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1 INTRODUCTION TO JT60SA

The Tokamak JT-60SA, which is currently under construction in Japan, is a nuclear fusion experiment aimed to research the technical and physical basis of future fusion power plants. Large superconducting magnets create a toroidal magnetic field, thus confining the high temperature plasma in a ring like shape. The plasma can reach temperatures of up to 200 million degrees Celsius (20keV) at its centre. At these temperatures, nuclei of hydrogen isotopes have a high probability of fusing to helium nuclei.

All components exposed to the plasma inside the tokamak vessel (i.e. in-vessel components), must be able to withstand extreme heat fluxes (up to 10MW/m2). Moreover, some specific components must act as a collector for the hot ashes coming from the plasma (i.e. the Divertor). The Divertor must be protected by a series of heat resistant elements (i.e. high heat flux elements), made of carbon-based material attached to an actively cooled metallic heat sink.

2 DIVERTOR HIGH HEAT FLUX (HHF) ELEMENTS

The role of the Divertor is to absorb the stray particles and heat radiation escaping the plasma, diverting this high energy to the in vessel cooling system. The divertor is made of 36 identical cassettes (Figure 1), equipped with 24 HHF elements, arranged in an inner target (10 elements) and an outer target (14 elements). Together with the HHF elements there are some passive elements made of pure graphite which are devoted to the removal of smaller peripheral heat fluxes. The targets are assembled on the cassette, which also works as a flow distribution manifold.

The scope of this procurement is the HHF elements of the divertor targets (Figure 2). The full procurement consist of 1000 of these targets. All targets are identical, with the exception of a subset (around 10%) which must be instrumented with thermocouples.

The elements are designed to withstand localized heat fluxes of 10 MW/m2 in steady state operation. Cooling is provided by forced water flow at 40 C inlet temperature, and 20 bar inlet pressure. The mass flow rate per element is 0.8 kg/s.

The armour material of choice is fine isotropic graphite (e.g. Toyo Tanso IG-610 or better, in terms of thermomechanical properties), which will directly face the hot plasma. The choice of carbon-based material is driven by the JT-60SA research plan, and is therefore fixed.

The heat sink material of choice is TZM (titanium-zirconium-molybdenum) alloy. The choice is driven by the good thermal compatibility with graphite, the excellent material properties at operating temperature (up to 800 C) and the compatibility with the vacuum environment of the tokamak vessel.

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The water flow must be guided in a cooling tube, embedded in the heat sink material. The tube must be chemically compatible with water, and should retain good ductility in all operating and transport temperatures (from 0 to 500°C).

The joining of all subcomponents (armour, heat sink and tube) must be void-free and should withstand the high operating temperature. Typically, the interface of graphite and TZM will reach up to 900°C, and the interface between the tube and the heat sink will reach up to 500°C. The inner surface of the tube, in contact with the cooling water, will exceed slightly the saturation temperature of water at 20 bar (i.e. 260°C).

The elements must include fixing features to connect to the divertor cassette. These must be either part of the heat sink, or bonded to it in a way suitable to transfer forces at temperatures up to 500°C. The detail design of these features will be part of the component technical specification.

3 PROCUREMENT STRATEGY

The procurement will be divided in two stages:

- Stage 1 consists in the manufacturing of a small series of full-scale mock-ups, which will be tested at the care and expense of F4E, in a dedicated HHF testing facility at the operating conditions. The success of this testing will validate the Supplier’s manufacturing route and will conclude the stage 1.

- Stage 2, which will be released after successfully completing the HHF testing at the end of stage 1, consists in the series production of the 1000 elements, according to the design and manufacturing route of the elements procured in stage 1. The main quality control scheme in this stage is the NDT put in place by the Supplier, which has to guarantee that the quality of the elements of the series remains constant between stage 1 and stage 2. F4E reserves the right to perform randomized HHF testing on elements from the series production, to independently validate the quality of the manufactured elements. Deviations will be investigated and proper root cause analysis and remedial activities will be performed as defined in the Contract.
4 EXPECTED SKILLS/EXPERIENCE

The successful tenderer is expected to have, either internally or by its sub-contractors, the following skills/experience:

- Manufacturing/sourcing of refractory metals (TZM)
- Manufacturing/sourcing of high purity nuclear-grade isotropic graphite
- Access to material laboratories to verify, if needed, the material properties of the base materials.
- Diffusion bonding/brazing of refractory metals with graphite
- Non-destructive examination of joints between refractory metals and graphite (e.g. UT, RX)
- Precision machining of TZM/graphite semi-finished products
- Well-developed quality control system, under an international quality standard (e.g. ISO9001)

![Figure 1 - Divertor cassette](image)

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5 MARKET SURVEY

To establish an optimum contract strategy, F4E needs to develop its understanding of the market with a comprehensive list of possible interested EU suppliers.

In the frame of the Market Survey, interested suppliers are invited to submit information. This information will be visible to F4E only and will not be communicated to other parties, except if agreed upon by the respondent(s).

Please answer to the F4E Market Survey. You can access the survey by clicking on this link:

https://ec.europa.eu/eusurvey/runner/Market_Survey_OPE-1149_Divertor_HHF_Targets_JT60SA

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