TECHNICAL NOTE RELATED TO THE MARKET SURVEY ON WAVEGUIDES AND MITER BENDS

1 INTRODUCTION TO ITER & FUSION FOR ENERGY

The ITER project aims to build a fusion device, twice the size of the largest current devices, with the goal of demonstrating the scientific and technical feasibility of fusion power. It is a joint project between the European Union, China, India, Japan, South Korea, the Russian Federation and the USA. ITER will be constructed in Europe, at Cadarache in the south of France. The fusion reactor is expected to be ready for operation in 2025.

Most of the components that make up the ITER project are to be manufactured by each of the participating countries and contributed in kind through so-called Domestic Agencies including Fusion for Energy. In many cases the engineering and technologies required to manufacture these components are very advanced.

2 SCOPE OF SUPPLY

The scope of supply includes a set of waveguides and miter bends as described below.

WAVEGUIDES

The procurement includes a total length of 10 m of oversized waveguides, in sections of 0.5 and 1 m, with an inner diameter of 50 mm for the transmission of Radio Frequency at the frequency of 170 GHz with a maximum power of 1.2 MW.

The waveguides are straight tubes having a length of 0.5 and 1 m, made of aluminum with an internal corrugation (See Figure 1) for the transmission of the $HE_{1,1}$ mode and a coupling system at the two ends which ensures tight tolerances (see appendix 1 A1.1-A1.5) in terms of misalignment (offset and angular error) at the junction between the joined waveguide sections.

The waveguides need to respect the mechanical tolerances reported in appendix 1 (A2.1-A2.17) for the corrugation and the bore geometry in order to avoid mode conversion and hence power losses. Particularly important are the waveguide axial curvature, the ellipticity and the concentricity of the corrugation. The corrugation shall feature round corners with a target maximum radius of 0.1 mm

The waveguides and their coupling system shall be compatible with a maximum operating pressure of 10^{-5} millibar and ensure a vacuum tightness and an outgassing rate as specified in appendix 1 (A3.1-A3.3) at an operating temperature of 40-50°. To this purpose the couplings shall include a helicoflex metallic seal (appendix 1 A.1.4) compatible with high levels of RF power and have an adequate surface finishing for the helicoflex seal housing (appendix 1 A.1.5).

The waveguides shall also feature a cooling system able to dissipate a thermal power of at least 2 kW per meter steady state with a target maximum temperature of 50°.

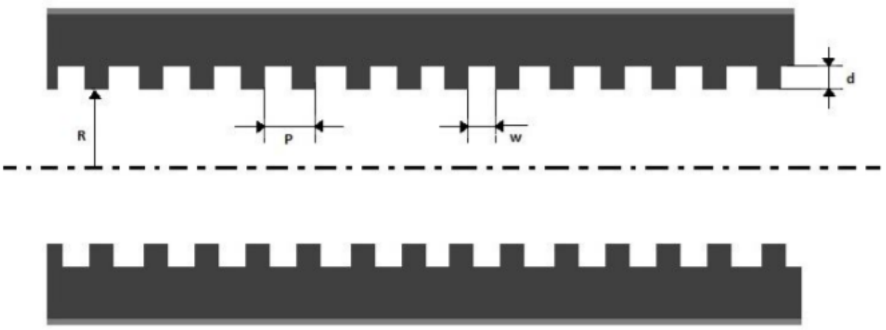


Figure 1 (Corrugated waveguide)

Where ‘R’ is radius of waveguide,
‘p’ is period of corrugation,
‘w’ is corrugation width and
‘d’ is depth of corrugation.

MITER BENDS

The procurement includes a set of 4 Miter Bends with a waveguide diameter of 50 mm and a flat mirror for the transmission of a 1.2 MW RF beam with a frequency of 170 GHz.

Miter bends (Figure 2) are used in the millimeter wave transmission line to bend the path of radiation in the required direction. Those requested as part of the scope of supply will use a flat mirror to deflect the path by 90°.

The parts of waveguide leading to the mirror shall be corrugated up to the mirror with the same geometry and tolerances as the main waveguides.

The mirror shall comply with the requirements set in appendix 1 (B3.1-B3.3)

The mirror shall include a cooling system able to dissipate at least 20 kW of thermal power steady state with a target maximum temperature of 120° and a maximum deflection in the order of 50µm.

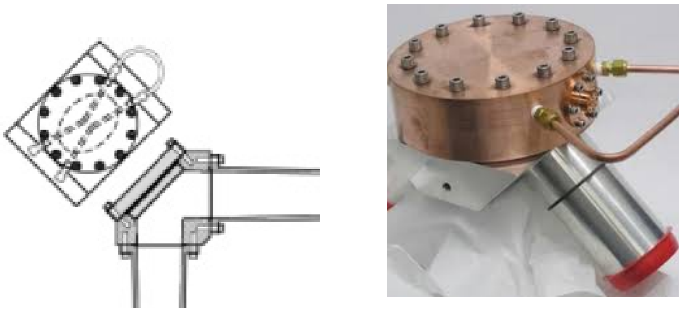
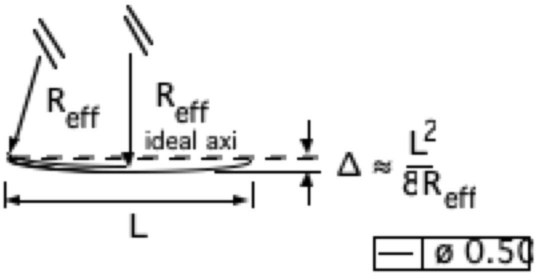


Figure 2: Miter Bend (General Atomics)

APPENDIX 1: MECHANICAL TOLERANCES AND REQUIREMENTS

A.1	Coupling Specifications	desired Spec.s
A.1.1	Radial misalignment (radial offset of the axes of two components being joined)	$\leq$ 0.075mm.
A.1.2	Angular misalignment (angular tilt between the axes of two components being joined)	$\leq$ 0.085°
A.1.4	Vacuum joint	Helicoflex®
A.1.5	Surface finish for Helicoflex® sealing surfaces	N6 or better ($\leq$0.8µm)

A.2	General waveguide Specifications	
A.2.1	Operation frequencies	170 GHz
A.2.2	Bandwidth	$\geq \pm$ *1GHz*
A.2.4	Minimum CW power handling capability (CW, evacuated)	$\geq$ 1.2 MW
A.2.5	Groove shape (rectangular, sinusoidal, etc.)	
A.2.6	period of grooves (p)	0.65 ± 0.05 mm
A.2.7	depth of grooves (d, peak-to-peak amplitude)	0.48 ± 0.05 mm
A.2.9	width of grooves (w)	0.20 ± 0.05 mm
A.2.10	Inner diameter (2·R)	50.0 ± 0.05 mm
A.2.11	Maximum length variation (@20°C)	< 0.5 mm per m
A.2.12	Circularity ○ 0.1	< 0.1 mm

A.2.13	Mean effective bending radius R_{eff} per section. 	R_{eff} >1000m
A.2.14	Material (The material must be compatible with vacuum operation and cooling)	Aluminum alloy
A.2.15	Inner wall surface finish	N7 or better (≤1.6µm)
A.2.16	Surface Finish	N7 or better (<1.6µm r.m.s.)
A.2.17	Concentricity, with the axis of the inner diameter as reference	0.04mm

A.3 Vacuum Specifications

A.3.1	Maximum operating pressure	$\leq 10^{-5}$ *mbar*
A.3.2	He leak rate of coupling/seal at 1atm differential pressure	$\leq 10^{-11}$ mbar•l/s
A.3.3	Outgassing rate of the components after cleaning/baking	$5 \cdot 10^{-12}$ mbar l/s cm^{-2}

B.3 Miter Bend

B.3.1	Expected tolerance in 90˚ direction change	≤ 0.085˚
B.3.2	Expected tolerance in plane of incidence	≤ 0.085˚
B.3.3	Mirror surface finish	≤ *0.2 µm*