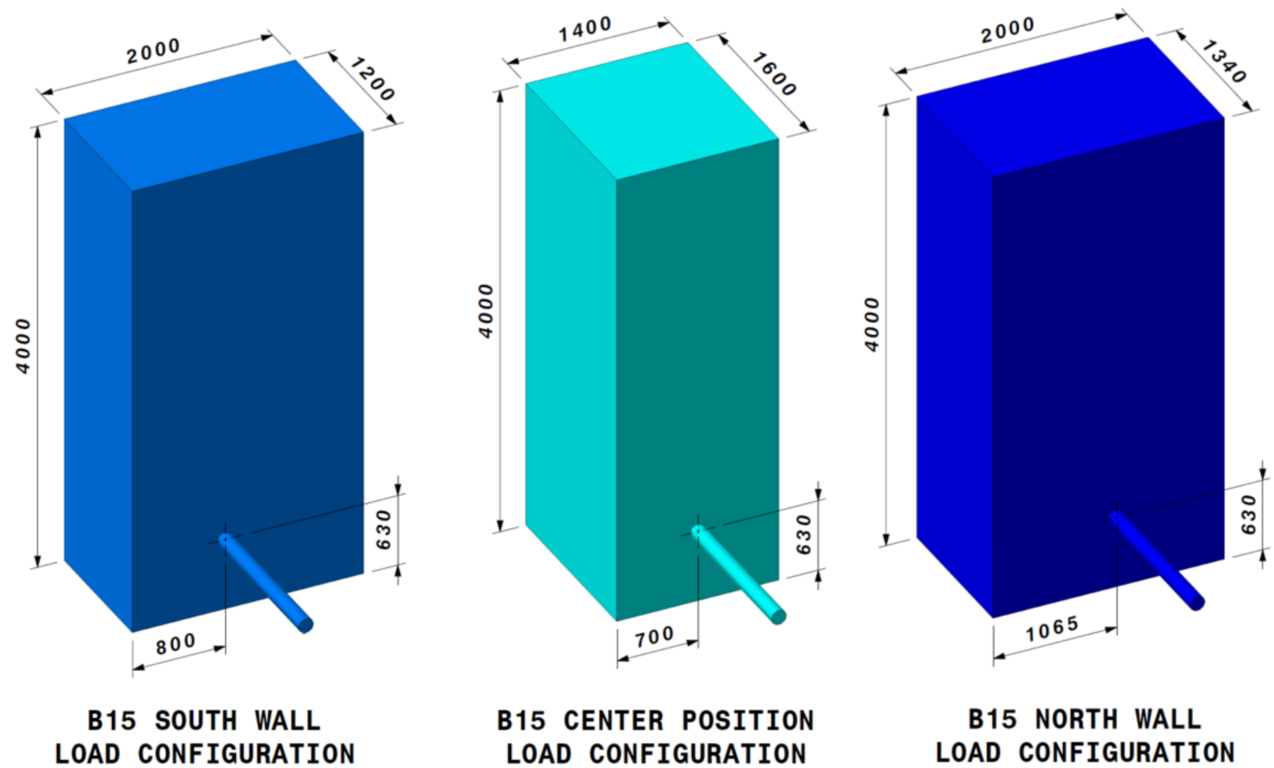

Figure A-1. Space Reservations for the 3 different RF Load Configurations.

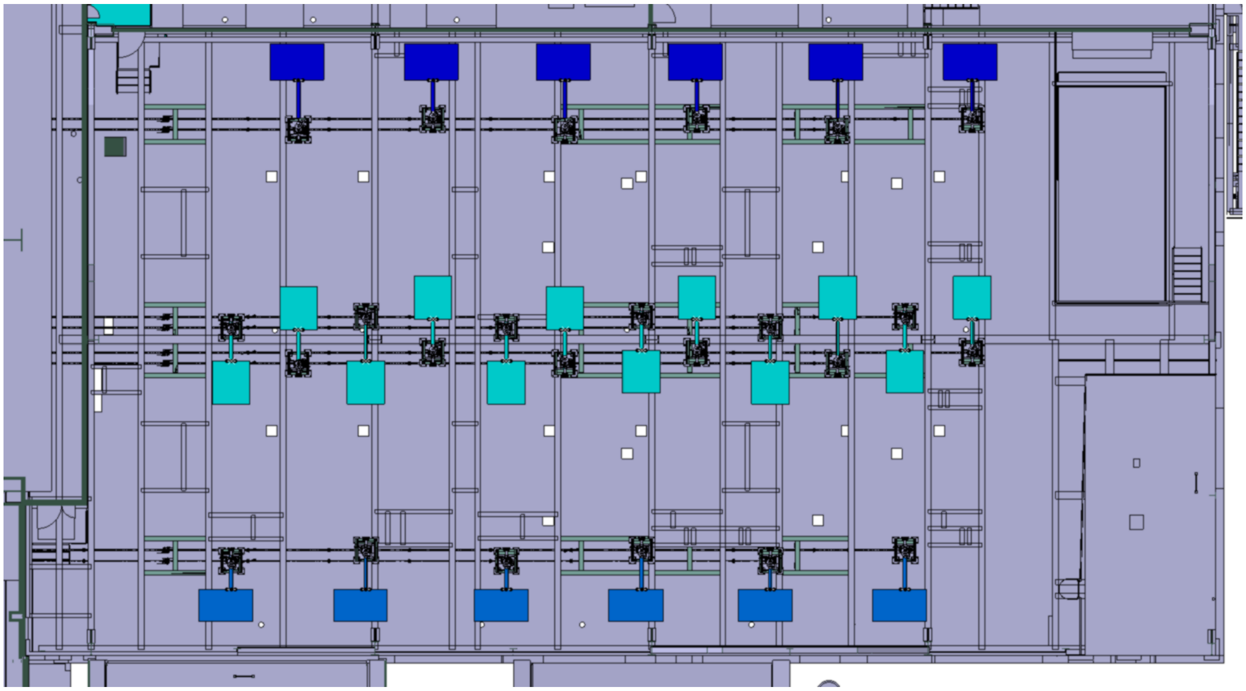

Figure A-2. Layout of the RF Loads in Building 15. Color coordination with the three space reservations shown in Figure A-1.

APPENDIX B – LOADS

B.1 Single Load Cases

Table B-1 provides a list of the main loads applicable to the component. See the sections below for more information about the individual load cases and their application.

Table B-1. ECH MOU-TL adapter characteristic loads

Load event	Characteristic load
Assembly & pretension	Load due to the assembly of the component
Self-weight (DW)	Load due to the component self-weights
Pressure (Po)	Cooling water pressure during operation
Pressure (Po)	Pressure due to vacuum
Pressure (Atm)	Atmospheric pressure
Temperature (To)	Thermal loading during operation
Temperature (Tr)	Room temperature (range)
SL-1	Seismic event

B.1.1 Assembly and Pretension Loads

The component analysis shall consider the assembly and pretension loads local to the component, as applicable.

The primary source of such loading is the development of adequate compression of the vacuum seals at waveguide couplings and mirrors. The magnitude of this load will be determined based on the final seal design selected. No additional fabrication or assembly loads affecting the component are foreseen that are not enveloped by other loads or load combinations.

This section is consistent with §3.2 of *Load Specification of EC TL,* [Ref. 3.1.14].

B.1.2 Normal Operation

B.1.2.1 Self-weight (DW)

The loads applied to the component due to the self-weight response of the system shall be considered. *Self-weight loads occur due to masses used for design that are accelerated by gravity. Due to its inherent design, the component analysis does not need to consider self-weight. Instead, the weight of the component is considered in the system-level analysis and the response of the system informs the component analysis.*

This section is consistent with §3.1 of [Ref. 3.1.14].

B.1.2.2 Pressure (Po), (Atm)

The loads applied to the component due to the pressure response of the system shall be considered. The component analysis shall consider a static cooling water pressure of 1 MPa where applicable.
All internal volumes intended for vacuum operation shall be designed considering an internal pressure less than or equal to 0.01 Pa where applicable.

All external surfaces of the component shall consider an atmospheric pressure of 101.3 kPa during normal operation where applicable.

Due to its inherent design, the component is considered adequately robust when considering pressure cycling. The cooling water system is also not expected to experience significant dynamic pressure amplifications, such as water hammering, within the TL system. Therefore, effects due to such cycling or dynamic amplification can be neglected.

This section is consistent with §3.4 of [Ref. 3.1.14].

B.1.2.3 Temperature (Tr)

The loads applied to the component due to the environmental temperature response of the system shall be considered.

The component analysis shall consider an ambient temperature range of the environment during normal operation of 8°C ≤ Tr ≤ 37°C.

This section is consistent with §4.1.1 of [Ref. 3.1.14].

B.2 Seismic Loads

The loads applied to the component due to the seismic responses of the system to all applicable seismic events shall be considered.

Due to its inherent design, the component is considered adequately stiff when considering excitation due to seismic events. Therefore, the effects of such excitation on the internal behavior of the component can be neglected. Similarly, the component does not directly interface with the buildings. As such, the response spectra are applied to the supports and analyzed at the system-level and the response of the system informs the component analysis.

This section is consistent with §3.5 of [Ref. 3.1.14].