

# **EC Transmission Line Materials**

**April 2012**

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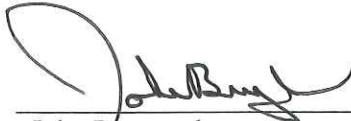
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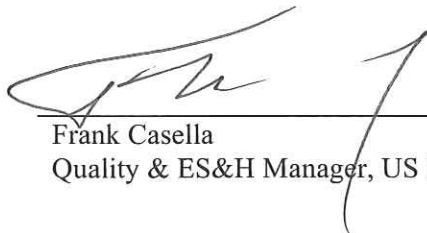
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## 1. PURPOSE AND SCOPE

The purpose of this document is to identify materials acceptable for use in the US ITER Project Office (USIPO)-supplied components for the ITER Electron cyclotron Heating and Current Drive (ECH&CD) transmission lines (TL), PBS-52.

## 2. ECH&CD TRANSMISSION LINE COMPONENT MATERIALS

Table 1 identifies materials that are expected to be used in the ECH TL components.

**Table 1. ECH&CD Transmission Line Component Materials**

ID	Subassembly / Component	Materials	Notes / Features	Materials Exposed to Cooling Water	Materials Exposed to Vacuum
<i>Support Structures</i>					
1	Building 11 TL support system				
1a	Support structure	Carbon steel, non-magnetic stainless steel	Structural supports attached to building embeds		
1b	Waveguide support framing	Carbon steel, non-magnetic stainless steel	Seismic boundary, Lindapter <sup>®1</sup> (clamping system)		
1c	Waveguide V-notch clamps, fasteners	FR-4 <sup>2</sup> , nylon, non-magnetic stainless steel, teflon	V-notch clamps will use FR-4 insulating material		
2	Building 13 TL support structure				
2a	Support structure	Carbon steel	Structural supports attached to building embeds, runners, knee braces		
2b	Waveguide support framing	Carbon steel	Seismic boundary, Lindapter <sup>®</sup>		
2c	Waveguide V-notch clamps, fasteners	FR-4, nylon, non-magnetic stainless steel, Teflon	V-notch clamps will use FR-4 insulating material		
3	Building 15 TL support structure				
3a	Support structure	Carbon steel, non-magnetic stainless steel (near gyrotrons)	Structural supports attached to building embeds, runners, knee braces		
3b	Waveguide support framing	Carbon steel, non-magnetic stainless steel (near gyrotrons)	Seismic boundary, Lindapter <sup>®</sup>		
3c	Waveguide V-notch clamps, fasteners	FR-4, nylon, non-magnetic stainless steel, Teflon	V-notch clamps will use FR-4 insulating material		

ID	Subassembly / Component	Materials	Notes / Features	Materials Exposed to Cooling Water	Materials Exposed to Vacuum
3d	Dummy load support structure	Non-magnetic stainless steel, FR-4, Teflon	Electrically isolated		
<b>Waveguide (Transmission Line)</b>					
4	Waveguide tubing with attached cooling lines	6061-T6 aluminum, 6005A-T6 aluminum, stainless steel copper, epoxy, brass, silver/tin soft solder	Copper cooling lines attached using epoxy	Copper, brass, stainless steel silver/tin soft solder	6061-T6 aluminum, 6005A-T6 aluminum VQC-3A <sup>3</sup>
5	Waveguide flanges	6061-T6 aluminum, brass, stainless steel	Stainless steel fasteners 18-8		
6	Miter bends, standard	Aluminum 6005-T6 or 6061-T6 or 7075-T6, copper or CuCrZr, stainless steel, brass		Copper, stainless steel, brass, silver	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr VQC-3A
7	Miter bends, arc detector	Aluminum 6005-T6 or 6061-T6 or 7075-T6, copper or CuCrZr, stainless steel, brass, sapphire, silver/tin soft solder	Sapphire window sealed using soft solder	Copper, stainless steel, brass, silver	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr, sapphire window, silver/tin soft solder VQC-3A
8	Miter bends, power monitor	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr, stainless steel, brass, quartz, alumina, silver/tin soft solder	Quartz or alumina window sealed using soft solder	Copper, stainless steel, brass, silver	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr, quartz, alumina, silver/tin soft solder VQC-3A
9	Miter bends, plane polarizer	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr, stainless steel, copper, brass, ferrofluid	Ferrofluidic feedthrough, magnet, motor, electronics	Copper, stainless steel, brass	Aluminum 6005-T6, 6061-T6 or 7075-T6, ferrofluids VQC-3A
					Copper or CuCrZr VQC-3B <sup>3</sup>
10	Miter Bends, elliptical polarizer	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr, stainless steel, brass, ferrofluid	Ferrofluidic feedthrough, magnet, motor, electronics	Copper, stainless steel, brass	Aluminum 6005-T6, 6061-T6 or 7075-T6, ferrofluids VQC-3A
					Copper or CuCrZr VQC-3B

ID	Subassembly / Component	Materials	Notes / Features	Materials Exposed to Cooling Water	Materials Exposed to Vacuum
11	Waveguide switch, standard	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr, stainless steel, copper, brass, silver	Drive piston with elastomer seal, limit switches	Copper, stainless steel, brass, silver	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr VQC-3A
12	Waveguide switch, compact	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr, stainless steel, copper, brass, silver	Drive piston with elastomer seal, limit switches	Copper, stainless steel, brass, silver	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr VQC-3A
13	Waveguide pumpout, gap type waveguide	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper, stainless steel, copper, brass, titanium dioxide	Turbo pumps and valves (supplied by vacuum group); titanium dioxide used as lossy coating on walls of stainless vacuum Tee	Copper, brass	Aluminum 6005-T6, 6061-T6 or 7075-T6, stainless steel VQC-3A
					Copper, titanium dioxide VQC-3B
14	Waveguide pumpout grooved waveguide type	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr, stainless steel, copper, brass	Turbo pumps and valves (supplied by vacuum group)	Copper, brass	Aluminum 6005-T6, 6061-T6 or 7075-T6, alumina VQC-3A
					Copper VQC-3B
15	DC break, compact	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr, stainless steel, brass, alumina	Microwave absorber	Copper, brass	Aluminum 6005-T6, 6061-T6 or 7075-T6, alumina VQC-3A
					Copper VQC-3B
16	DC break	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr, stainless steel, copper, brass, alumina	Microwave absorber may be used outside of vacuum	Copper, brass	Aluminum 6005-T6, 6061-T6 or 7075-T6, alumina VQC-3A
					Copper or CuCrZr VQC-3B
17	Seismic break	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr, stainless steel, copper, brass nylon, alumina	Nylon and/or alumina used to hold WG segments together. Weld on bellows	Copper, brass	Aluminum 6005-T6, 6061-T6 or 7075-T6, stainless VQC-3A
					Copper or CuCrZr, nylon, alumina VQC-3B

ID	Subassembly / Component	Materials	Notes / Features	Materials Exposed to Cooling Water	Materials Exposed to Vacuum
18	Waveguide expansion joint, bellows type	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr, stainless steel, copper, brass	Weld on bellows	Copper, brass	Aluminum 6005-T6, 6061-T6 or 7075-T6, stainless steel VQC-3A
					Copper or CuCrZr VQC-3B
19	Vacuum seals	Aluminum, stainless steel	Helicoflex <sup>®4</sup> seals		Aluminum, stainless steel VQC-3A
20	Waveguide expansion joint, sliding joint type	Aluminum 6005-T6, 6061-T6 or 7075-T6, copper or CuCrZr, stainless steel, copper, brass	Weld on bellows	Copper, brass	Aluminum 6005-T6, 6061-T6 or 7075-T6, stainless steel VQC-3A
					Copper or CuCrZr VQC-3B
21	Power monitor rectangular waveguide components, detector, attenuator	Copper, silicon detector, stainless steel hardware, aluminum, bronze	Rectangular waveguide may be gold-plated silver or gold-plated bronze		
<b>Cooling System Components</b>					
22	Waveguide cooling components (tubing)	Copper, stainless steel, brass, plastic line (high-density polyethylene or nylon)	<i>(Note: SRD-52 is more restrictive than SRD-26 CC with regard to allowable materials for cooling system components)</i>	All	
22a	Cooling tubing adhesive (bonding material)	Aluminum-filled thermally-conductive epoxy			
23	Water seals	Stainless steel, copper, silver (TBD), Teflon tape/paste, EPDM rubber, nylon, polyethylene, graphite paste thread sealer		All	
24	Cooling system Delta-T	Stainless steel, steel (TBD), brass, aluminum, copper, plastic connectors	<i>(Note: SRD-52 is more restrictive than SRD-26 CC with regard to allowable materials for cooling system components)</i>	Stainless steel, copper, brass	
25	Cooling system thermocouple	Stainless steel sheath Type K thermocouple	Insulation type not yet specified	Stainless steel sheath	

ID	Subassembly / Component	Materials	Notes / Features	Materials Exposed to Cooling Water	Materials Exposed to Vacuum
26	Cooling system flow switch	Stainless steel, bronze/brass, plastic	Not yet specified <i>(Note: SRD-52 is more restrictive than SRD-26 CC with regard to allowable materials for cooling system components)</i>	All	
27	Cooling system flow meters	Stainless steel, copper, bronze/brass, plastic	Not yet specified <i>(Note: SRD-52 is more restrictive than SRD-26 CC with regard to allowable materials for cooling system components)</i>	All	
28	Cooling system water fittings, swage type	Stainless steel, copper, bronze/brass		All	
29	Cooling system water manifolds	Copper, brass, stainless steel	Braze or silver solder	All	
30	Cooling system Helicoflex <sup>®</sup> seals	Copper, stainless steel, silver (TBD)	Miter bends, arc detector window seals	All	
31	Cooling system elastomer seals	EPDM rubber	Manifold interface (PBS-26 CCWS interface)	All	
<b><i>Vacuum System</i></b>					
32	Vacuum system flanges	Stainless steel	Copper seals (line 35) Helicoflex <sup>®</sup> seals (line 36)		All VQC-3A
33	Vacuum system compound pressure gage	Stainless steel, copper, copper wire, insulation	Electronic device		Stainless steel VQC-3A
34	Vacuum system compound gage readout	Electronics, copper wire, insulation	Electronic device		
35	Vacuum system conflat gaskets	Copper			Copper VQC-3A
36	Vacuum system Helicoflex <sup>®</sup> gaskets	Aluminum, stainless steel			All VQC-3A
<b><i>Electrical and Controls</i></b>					
37	Plane and elliptical polarizer servo motor	Copper, stainless steel, aluminum, insulation, ferrite or iron pole pieces	Electronic device		
38	Plane and elliptical polarizer servo motor controller	Electronics, copper wire, insulation	Electronic device		

ID	Subassembly / Component	Materials	Notes / Features	Materials Exposed to Cooling Water	Materials Exposed to Vacuum
39	Cabling	Copper wire, insulation	TBD		
40	Control system PLC & IO	Electronics & packaging	TBD		
41	Control system sensors	Electronics & packaging, copper wire and insulation	TBD		
42	Control system, air controls	Electronics & packaging	TBD, polyethylene tubing, copper tubing		
43	Arc detector fiber optic cables	Quartz, insulation, stainless steel connectors			
44	Arc detector electronics	Electronics	Electronic device		
45	Power monitor amplifier	Electronics	Electronic device		

<sup>1</sup> Lindapter® is a registered trademark for Lindapter® International.

<sup>2</sup> FR-4 (or FR4) is a grade designation assigned to glass-reinforced epoxy laminate sheets, tubes, rods and printed circuit boards. FR-4 is a composite material composed of woven fiberglass cloth with an epoxy resin binder that is flame resistant (self-extinguishing).

<sup>3</sup> VQC 3A class materials are part of a Vacuum boundary, VQC 3B materials are within Vacuum but not a part of the boundary, [Ref. 2; Sect. 3.1]

<sup>4</sup> Helicoflex® Spring Energized Seals - Garlock Sealing Technologies, Inc., LLC.

### 3. MATERIAL REQUIREMENTS

#### 3.1. General Requirements [Ref. 1; Sect. 2.17]

The source of material property information for design analysis shall be either the applicable structural code or the ITER Material Properties Handbook. In the case of conflict, the ITER Material Properties Handbook shall take precedence.

Materials selection, and use, shall follow the guidelines established in the Materials Assessment Report (MAR).

Materials exposed to vacuum shall conform to the ITER Vacuum Handbook. [Ref. 2]

Commercial materials shall conform to the applicable standard (e.g., ASTM, JIS, DIN) for the definition of their grade, physical, chemical and electrical properties and related testing. All materials for which a suitable certification from the supplier is not available shall be tested to determine the relevant properties, as part of the procurement.

A complete traceability of all the materials including welding materials shall be provided.

Halogenated materials (example: insulating materials) shall be forbidden in areas served by the detritiation systems. Exceptions must be approved by the Tritium System and Safety Section Responsible Officers.



### **3.2. Fire Protection, Insulation, and Electrical Requirements**

Components in the Tokamak Building and the Assembly Building shall be non-flammable. [Ref. 1; Sect. 2.6].

Components in the RF Building shall be non-flammable except insulation oil in a gyrotron oil tank. [Ref. 1; Sect. 2.6].

Insulating or other material must not emit toxic gases in the event of a fire (no PVC). [Ref. 1; Sect 2.6, 2.7].

Insulation containing halogens shall be forbidden in areas served by the detritiation systems. Exceptions must be approved by the Tritium System and Safety Section Responsible Officers. [Ref. 1; Sect. 2.8].

### **3.3. Electromagnetic Requirements**

Magnetic materials near gyrotrons must be avoided within a certain radius (need further analysis) of each gyrotron. [Ref. 1; Sect. 2.14].

### **3.4. Chemical Requirements**

The portion of all water-cooled ECH transmission line ex-vessel components wetted by water shall be compatible with Component Cooling Water System (CCWS) water coolant chemistry. [Ref. 1; Sect. 2.16].

Water-cooling circuits connected to the CCWS shall use stainless steel or copper. Flexible piping shall be made of material suitable for long life operation. [Ref. 1; Sect. 2.16].

### **3.5. Vacuum Requirements**

This Vacuum Handbook outlines the mandatory requirements for the design, manufacturing, testing, assembly and handling of vacuum items to realize and subsequently to maintain the various different ITER vacuum systems. [Ref. 2; Sect. 2].

ECH Transmission Line components are classified VQC-3A, VQC-3B or VQC N/A. [Ref. 2; Sect. 3.1]. Material requirements are determined by Vacuum Quality Class (VQC). Predetermined acceptable materials are defined in Vacuum Handbook Appendix 3. [Ref. 2; Sect. 5.1]. Unlisted materials may be proposed for use in vacuum by submitting a “Materials Acceptance Request Form” to the ITER Vacuum Responsible Officer. [Ref. 2; Sect. 52].

## **4. REFERENCES**

- [1] System Requirement (SRD) Document SRD-52 (ECH&CD) ITER\_D\_28B365
- [2] ITER Vacuum Handbook, ITER\_D\_2E29UM