Technical Note for Market Survey on WCLL Test Blanket System PbLi loop

Contents

1 SCOPE OF THE DOCUMENT

Fusion For Energy (F4E) is launching a Market Survey in preparation of a Call for Tender (CFT) on the Water Cooled Lithium Lead Test Blanket System (WCLL-TBS) Lead Lithium loop (LLP). This Technical Note provides supporting information so that interested companies can answer the survey with a minimum of background.

2 DESCRIPTION OF THE LEAD LITHIUM LOOP

2.1 Introduction

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 is currently under construction at Cadarache' site, in the south of France.

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. Fusion for Energy is the European Domestic Agency (EUDA)

Among ITER's objectives there is the demonstration of feasibility to produce tritium directly within a fusion reactor. The concept of 'breeding' tritium during the fusion reaction is fundamental for the future of fusion energy. ITER will provide the possibility to test mock-ups of these breeding blankets, called Test Blanket Modules (TBM), in a real fusion environment.

The TBM is the plasma-facing part of the Test Blanket System (TBS) which has the main functions to transform the nuclear into thermal power and to generate tritium.. In ITER there are four separate TBS, employing different technologies, and they will serve as the testing mock-ups of future breeding blankets to be designed and installed in future fusion power plants. The Water Cooled Lithium Lead (WCLL-TBS), whose layout in ITER is shown in Figure 1, is one of the four above mentioned TBS, which is under the responsibility of F4E.

. The **PbLi loop** is one of the WCLL-TBS sub-system. It implements the following main process functions:

- to promote the circulation of the molten lead lithium in the planned operational conditions;
- to transport the tritium produced from the TBM to a specific component (TEU, Tritium Extraction Unit) where tritium will be moved from the liquid to a gas phase;
- to remove corrosion products and other solubilised impurities by a suitable trapping device.

The PbLi loop is shown if Figure 2 with the layout integrated inside the AEU (Ancillary Equipment Unit) of the PC#16 (Port Cell#16).

The main components of the PbLi loop are:

- Tritium Extraction Unit (TEU)
- Cold Trap (Figure 3)
- Indirect cooler (Figure 4)
- Heater
- Storage tank
- Permanent Magnet Pump
- Expansion vessel
- Valves (both for process control and nuclear safety)
- Piping
- Supporting structures

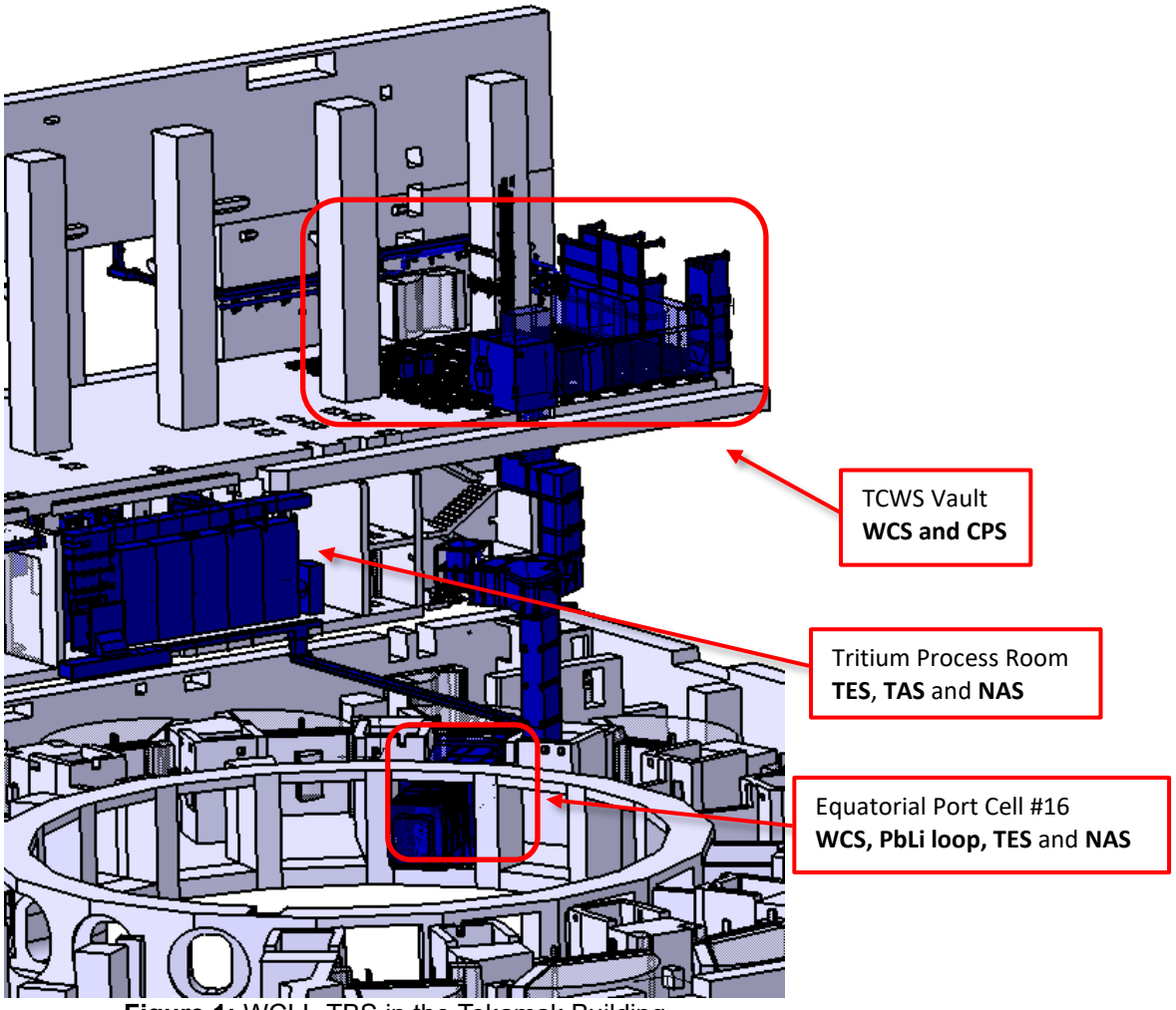

Figure 1: WCLL-TBS in the Tokamak Building

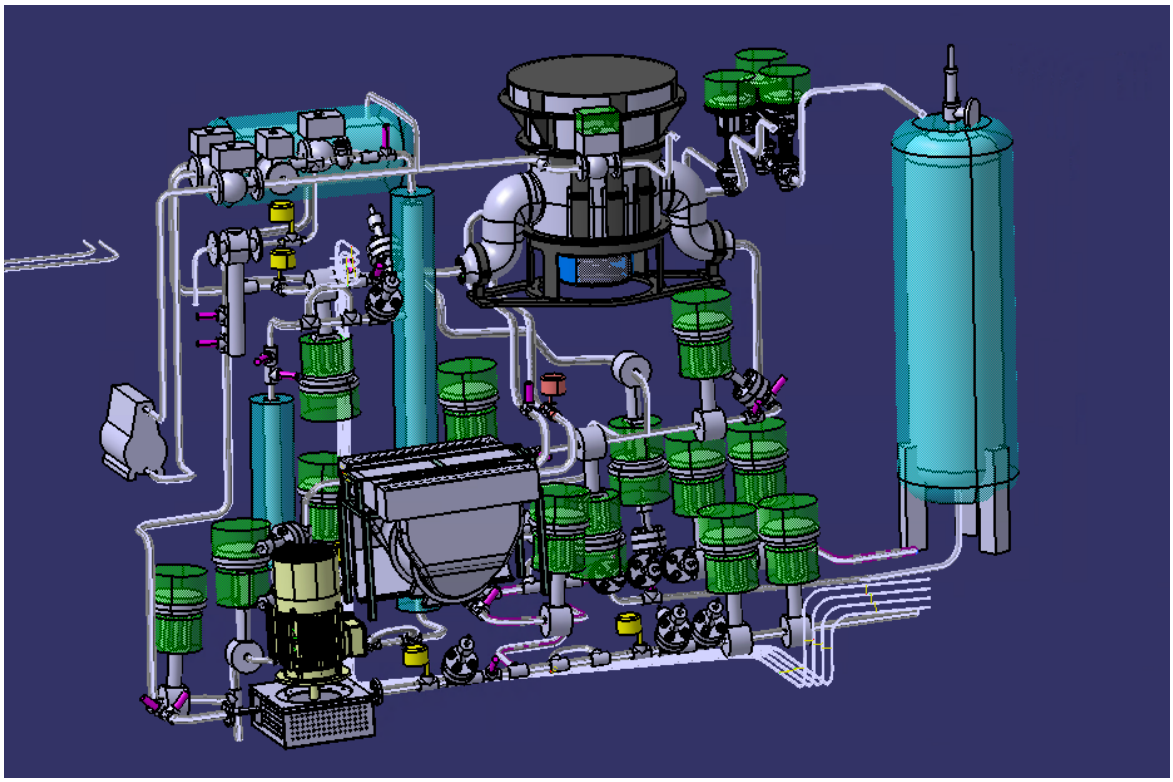

Figure 2: PbLi loop equipment and piping in PC#16.

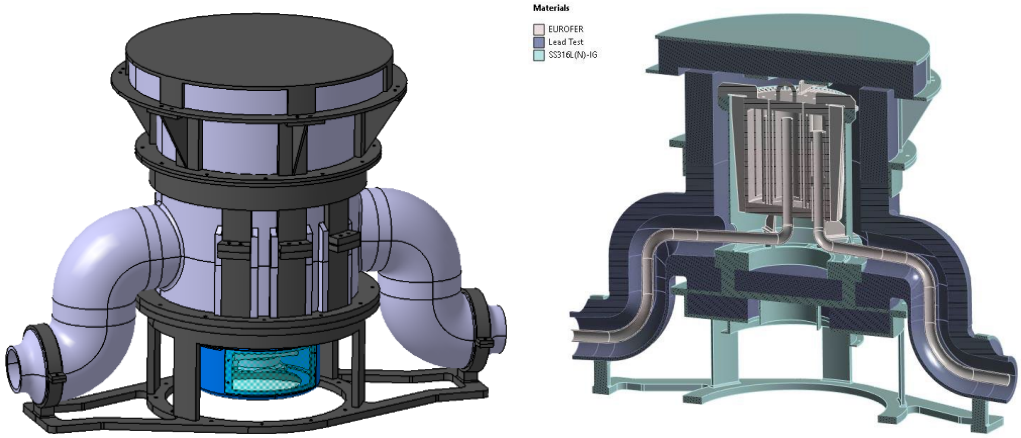

Figure 3: Cold Trap including the nuclear shield (left) and in section (right).

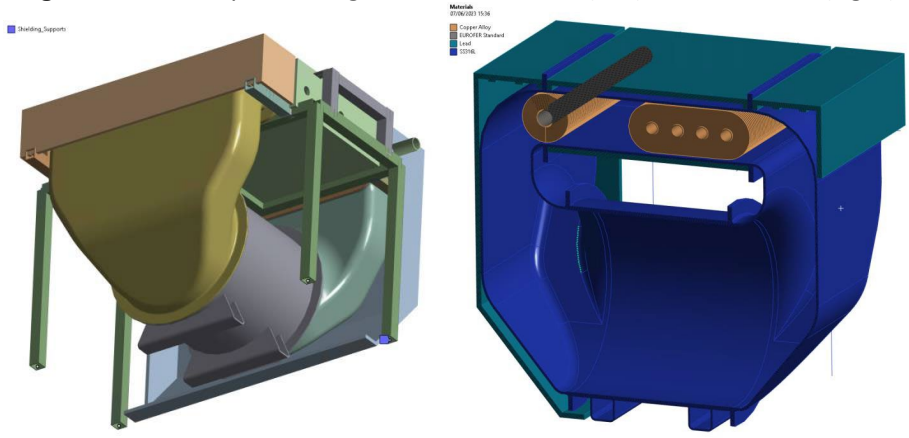

Figure 4: Cooler, with the section on the right; fan not present.

2.2 PbLi loop technical description

Size and features of the main equipment of PbLi loop are listed hereafter. All the components are realized in a ferritic martensitic steel, with Eurofer97 as reference material and T91 as backup material in case of unavailability of the reference one. The information and data provided here reflect the current technical baseline:

- ✓ **Tritium Extraction Unit**: cylindrical vessel, with flanged heads, 5 mm thickness, OD 90 mm. The vessel is filled with a structural filler (Baretti or Mellapack for example, with a specific surface of at least 350 m^2/m^3).
- ✓ **Expansion tank**: cylindrical vessel with welded heads, OD 500 mm, thickness 25 mm, 1480 mm length.
- ✓ **Cold Trap**: cylindrical vessel with welded heads, and internal concentric partitions, OD 260 mm, thickness of 210 mm.
- ✓ **Heater**: cylindrical vessel, OD 80 mm, length 800 mm.
- ✓ **Recirculation tank:** cylindrical vessel with welded ends, OD 300 mm, length 700 mm, thickness 25 mm.
- ✓ **Heat exchanger**: the heat exchanger is a double stage component. To prevent the reaction between PbLi and water, the liquid metal is cooled down by air in forced convection, with a second stage in which air is cooled by water. There are so two heat exchangers, the first one PbLi/air and the second one air/water, both constituted by copper finned pipes. Air is circulated in closed loop according to Figure 4.
- ✓ **Pumping system**: permanent magnets pump is the selected technology, with mass flow rate ranging from 0.2 to 1.2 kg/s and prevalence up to 6 bars.
- ✓ **Piping**: the lead lithium piping is DN25-40s.
- ✓ **Valves**: among control, on/off, check and Safety Isolation valves, there are about 35 valves.
- ✓ **PbLi storage tank**: two box shape tanks are foreseen, each one with a size of 3500 * 1900 * 335 mm, and thickness of 10 mm. The total volume is 0.499 m^3. They are connected and operated simultaneously.

The whole system is heated to keep the temperature over the melting point of PbLi (≈235°C) in all operational conditions. Consequently, the loop is fully thermally insulated to reduce heat losses.

As lead lithium is contaminated by activation products and slowly reacts with air, welded connections are preferred to flanged ones anytime possible to reduce the risk of leaks.

The PbLi equipment have been designed in accordance with the Nuclear Code RCC-MRx 2018..It is considered the reference code also for the future design development and manufacturing. However, if deemed advantageous and agreed with F4E, other design and construction codes can be adopted.

The PbLi loop equipment are classified ITER Quality Class 1, ITER Safety Class 2 (with the exception of SIC-1 Safety Isolation Valves), Tritium Class 2A and are subject to PED/ESPN regulation. For Quality and Safety Class information, please refer to F4E documents QA-115 and QA-113 publicly available at F4E industry portal. The equipment specification will detail the associated procurement requirements.

The Supplier will possibly be the regulatory manufacturer for the PED and ESPN components and/or for the assemblies but a final decision in this regard will be made later.

3 SCOPE OF THE FUTURE CALL FOR TENDER FOR THE PBLI LOOP

The scope of delivery is based on Preliminary design review status specification provided by F4E to the Supplier. The provisional scope of the contract includes, for the items described in Section 2.2:

- Production of manufacturing drawings and plans;
- Execution of the Manufacturing Readiness Review (MRR) with the participation of Experts from F4E, ITER Organization and external experts;
- Manufacturing, factory testing and delivery to Cadarache of lead lithium loop;
- Taking the role of regulatory manufacturer for all PbLi loop equipment and supporting F4E as regulatory manufactures of the PbLi loop assemblies

The supplier shall produce the manufacturing drawings and consequently procure materials, manufacture and deliver the components in line with the required delivery schedule for installation in Cadarache.

F4E will provide detailed input to the Supplier, like the system requirements, the load specification, documents covering different elements of design, engineering analyses including RAMI, all developed at a maturity level corresponding to the Preliminary Design.

It is relevant to indicate here that the preparation of the Final Design Review, to be approved by the Nuclear Operator (ITER Organization), will require the finalization of a large documentation package, whose basis is the outcome of the Preliminary Design Phase.

4 TECHNICAL AND INDUSTRIAL CAPACITY

The potential supplier is expected to be experienced in:

- Design rules for Class N2Rx nuclear components in RCC-MRx or equivalent
- Structural and thermo-mechanical FE analysis;
- Mechanical and integration engineering, CAD with CATIA V5;
- Pressure systems and component engineering
- Manufacturing of pressurized equipment and assemblies;
- Thermo-fluid dynamic analysis;
- Welding technologies of martensitic and austenitic steels, including heterogeneous welding;
- European Pressure Equipment Directive and French ESPN Order;
- Non-destructive examination such as RT and UT;
- Testing of equipment under pressure.

The main challenges will be:

- Qualification of the components located in the Port Cell due to foreseen electro-magnetic and irradiation conditions
- Integration of the PbLi loop inside the AEU volume in PC#16, sharing the space with the other foreseen WCLL and HCCP (Helium Cooled Ceramic Pebble) -TBS subsystems
- Implementation of maintainability provisions in the final design
- Control of the strict compliance with the technical specification for the most critical components
- Compliance with the PED and French regulatory body (e.g. ESPN order)
- Integration of the I&C components all along the loop

The Supplier must provide information on the parts of the contract which are intended to be subcontracted. Among the activities which may be considered subcontracted or insourced where applicable are welding analysis, cutting and machining activities, pressure and/or vacuum testing, NDT and dimensional inspection, qualification activities.

5 SCHEDULE

- F4E plans to launch a Call for Tender in 2025. The contract is planned to be signed by Q2 2026, after the PDR approval..
- The FDR meeting for WCLL-TBS is foreseen in June 2028.
- The delivery of the PbLi loop in form of assemblies to the ITER site is currently foreseen by the end of 2035

6 MARKET SURVEY

Please answer to the F4E Market Survey by clicking on this link:

https://ec.europa.eu/eusurvey/runner/TBM_Ancillary_3