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WEST: the challenges of reaching 100% of actively cooled components for long pulse operation

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The WEST (Tungsten Environment in Steady-state Tokamak) project in France is crucial for reaching sustainable fusion energy by simulating reactor-like conditions. WEST provides a unique facility to integrated and test technologies for Long Pulse Operations.

Previous operation on Tore Supra, and numerous studies showed that all components receiving convective heat flux from particles and thermal radiations from the plasma must be water-cooled. Key components such as the divertors and limiters were identified for their high thermal load. Their design has been studied for many projects and is well documented. The integration process involved rigorous design and manufacturing standards, particularly focusing on over 2000 Copper/Stainless Steel junctions critical for preventing water leaks during operation.

Additionally dedicated models were developed to compute thermal loads on all components within WEST Vacuum Vessel (VV), including the VV inner shell, ports walls, diagnostics…It was shown that depending on the plasma scenario and the reflectivity hypothesis of the surfaces, temperatures can significantly vary, forcing the design teams to take into account conservative envelop cases. Dedicated water cooled protection panels were integrated to shield the larger surfaces of the VV. Actively cooled protections on some of the most loaded diagnostics inside the ports were developed. These upgrades were installed during several annual shutdowns. The current WEST configuration includes more than 98% of the VV surface with actively cooled components. Innovative technologies are not indispensable, however all components must be manufactured and installed under high quality requirements, and stringent tightness control methods to prevent any risk of leak over the years from the numerous welds and hundreds of meters of cooling channels.

However, some areas were too complex to cool down, for two main reasons: either it was too difficult to integrate water cooled components, or it was too complex to route water pipes to feed these components and to perform all welds with the required quality. Those aspects cannot be overlooked since they can severely affect the operational domain for long pulse operations. The remaining inertial structures are monitored with thermocouples and IR diagnostics.

Flowmeter and thermocouples are installed in all water loops and a dedicated calorimetry diagnostic was developed. The energy balance is closed with an imbalance of about 10% of the total injected energy for most of the campaigns. Those diagnostics are mandatory to monitor the behaviour of poorly cooled components, to check that the cooling remains efficient during long pulse operation (no flow perturbation or critical flux …) and allow assessing the lifetime of inertial components.

Yet, degassing occurred during long pulse operation, leading to an increase of plasma density and eventually disruptions. This is likely caused by overheating of surfaces. Indeed, thermocouples show that the temperature is steeply rising on some areas around the WEST upper divertor, reaching values above 300°C after 300s pulses and 1GJ injected. Some inertial areas not controlled by thermocouple temperature measurement may also have caused this outgassing.

The path to high power continuous operation in WEST still requires improvements of protection of its internal components.

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