Italian National Agency for New Technologies, Energy and Sustainable Economic Development

DTT S.c.a.r.l.

Summary Session V: Specifics of coolant-material compatibility in fusion environment

Technical Meeting on Compatibility Between Coolants and Materials for Fusion Facilities and Advanced Fission Reactors

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03 November, 2023

Session V: Specifics of coolant-material compatibility in fusion environment

The session V was dedicated to **coolant material compatibility in Fusion Environment,** 4 presentation were carried out.

Three presentation related material corrosion/SCC in water and one related coating as corrosion mitigation strategy:

- On the water chemistry of fusion power reactors (I. Moscato)
- Corrosion AND SCC initiation of unirradiated and ion irradiated stainless steels in borated water coordinated water chemistries (C. Gasparini)
- Effects of ionising radiation on Corrosion behaviour of CuCrZr alloys under aqueous environment (J. LIM)
- Characterization of alumina permeation barriers on EUROFER 97 steel (M. Angiolini)

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- The Session was dedicated to the analysis effect of the coolant in contact with the structural material: Corrosion, SCC, Activated corrosion product generated and deposited outside the VV (316L and Eurofer F/M steel/Copper alloy);
- Common approach identified for water coolant:
  - Use borated water for the water chemistry control
  - Use addition of alkaline elements (LiOH, KOH, NaOH) in order to increase the pH based on LWR/WWERs experience;
- Coating were analysed as mitigation strategy in order to:
  - Avoid/reduce water corrosion from borated water
  - Avoid/reduce breeder-coolant corrosion (PbLi)

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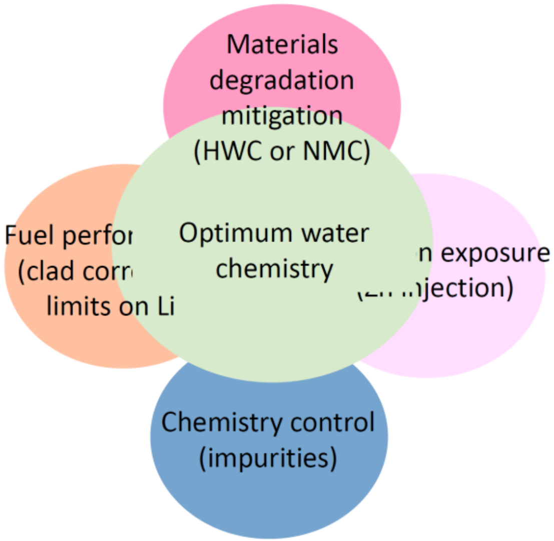
- Since Fusion Water Coolant required **different water chemistry** respected to **LWR/WWERs** and operate at different operative conditions dedicated R&D are required in order to identify the **optimum water composition** able to shield the coils, protect the materials, reduce radiation inventory and minimise the operator exposure => change of scope and operative cond. respect to LWR/WWERs

- Several factor are involved in the optimisation of the water chemistry: neutron exposure, material microstructure, alloy elemental composition, surface finish, residual stress and strain, water chemistry, contaminants, dissolved oxygen, and temperature.



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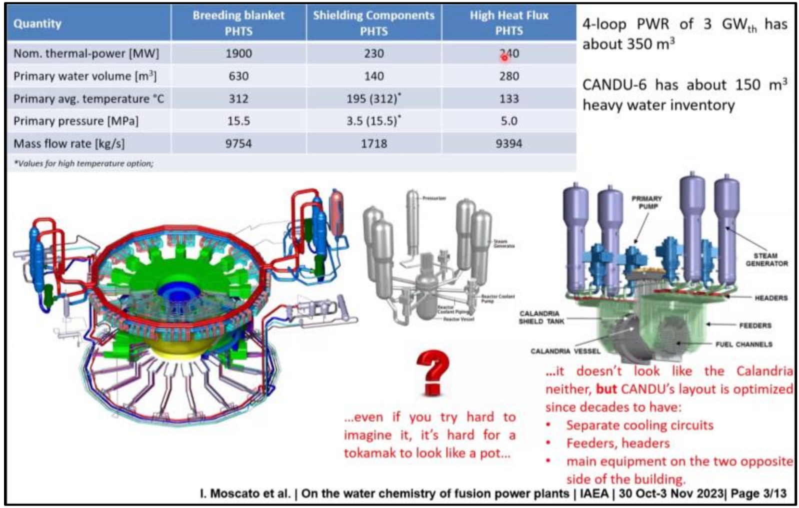
- Preliminary analysis were carried out in order to investigate:
  - Corrosion of structural material 316L/EUROFER with borated water (~8000 B ppm for DTT) compared with UPW
  - SCC in borated water compared with UPW
  - SCC with 316L irradiated with Ni ions
  - Use of Li in the borated water in order to increase the pH of the water and reduce SCC and Activated corrosion product formation.
- Oscar code was used for Fission (PWR) and Fusion application (v1.4a) in order to:
  - estimate the amount of Activated corrosion product produced in DTT VV, in ITER and in DEMO,
  - Evaluate the ACPs that will precipitate outside the VV in the auxiliary system.

The database has to be implemented in particular for high B concentration and applied magnetic field. => common action for all Tokamaks!



Quantity	Breeding blanket PHTS	Shielding Components PHTS	High Heat Flux PHTS
Nom. thermal-power [MW]	1900	230	240
Primary water volume [m^3]	630	140	280
Primary avg. temperature °C	312	195 (312)*	133
Primary pressure [MPa]	15.5	3.5 (15.5)*	5.0
Mass flow rate [kg/s]	9754	1718	9394

*Values for high temperature option;

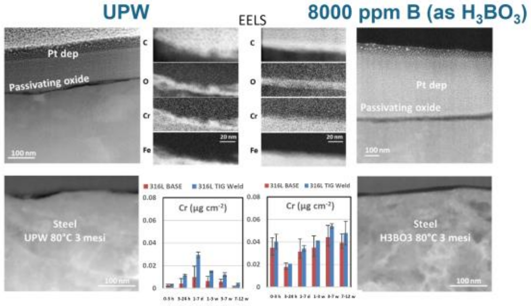
4-loop PWR of 3 GW_{th} has about 350 m^3

CANDU-6 has about 150 m^3 heavy water inventory

...even if you try hard to imagine it, it's hard for a tokamak to look like a pot...

...it doesn't look like the Calandria neither, **but** CANDU's layout is optimized since decades to have:
- Separate cooling circuits
- Feeders, headers
- main equipment on the two opposite side of the building.

I. Moscato et al. | On the water chemistry of fusion power plants | IAEA | 30 Oct-3 Nov 2023| Page 3/13



Oxide passive layer formed on SS316L steel samples exposed to UPW and 8000 ppm B water at 80°C

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- The preliminary experimental and numerical analysis on water corrosion and mechanical test (Slow Strain Rate test, Crack Growth test) carried out with the addition of LiOH or KOH in the borated water have shown the benefit of such solution:
  - In DEMO the maximum Lithium concentration add to water should be lower than 2.7ppm (preliminary estimantion to be confirmed);
  - In DTT application the Li content in water should be higher than 57ppm in order to increase the pH and reduce the corrosion effect => analysis is requested to evaluate the consequence of huge amount of Li in Water;
  - JT60 maybe will required higher Li content in borated water (B concentration in water is 12400 ppm, instead in DTT 8000ppm)
  - Possible use of H2 in water has to be investigated to reduce water radiolysis;

  The preliminary experimental analysis compared with numerical simulation has shown => It is requested a dedicated experimental validation at relevant operative condition.

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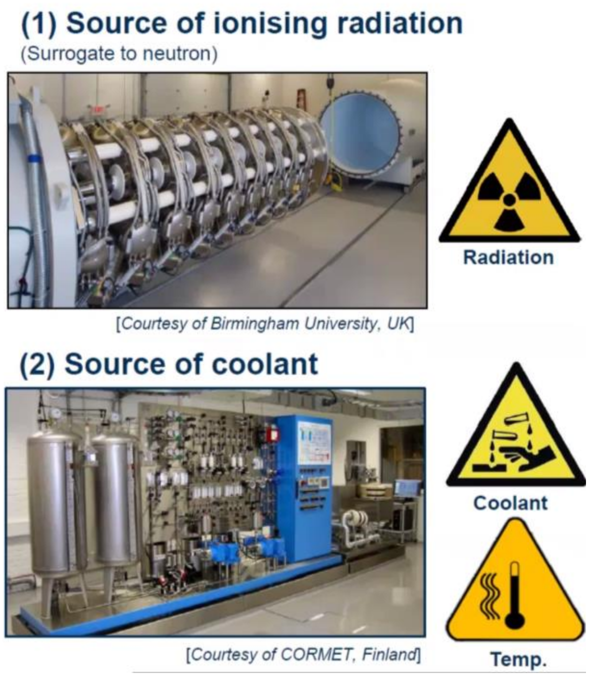
- In order to investigate SCC it is mandatory to analyse the performance of irradiated samples: Neutron irradiation at relevant operative condition is not available, characterisation test can be performed with Ion => it is necessary to understand how to correlate neutrona and ion irradiation taking into account that neutron flux energy for Fusion application is ~MeV => proposal??



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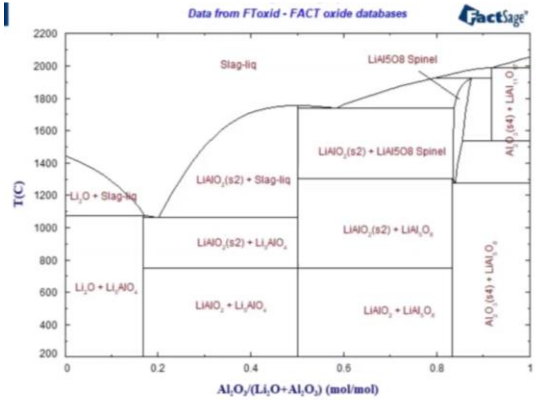
- Protective Coating: Inside the pipes/shell to avoid Corrosion and Stress Corrosion Cracking (SCC was investigated for Borated water of Tokamak facility in order to identity the ACPs) => open proposal to be investigate



- Outside the pipes in the case of the WCLL BB in contact with the breeder/coolant (PbLi): Al2O3 (alfa-phase) was investigated as coating material, the coating was manufactured by PLD (Pulsed Laser Deposition) process on plates. Preliminary characterization shown some concern related the presence of LiAlO2 that can impact the coating performance, possible solution => use Multilayer coating

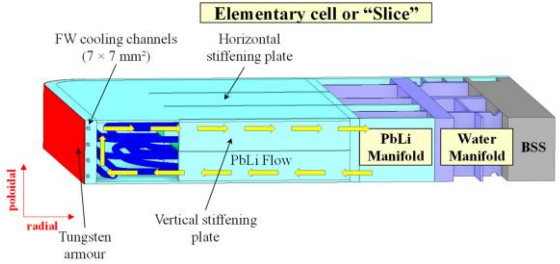


Figure 1. View of the WCLL BB elementary cell layout.

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