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# Overview of the last progresses for the European Test Blanket Modules projects

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**Abstract**

This paper gives an overview of the last progresses in terms of system design, calculations, safety and R&D done these last 2 years for the reference Test Blanket Modules developed in Europe, namely the Helium Cooled Lithium-Lead (HCLL) breeder blanket and the Helium Cooled Pebble Bed (HCPB), in order to cope with the ambitious objective to introduce two EU TBM systems for day-1 of ITER operation. The engineering design of the two systems is mostly concluded and the priority is now on the development and qualification of the fabrication technologies. From calculations point of view, the last modelling efforts related to the thermal–hydraulic of the first wall, the tritium behaviour, and the box thermal and mechanical resistance in accidental conditions are presented. Last features of the TBM and cooling system designs and integration in ITER reactor are highlighted. In particular, this paper also describes the safety and licensing analyses performed for each concept to be able to include the TBM systems in the ITER preliminary safety report (RPrS). Finally, overview of recent R&D progresses in fabrication, tritium experiments and test facilities development is given.


*Keywords:* ITER; HCLL; HCPB; Test Blanket Modules

## 1. Introduction

The long-term objective of the EU Breeding Blankets program is the development of DEMO breeding blankets, which shall assure tritium self-sufficiency, an economically attractive use of the heat produced inside the blankets for electricity generation and a

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sufficiently high shielding of the superconducting magnets for long time operation. In the short-term so-called DEMO relevant Test Blanket Modules (TBMs) of these breeder blanket concepts shall be designed, manufactured, tested, installed, commissioned and operated in ITER for first tests in a fusion environment. The main objective of the EU test strategy related to TBMs in ITER is to provide the necessary information for the design and fabrication of breeding blankets for a future DEMO reactor.

The two reference breeding blankets developed by Europe [1] are the Helium-Cooled Lithium-Lead (HCLL) blanket which uses the eutectic Pb–17Li as both breeder and neutron multiplier, and the Helium-Cooled Pebble-Bed (HCPB) blanket which features lithiated ceramic pebbles ($Li_4SiO_4$ or $Li_2TiO_3$) as breeder and beryllium pebbles as neutron multiplier. Both blankets are using the pressurized He technology for the power conversion cycle (8 MPa, inlet/outlet temperature 300 °C/500 °C) and the 9% CrWVTa Reduced Activation Ferritic Martensitic (RAFM) steel as structural material, the EUROFER. Main features of the TBMs and circuits design, of the basic parameters and of the test strategy in ITER has been presented at SOFT-23 in Venice 2004 [2] and at the ISFNT-7 in Tokyo [3]. This paper gives an overview of the last progresses done these last 2 years in terms of system design, calculations, safety and R&D.

## 2. TBMs design and system updates

For HCLL TBM, a first set of modifications have been realized [4]. They first concerned specific functional features in order to better comply with the testing objectives and to improve TBM reliability, such as: Pb–17Li flow path, TBM instrumentation, Pb–17Li draining, Pb–17Li manifold and He manifolds. They were also some modifications related to fabrication issues. Actually, after an industrial expertise on the In-TBM preliminary design to identify fabrication and mounting sequence issues, some following design guidelines have been adopted: avoid welding triple points on the junction first wall/stiffening grid, suppress sharp points on some welding trajectories, avoid possible interference between welding beams and welded parts (Back Plates/Side Walls), optimize thick plates welding. Finally, a preliminary version of the module attachment system to the frame, assuming flexible fixation and gliding shear keys system, has also been realized. More recently, two main modifications have been further introduced in the HCLL TBM design. The first one concerns the addition of a by-pass tube to extract part of the He first wall (FW) flow-rate in order to be able to increase up to 500 °C the cooling-plate (CP) outlet temperature. This feature is necessary because of the difference in terms of Neutron Wall Loading comparing DEMO operation (∼2.4 MW/m$^2$) and ITER DT Phase (0.78 MW/m$^2$). Moreover, the He cooling path has been reviewed following thermal–hydraulics studies performed for the HCLL DEMO design: the new reference cooling scheme is a full in-series cooling, FW first, then Stiffening Plates and covers, and CP at the end.

For HCPB, the design presented in 2004 has been in these years continuously optimised and dedicated to the first, so-called EM-TBM, to be installed into ITER. The major change that has been done since 2004 is a modification of the breeding unit. The breeding canister has been redesigned and its orientation changed from horizontal to vertical. Instead of the double canister with straight channels, the canister is now made from two cooling plates connected by a wrapper. Some of the coolant channels in the plates run along the circumference, some are meandering in toroidal direction some in the radial one. Moreover, the question of instrumentation of the HCPB EM-TBM has also been addressed. There are sensors in the high pressure zone of the helium coolant, the low pressure zone in the purge gas system and in the vacuum vessel on the surface of the TBM. Electrical and pressure signals have to be transferred. No sensor line should be interrupted in the vacuum vessel, requiring a continuous line from the sensor through the vacuum vessel vacuum boundary to the plug where the signal is passed to the data acquisition system. Handling of lines of the required length must be proven in advance with dedicated tests. The sensor plugs are very space consuming; they will be mounted on the pipe integration cask in the port cell. If a sensor fails no repair is possible, so there is the conflict of request for a high redundancy and the limited space. To cope with this problem extensive out of ITER tests are needed in the TBM mock-ups planned to gather experience with the sensors to be used and the issue to be investigated.