THE ITER DIVERTOR CASSETTE PROJECT MEETING
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The Divertor Cassette Project (ITER Large Project L-5) topical meeting was held on May 26 - 28, 1999 at the ENEA Brasimone Research Centre in Camugnano (Bologna), Italy. Specialists from all the four Parties and the JCT participated in the meeting that was aimed at summarising the status of the divertor R&D activities. The meeting was opened by Dr. A. Pizzuto, ENEA Fusion Division Deputy Director for the Experimental Engineering, with an overview of the fusion activities carried out in Brasimone.

The JCT outlined the features expected to be incorporated into the latest divertor design of the Reduced Technical Objective/Reduced Cost ITER (RTO/RC ITER). Although the proportion of the in-vessel space allocated to the divertor is smaller than in the 1998 ITER design, the new design still manages to maintain the predicted peak heat flux onto the targets at similar levels. A reduction of the coolant inlet temperature from 140 to 100°C has been proposed and should allow the use of series flow through the divertor plasma facing components (PFCs), which promises benefits in terms of divertor cost and overall machine safety.

The status of R&D activities related to component design, manufacturing and testing was then presented by the four Parties, in particular the progress made since the last L-5 meeting held in St Petersburg in June 1998. Efforts in the Home Teams have focused on developing Carbon-fibre Composite (CfC) armoured PFCs capable of sustaining the 20 MW/m² heat flux anticipated where the separatrix intercepts the divertor targets, and tungsten armoured PFCs capable of handling up to 5 MW/m², the peak heat flux expected elsewhere in the divertor. Apart from developing the PFCs, the Large Project L-5 aims at demonstrating the integration of PFCs built by all four Home Teams onto a divertor outboard channel cassette mock-up fabricated in the EU and an inboard channel cassette mock-up fabricated in the US.

In the EU, a prototypical target, with both (CfC) monoblock and tungsten brush-like armours, has been manufactured by Plansee (Austria) and Ansaldo (Italy) (Fig.1). The monoblock is a robust design that uses
drilled blocks of CfC into which a copper alloy tube is inserted and joined via a cast pure copper interlayer. The tungsten brush uses rectangular pins of tungsten set in a cast pure copper matrix as a means of accommodating the different thermal expansions of copper and tungsten. This is then electron-beam welded to a copper alloy heat sink. The prototype is presently under test at the Le Creusot facility in France, where it will be cycled up to 20 MW/m². Note that smaller scale mock-ups built by Plansee have already demonstrated satisfactory performance of the CfC monoblock at 20 MW/m² for 1000 cycles and the tungsten brush at heat flux in excess of 15 MW/m². In common with most PFCs, the most critical feature of these components is the armour to copper alloy heat sink joint. Hence a number of European laboratories and industries (Seibersdorf, ENEA, VTT, CEA, Plansee) have contributed to the development of non-destructive examination of this joint using ultrasonic inspection and thermal imaging techniques. These have been demonstrated to be workable methods for reliably detecting 2-3 mm defects in the armour to heat sink joints.

The post-neutron-irradiation high heat flux testing of samples and prototypical components with CfC, Be and W armours, irradiated to conditions expected at the end of divertor life in ITER, is nearing completion in the hot cell facility at FZJ in Julich, Germany. A highlight of these tests so far is that an irradiated CfC armoured component was successfully tested at 15 MW/m² for 1000 cycles.

The thermohydraulic database produced by CEA Cadarache, France, on critical heat flux tests of divertor components has been confirmed by the round robin test on mock-ups performed in JA and US.

The JA Home Team reported encouraging results of fatigue testing of a full-scale mock-up using a 2-D CfC monoblock design employing a large diameter tube (21 mm outer diameter instead of 12 mm of EU reference design). The mock-up sustained 5 MW/m² for 3000 cycles, and further two tiles at the center of the mock-up sustained 20 MW/m² for 1000 cycles. Although during the test at 5 MW/m² a few tiles exhibited elevated temperatures which would be caused by joint flaws during the manufacturing process; the flaws did not propagate during the fatigue test.

In the RF, a brazed lamellae tungsten mock-up, proposed as a cost effective variant of the tungsten brush, survived up to 18 MW/m² and 900 cycles at 15 MW/m². The US Home Team reported that two W brush mock-ups have sustained an incident heat flux of 30 MW/m² for 1000 cycles. A further two brush mock-ups using tungsten hot isostatically pressed (HIPed) to the CuCrZr heat sink with an intermediate soft Cu layer survived up to 25 MW/m². These results, and those of the European brush, indicate that a tungsten armoured target capable of sustaining 20 MW/m² is an attainable goal which will be pursued by future Home team R&D.

A hot liner in the private region of the divertor, with a surface operating temperature of ~800-1200° C, is being investigated by the RF as a potential means of minimising the trapping of tritium. A test programme to investigate its performance is underway.
The EU Home Team (Ansaldo, FN and CSC (Italy)) has built a 3.2 t welded, stainless steel mock-up representing the outboard divertor cassette. Dimensional tests proved that all the required tolerances have been achieved. European built PFCs have already been installed onto the outboard cassette and the Russian built liner PFC is scheduled to be attached in the next two months. In a visit to the ENEA Brasimone laboratories the meeting participants were able to see this assembly (Fig. 2). In the US a 5 t centre segment of the cassette body has been built using stainless steel casting. Tests showed that the material is suitable from both an outgassing and a corrosion point of view. The integration of the JA and RF Home Team components onto the centre segment is planned to be completed by the end of September. The relative merits of producing the divertor cassettes by welding forged material will be compared with fabrication from castings.

There was discussion on the issues that remain to be solved by R&D. In future the EU will continue to focus its efforts on the reference design, on the welded divertor cassette and the development of HIP joining of the armour to the heat sink. The EU, JA and RF will study cost effective alternative designs, such as:

- tungsten monoblocks (EU) as a competitor to the tungsten brush;
- widening the monoblocks to take advantage of the lower coolant temperature (EU);
- flat tiles with hypervapotron cooling (EU);
- monoblock based on large tube diameters and, if feasible, including annular flow (JA);
- hot pressing of tungsten pins into a Cu substrate (JA);
- optimisation of the ohmic fast brazing technique (RF);
- a liner with radiatively cooled tungsten tiles (RF).

In summary, the overall L-5 project has significantly contributed to solving a large part of the critical issues of the ITER divertor design, and impressive achievements have been obtained in the technology of high heat flux components. The divertor design is now based on robust solutions which meet practically all the ITER requirements. Future work will focus on improving the reliability and repeatability of the manufacturing process and on the development of cost effective alternative concepts.

The next L-5 Meeting is provisionally scheduled for April 2000 in Naka.