Technical Note for Market Survey on

Test Blanket Module WCS & CPS

In preparation of Call for Tender

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1. Scope of the document

Fusion For Energy (F4E) is launching a Market Survey in preparation of a Call for Tender on Final Design and Procurement of the WCLL-TBS[1] Water Cooling System (WCS) and Coolant Purification System (CPS). This Technical Note provides supporting information so that interested potential tenders can answer the survey with a minimum of background.

2. Description of the WCS and CPS

a. Introduction to ITER, Test Blanket Modules and Cooling function

The ITER[2] 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 (TBMs), in a real fusion environment.

The TBM is the plasma-facing component of the Test Blanket System (TBS). The TBS is the overall system that has the function to breed tritium by neutron capture (and multiplication) in a breeder material. In ITER there are four different TBS concepts, employing different technologies, and they will serve as the blueprint for future fusion power plants. The scope of this document is the European TBS which is called Water Cooled Lithium Lead (WCLL-TBS), see in Figure 1 an overview of the system inside the Tokamak Building.

The cooling function is performed by the Water Cooling System, while the Coolant Purification System ensures the right composition of the cooling water. These are two of the sub-systems that comprise the WCLL-TBS. Overall these two sub-systems are based on the scheme of the same two systems of commercial PWR fission reactors, employing pressurized water at 155 bar in the temperature range of 295-328°C. In Figure 2 it is shown the WCS and CPS (except the WCS part in Port Cell #16), and in Figure 3 in detail the two largest WCS components (namely the pressurizer and the economizer).

The WCS is composed by a primary cooling loop (contaminated with tritium and ACPs[3]), with the coolant extracting heat from the TBM, then a secondary process loop which is an intermediate (non-contaminated) loop taking heat from the primary loop and finally rejecting it to the heat sink. The WCS is composed by:

- Shell & Tube heat exchangers

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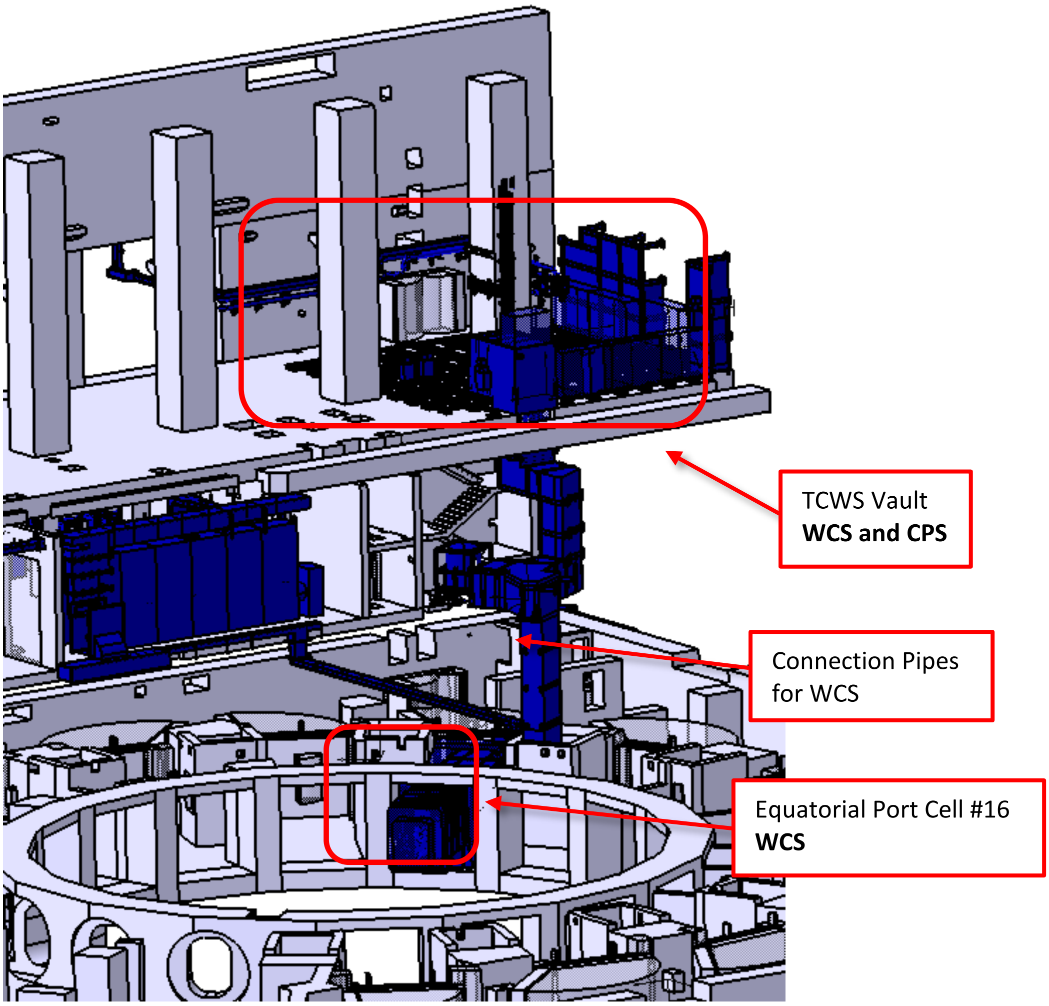
[1] WCLL stands for Water-Cooled Lithium Lead, and TBS stands for Test Blanket System. A TBS is the system composed by a Test Blanket Module (TBM) and the needed Ancillary Systems.

[2] ITER stands for International Thermonuclear Experimental Reactor

[3] ACP stands for Activated Corrosion Products

- Pressurizers
- Relief tank and discharge tanks
- Electrical heater
- Pumping system
- Valves (both for process control and nuclear safety)
- Piping
- Supporting structures



- **Figure 1:** WCLL-TBS in the Tokamak Building

The CPS is a process loop that takes a fraction of the mass flow rate from the WCS primary loop to maintain the WCS coolant purity and activity level within acceptable limits and to maintain the WCS coolant chemistry within the required specifications. The CPS is composed by:

- Filters
- Cationic and Anionic Demineralizer
- Degasifiers
- Chemical injection set
- Pumping system and vacuum pump
- Tanks
- Valves
- Piping
- Supporting structures

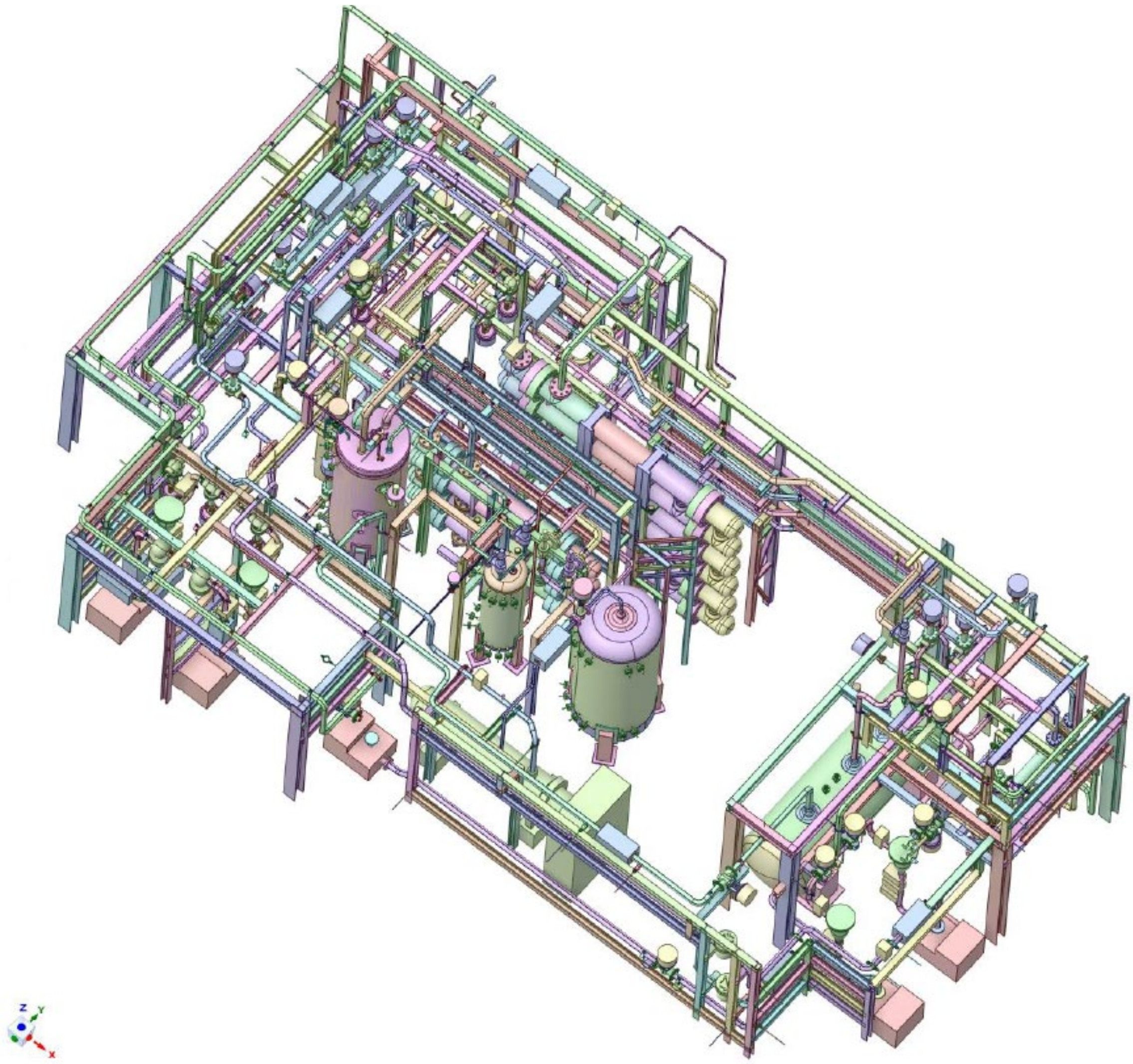


Figure 2: WCS and CPS equipment, piping and supporting structures in TCWS Vault.

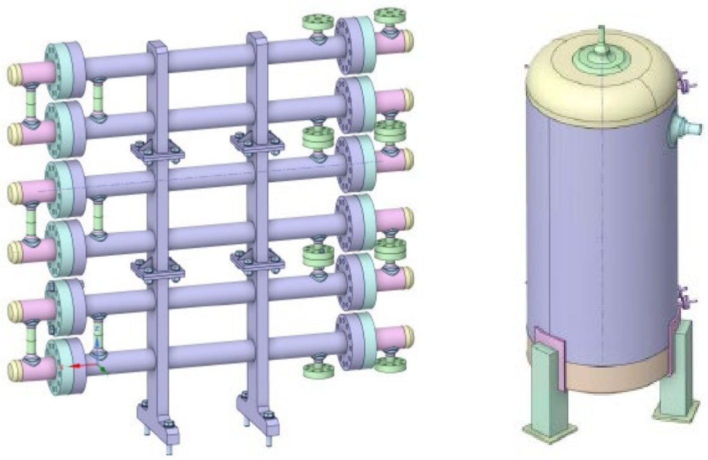


Figure 3: WCS Economizer hairpin type heat exchanger (left) and Primary loop steam bubble pressurizer (right).

b. WCS and CPS technical description

Size and features of the main equipment of WCS and CPS are listed here:

- ✓ **Primary pressurizer**: steam bubble pressurizer with electrical heater and cold spray line. Pressure vessel (185 bar design) with welded heads of 1.2 m OD x 2.7 m height, ~11 tons of 316L steel.
- ✓ **Secondary pressurizer**: steam bubble pressurizer with electrical heater and cold spray line. Pressure vessel (23 bar design) with welded heads of 0.7 m OD x 2 m height, ~1 ton of 316L steel.
- ✓ **Economizer**: hairpin type heat exchanger comprised of six Shell & Tube modules, each one is a 0.2 m OD x 3 m length 316L shell, with 69 Inconel-625 tubes of ½" OD.
- ✓ **Intermediate heat exchanger**: hairpin type heat exchanger comprised of four Shell & Tube modules, each one is a 0.15 m OD x 1.7 m length 316L shell, with 37 Inconel-625 tubes of ½" OD.
- ✓ **Heat Sink**: hairpin type heat exchanger comprised of four Shell & Tube modules, each one is a 0.15 m OD x 1.6 m length 316L shell, with 37 Inconel-625 tubes of ½" OD.
- ✓ **Electrical heater**: Shell & Tube type process heater with electrical heating rods (~150 kW), off-the-shelf component.
- ✓ **Relief tank**: tank with pressure suppression system equipped with steam spargers. Shell of 1 m OD x 2.6 m height with welded heads, ~1.2 tons of 316L steel.
- ✓ **Discharge tanks**: non-pressurized tanks to store and discharge coolant inventory, the volume of the first one is 3 m^3 and second one is 0.3 m^3.
- ✓ **CPS Tank**: low pressure tank (6 bar) 0.8 m OD x 2 m height, ~1 ton of 316L steel.
- ✓ **Pumping system**: single stage canned centrifugal pump in redundant configuration. WCS Primary pumps: 3.74 kg/s flow rate and ~7 bar head. WCS Secondary pumps 4.3 kg/s flow rate and ~1 bar head.
- ✓ **Piping**: about 250 m of 316L process pipes, from DN20 to DN80, up to SCH160.
- ✓ **Valves**: there are about 140 valves between WCS and CPS: ball valves, globe valves, swing check valves, stop check valves, pressure reducing valves. Most critical conditions are design pressure of 185 bar, design temperature of 360 °C, sizes up to DN80. Further requirements are high leakage rate class and external leakage class, operation in magnetic field and nuclear environment.
- ✓ **Particle filters**: four cartridge type filters, two with 0.1 ~ 0.5 µm mesh, two with 1 ~ 5 µm mesh.
- ✓ **Bed demineralizers**: Two resin beds in series, first one is composed of cation and anion resins, second one is filled with cation resin. Volume of each vessel is roughly 90 liters.
- ✓ **Degasifiers**: two vessels with membrane system under vacuum condition with helium as sweeping gas, volume of each one is roughly 2.5 liters.

The design and construction code RCC-MRx 2018 could be selected, among other possibilities, as the applicable code for the design and manufacturing of WCS and CPS.

The WCS and CPS equipment are classified:

- ITER Quality Class 1;
- ITER Safety Importance Class 2 (SIC-2) with the exception of WCS SIC-1 Safety Isolation Valves,
- Tritium Class 2A
- and are subject to PED/ESPN.

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.

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.

3. Scope of the future Call for Tender

The scope of delivery for the Final Design and Manufacturing of WCS and CPS is based on specification provided by F4E to the Supplier.

The provisional scope of the contract includes:

- Engineering analyses of equipment and system;
- Finalization of design including configuration;
- 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 and procurement of all components, including sensors and I&C system;
- Factory testing and delivery to ITER Site at Cadarache;
- Optionally: On Site Assistance to IO during Installation and Commissioning.

F4E will provide detailed input to the Supplier such as the system requirements, the load specifications, documents covering different elements of design, engineering analyses including RAMI, 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 have demonstrated experience in:

- Manufacturing of large Pressure Equipment and Nuclear Pressure Equipment;
- Manufacturing engineering;
- Process engineering for radioactive fluids and for high pressure coolant loops
- Welding technologies of austenitic stainless steels;
- Non-destructive examination such as RT and UT;
- Testing of equipment under pressure.

5. Risks

The main risks related to the final design and manufacturing of these subsystem will be:

- The complexity of integration of components in the AEU due to the limited space available;
- The implementation of the AEU equipment maintainability provision in the design due to the complex integration;
- Design iterations are needed due to unstable or not frozen interfaces with other systems;
- The implementation of the regulatory framework may take additional effort and takes longer than planned as a result of the applicability of the ESP/ESPN regulation to the TBS.

6. Schedule

The main tentative dates of the current planning are indicated below:

- F4E plans to launch a Call for Tender in late 2025. The contract is planned to be signed by in Q1 2027, after PDR approval.
- The Final Design Review meeting is foreseen in 2028.
- The delivery is foreseen tentatively in 2036 to allow the performance of the On-Site Assembly and Commissioning in the period 2037-2039.

7. Market Survey

Please answer to the F4E Market Survey by clicking on this LINK

This Technical Note is for information purposes. The corresponding Market Survey is carried out for information purposes only, in accordance with Fusion for Energy's Financial Regulation.

Participants/respondents to this Market Survey acknowledge that by replying to this Market Survey imposes no obligation on Fusion for Energy to a future procurement procedure. Submission of the survey does not imply the right to be informed of, or participate in, any procurement procedure launched by Fusion for Energy.

Based on the received responses, F4E may contact and visit interested companies/entities to further explore the market and technical conditions of this development.