The experimental fusion reactor ITER will require 3 Heating Neutral Beam Injectors and one Diagnostic Neutral beam Injector, which will all be equipped with large cryopumps. The build-to-print design of these pumps has recently been completed. A Call for Tender for the manufacturing of a prototype to be installed in the MITICA Facility at RFX in Padua, will be launched in spring 2016. This report outlines the design of the MITICA Cryopump as well as its procurement schedule and strategy.
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1. Introduction

The experimental fusion reactor ITER will require 3 Heating Neutral Beam Injectors (NBI) and one Diagnostic Neutral Beam Injector (DNB). The NBI of ITER are all equipped with 2 cryopumps that pump gases by adsorption on activated charcoal cooled to a temperature of about 4.5 K. The MITICA facility in Padua is a test facility for the NBI and includes a full size heating neutral beam injector. Its beam line vessel (BLV) will therefore be equipped with 2 cryopumps which are almost identical to the ITER NBI cryopumps.

The build-to-print design of these cryopumps has recently been completed and a call for tender is planned to be published by F4E in spring 2016.

2. Design overview

2.1. Introduction

The 2 cryopumps are installed in the BLV which is not part of the scope of supply. The cryopumps are about 8m long, 3m high and 1m wide. The overall weight of each pump is 3.6T (1.6T for the cryogenic circuits and 2T for the support frame).

The figures below show these components:
### 2.2. Subcomponents

Each cryopump is composed of the sub-components listed in the table below. Some of these components are described with more details in the following chapters.

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>One support frame supporting all the components of the cryopump together.</td>
<td>The frame includes supports that interface with the BLV (1.4429 Stainless steel structure)</td>
</tr>
<tr>
<td>One frame stiffener (1.4429 Stainless steel structure)</td>
<td></td>
</tr>
<tr>
<td>32 pumping sections including three 4K cryopanels (CP) and four 80K Thermal Radiation Shield (TRS) panels.</td>
<td></td>
</tr>
<tr>
<td>Inlet and outlet manifolds</td>
<td></td>
</tr>
<tr>
<td>Passive radiation shields</td>
<td>(in purple and yellow)</td>
</tr>
<tr>
<td>One vacuum flange with 4 cryogenic feeds (Johnston couplings) and one electrical feedthrough.</td>
<td></td>
</tr>
</tbody>
</table>
2.2.1. The frame

The frame supports and aligns all the components of the cryopump. The supports of the cryopump, which are the interface with the BLV, are installed on this frame. H profiles with non-standard geometries are used to manufacture the frame. The material for the whole frame is 1.4429 stainless steel.

2.2.2. The pumping sections

The pumping sections are the active parts of the pump. They include the 4K charcoal coated cryopanels (CP) that trap the gases (in blue on the figure to the right). These charcoal coated surfaces are cooled by a forced flow of supercritical Helium at a pressure of about 0.4 MPa and an inlet temperature of about 4.3 K.

To minimize heat loads, the charcoal coated surfaces are surrounded by thermal radiation shields (TRS) cooled to about 80 K by forced flow cooling with gaseous Helium at 1.8 MPa and an inlet temperature of 80 K (in green on the figure to the right).

In total, for the two cryopumps, 68 pumping sections need to be produced (this number includes the spares foreseen for the manufacturing). Once assembled, each pumping section should be subject to a cold shock test (80K), a pressure test and a leak test. For these tests, the pumping sections need to be placed in the vertical position in a vacuum chamber (purpose made or available).

Profiles

The CP and TRS have a profiled shape and are about 2.8m long. They are obtained from aluminium extruded profiles and stainless steel pipes. The stainless steel pipe is inserted inside the aluminium profile then expanded in order to achieve a good contact between the aluminium profile and the pipe. The expansion process is made by applying high hydrostatic pressure inside the pipes. The pictures below show the result of this expansion process:

The material to be used for the pipes is 1.4306.

The material to be used for the aluminium profiles is AW 6082-T6.

Because some profiles will be used for production proof sampling, for qualification of some processes, or as spares, in total, about 100 of each type of profile will need to be produced. There are 7 different types of profiles.
Surface treatments

The surfaces of the profiles described above will be subject to the following treatments:
- Charcoal coating,
- Electropolishing,
- Blackening.

The picture below shows which surface is subject to what treatment.

![Surface treatments diagram](image)

The blackening shall be done by plasma spray coating using Al2O3/TiO2 (87%/13%, PP-19.S, sealed). The components will be operated between 400 K and 80 K. The emissivity of the surfaces after blackening shall be greater than 0.9.

The cryopanels are coated with charcoal particles. It is required to use the glue THERMOGUSS 2000 from KLEIBERIT in order to glue the charcoal particles to the panels. The density of charcoal after coating shall be uniform on the panels and shall be comprised between 350g/m² and 450g/m².

During the coating process, the panels should undergo a baking step at 100°C for 10 hours after the glue has dried.

2.2.3. The vacuum flange

For each cryopump, the vacuum flange is the main interface to the vacuum vessel. It includes Johnston couplings for the supply of Helium to the TRS and CP circuits as well as an electrical feedthrough for the measurement of the temperature of the cryopump (10 TVO temperature sensors are installed on each cryopump).

Two double metallic spring loaded seals are mounted between the CP’s flange and the VV’s flange as shown on the picture below. The following sketch shows the assembly between these 2 flanges and the position of the two seals:
2.3. **Applicable codes and standards**

The cryogenic circuits of the cryopumps are Cat II and Cat III pressure equipment according to PED. The cryopumps were designed according to EN 13445 and shall be manufactured according to this standard.

3. **Installation tool**

A tool to hold the cryopump during its installation in the beam line vessel needs to be supplied together with the cryopump. This tool can be used also to handle the cryopump in the supplier premises. The manufacturer of the cryopump will be responsible for the design, manufacturing, and the certification of this lifting tool. This tool is shown in light blue on the figures below

4. **Scope of work**

F4E will provide a build to-print design for the manufacture of the cryopumps. This design will only exclude the installation tool and any equipment for the testing of the cryopumps.

F4E plans to place a contract with a contractor which will demonstrate the **capability to machine, assemble and inspect complex high-vacuum equipment** (this includes the availability of clean facilities, excellent welding & weld inspection capabilities, leak testing capabilities at ambient and LN2 temperature). The company will only be responsible for the manufacture of the cryopumps.

The following activities will be part of the scope of work of the selected supplier:

- Contract management and Quality Assurance according to F4E standards;
- Supply of the manufacturing drawings;
- Procurement of raw materials;
- Manufacturing and inspection of components according to a build-to-print drawing package supplied by F4E. The main components to be manufactured and/or procured are:
  - 2 support frames with 2 frame stiffener (1.6T each, 1.4429);
  - About 100 of each types of the CP and TRS profiles (used for the assembly of the pumping sections) incl. surface treatment (plasma spray coating, electropolishing, charcoal coating);
  - 68 pumping sections (made up of the above profiles);
  - Internal piping and support structure;
  - Passive radiation shields;
  - 2 vacuum flange with Johnston couplings, electrical feedthrough, and HELICOFLEX seals;
- Assembly of the cryopump according to UHV standards and a technical specification provided by F4E;
- Welding and weld inspections performed according to vacuum standards;
- Planning and conduction of acceptance test and related records, including pressure and leak tests (max. allowable leak rate of $10^{-10}$ Pa·m$^3$·s$^{-1}$) at ambient and LN2 temperature;
- Preparation of a manufacturing dossier including all necessary documentation (welding documentation, material list and certificates, manufacturing and inspection plans, etc);
- Supply of “as built” drawings and related QA documentation;
- Supply and delivery of any handling and assembly tools used in the scope of the contract;
- Design of the installation tool (3D model, drawings, calculation report);
- Manufacturing of the installation tool;
- Certification of the installation tool;
- Packing, insurance and transportation to Padua, Italy.
5. F4E MARKET SURVEY

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

In the frame of the market survey, interested suppliers are invited to submit information. This information will be used by F4E and IO and will not be communicated to other parties.