



Abstract : Up to now, Tore Supra is the only fusion device fully equipped with actively cooled Plasma Facing Components (PFCs). In case of abnormal events during a plasma discharge, the PFCs could be submitted to a transient high power density (run away electrons) or to a continuous phenomena as local thermal flux induced by trapped suprathermal electrons or ions). It could lead to a degradation of the PFC integrity and in the worst case to a water leak occurrence. Such water leak has important consequence on the tokamak operation that concerns PFCs themselves, monitoring equipments located in the vacuum vessel or connected to the ports as RF antennas, diagnostics or pumping systems. Following successive water leak events, a large feedback experience has been gained on Tore supra since more than 15 years that could be useful to actively cooled next devices as W7X and ITER.

Pressurised water loop :

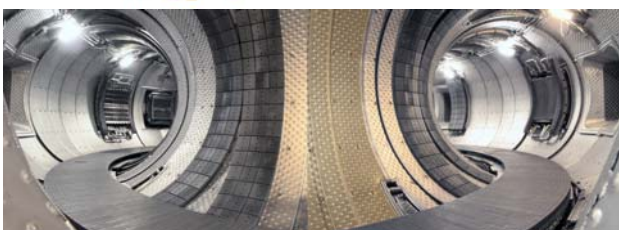
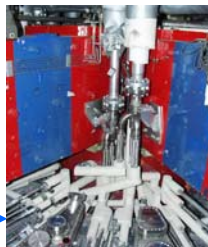
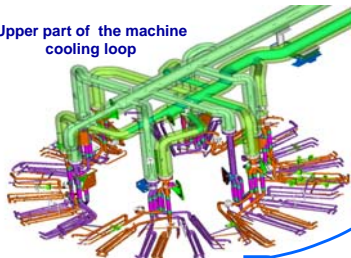
- total water flow of 1100 tons/h
- 3 MPa-120°C during operation
- 2 MPa-200°C during baking
- pressure drop : 0.7 MPa
- velocity in the HHF Components up to 10 m/s

The water distribution to the machine is made at three different levels (sub-circuits) :

- Upper Part:** Vessel Protection panels, Electrons targets, Bumpers, Endoscopes
- Mid Part:** ICRH, ECRH, LHH antennas, outboard guard Limiter
- Lower Part:** Toroidal Pump Limiter

Each part feeds in parallel 6 toroidal 60° modules. The main difficulty comes from the inlet and outlet feeding pipes that are located at the top of the machine leading to some difficulties for draining some PFCs as vessel protection panels.

Upper part of the machine cooling loop



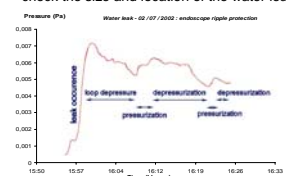
Panoramic overview of the Tore Supra Plasma Facing Components (CIEL configuration, 2002)

"Micro leak" occurrence :

vessel pressure maintained below 1 000 Pa

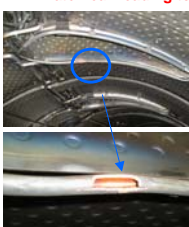
As long as the vacuum vessel pressure and temperature do not reach the conditions for water condensation, the standard vacuum pumping system is operating. For a pressure between 1 and 1000 Pa, a specific fore pumping cluster made of a Roots and a primary pump is used in order to supply the turbo molecular pumping that can't operate over 1Pa.

The three parts of the cooling loop are isolated using valves. Successive water depressurizations and pressurizations are performed in order to check the size and location of the water leak.



endoscope ripple protections micro leak July 2003

Water leak leading to a Pressure vessel over 10 000 Pa



electron ripple protection September 2002



vinyl hoses to drain water from the bottom parts of the machine

In September 2002, the most important water leak that appeared on Tore Supra was consecutive to an explosion of a HHF upper target element (electron losses). The CuCrZr tube was unfortunately not water fed during a 120s plasma pulse duration. 2000 liters of condensed water were spilled in the vacuum vessel (lower part).

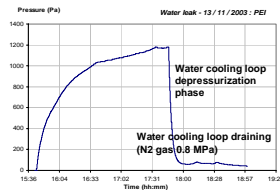
The vessel was filled with dry nitrogen gas at a 35 mbar over pressure to maintain oxygen free the vessel, thus protecting the internal components and in particular the aluminium tightness seals. The Nitrogen gas was heated over 60°C and blown into the machine in order to heat the vessel and evacuate the trapped water vapor. All the ports located at the bottom part of the machine were equipped in the initial design with drain openings. The heated and pressurised nitrogen gas circulation during several days helped in emptying and drying the plasma vessel.

At the end, no air leak was detected and no defect in situ sensor (optical fiber-optic, langmuir probes, thermocouple) had to be replaced.

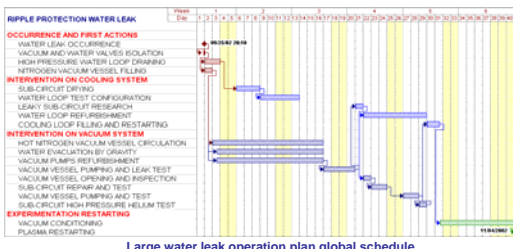
Pressure between 1 000 Pa and 10 000 Pa

In this pressure range, water condensates on the vessel cold wall (20°C) as TPL pumping shafts. The vacuum is then maintained using a specific device able to pump water (Rotomil's 50 m³/h).

Inner vessel temperature is maintained at 120°C using in situ electrical heating conductors.

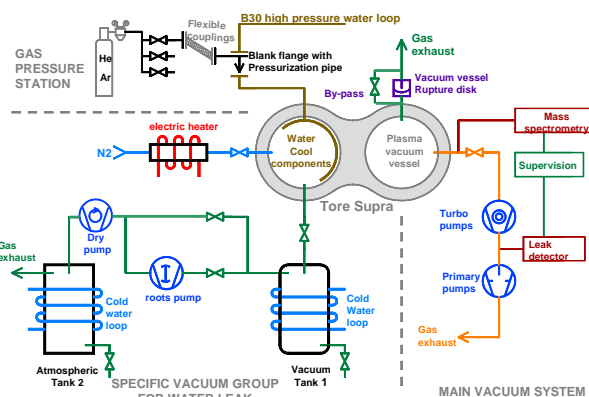


Vessel protection panel SS melting due to ripple trapped ions, 3 MW/m² power density. Water leak occurrence : November 2003



Large water leak operation plan global schedule

Helium test and water pumping group upgrade



Following several water leak occurrence during the CIEL experimental campaign from 2002 to 2004, an upgraded system and associated procedure were defined to be set up in the near future on Tore Supra.

The safety aspects were taken into account in the proposed pumping system by setting up 2 liquid water tanks (2 x 2 m³), one upstream to protect the dedicated water vapor fore pumping system, the other one downstream for storage and analysis of removed condensed water.

The design of the circuits modifications and procurement of required equipments are on going, scheduled to be operated in 2005, if required !