DIV-IDTT.S.11-T002-D004 Simulations to assess activated corrosion products (ACP)

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CONSORZIO RFX
Ricerca Formazione Innovazione

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The views and opinions expressed herein do not necessarily reflect those of the European Commission.

Outline

- Main goals of the task
- Methodology and simulation codes for ACP assessments
- Status of the work on the OSCAR-Fusion modelling
- Challenges and issues

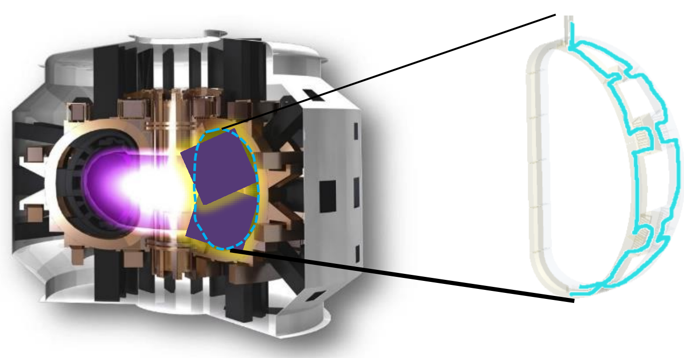
DIV-IDTT.S.11-T002-D004

Main goal:

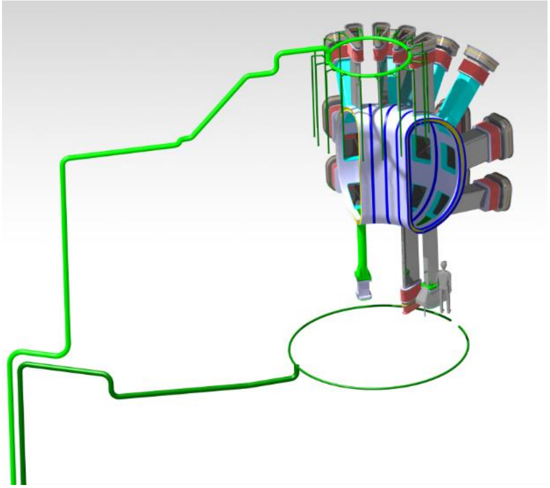
- Subtask of DIV-IDTT.S.11-T002: Vacuum Vessel (VV) Design 2022.
- Simulations to assess activated corrosion products (ACP) of Vacuum Vessel loop.

Methodology proposed:

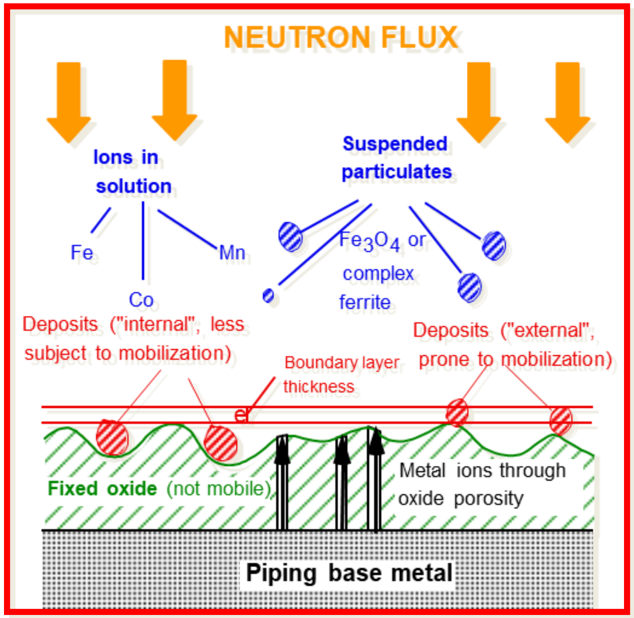
- Use of OSCAR-Fusion-V1.3, developed by CEA in collaboration with Framatome and EDF.



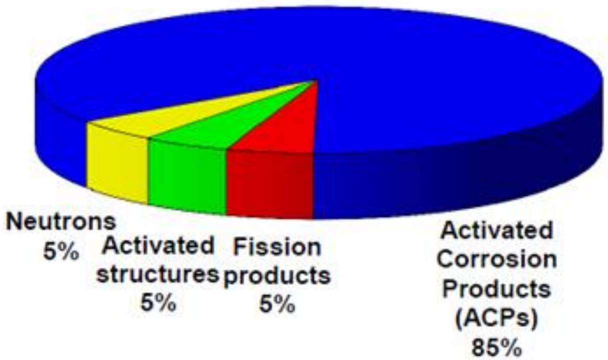
G. Di Gironimo, Fusion Engineering and Design 146, Part B, 2019, 2483-2488

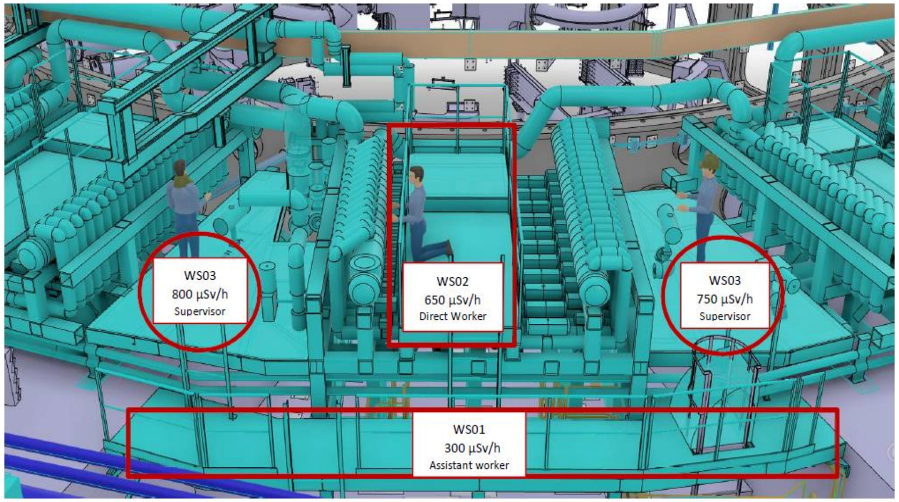


Main goal



- **Radioprotection**: Reduction of ORE;
- **Environment**: Minimization of release/waste – Optimization of dismantling process – Source term in case of accident/incident
- **Availability**: Optimization of reactor operation





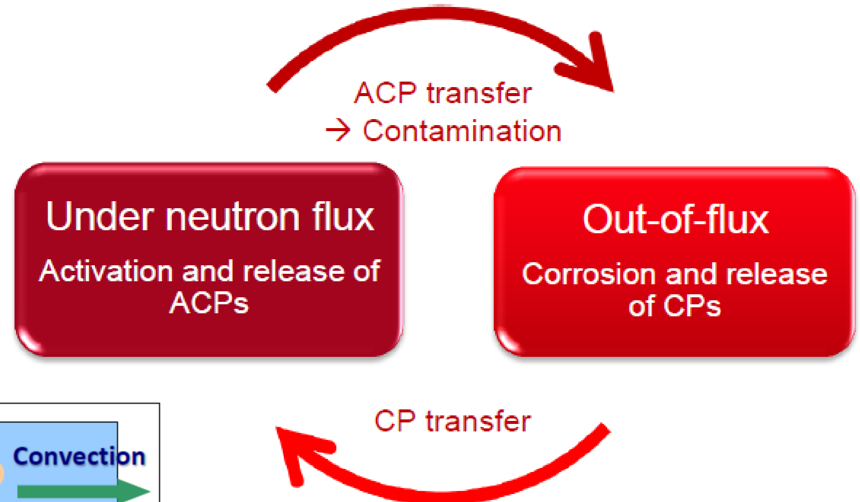
ACPs have been identified as possible source term in DTT to be considered in safety analysis.

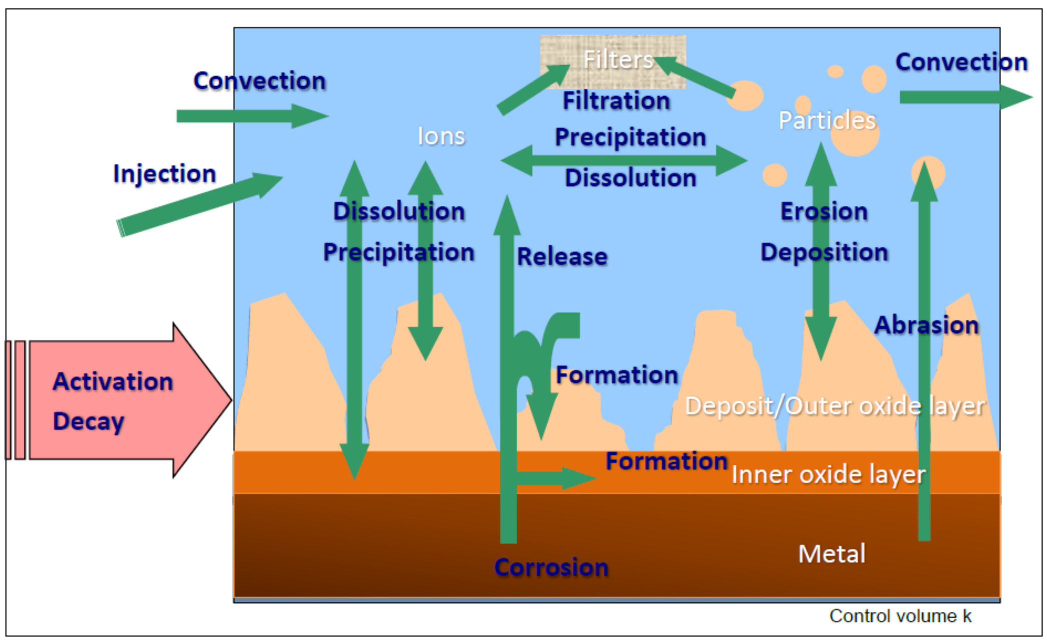
Courtesy of D. Carloni and Y. Le Tonqueze, ITER. Copyright ITER Organization

OSCAR-Fusion

Outil de **S**imulation de la **C**ont**A**mination en **R**éacteur (t**O**ol of **S**imulation of **C**ont**A**mination in **R**eactor)

Principle of contamination transfer in a nuclear cooling system





$$\frac{\delta m_i}{\delta t} + (\dot{m}_{out} - \dot{m}_{in}) = \sum_{source} J_m - \sum_{sink} J_m$$

$$J_{corr}^{el} = V_{corr}^{el} \cdot S_w \cdot \alpha_{met}^{el}$$

$$J_{rel}^{el} = V_{rel}^{el} \cdot S_w \cdot \alpha_{rel}^{el}$$

Wet surface

V_i Release/ corrosion rates

Methodology: Intro on OSCAR-Fusion

OSCAR –Fusion Input data requirements

- **Geometry and T-H**
  - **Wet surfaces**;
  - Hydraulic diameters;
  - Pipe slope;
  - Rel. lengths (laminar-turbulent transitions);
  - Coolant velocity;
  - Coolant temperature;
  - Pressure;
  - Flow rates and variations.
- **Material properties** (metal and oxides):
  - **Composition;**
  - Rugosity, porosity, tortuosity;
  - Density;
  - **Initial deposition**;
  - **Corrosion and release rates (constant, power law, Moorea law)**.

- **Neutron activation**
  - Decay data;
  - **Activation reaction rates;**
  - Ejection reaction rates;
  - **Space scaling factors (called DPA).**

- **Loop main data**:
  - By-pass;
  - CVCS efficiency and layout.

Geometry nodalization in simple 1D regions with assigned conditions

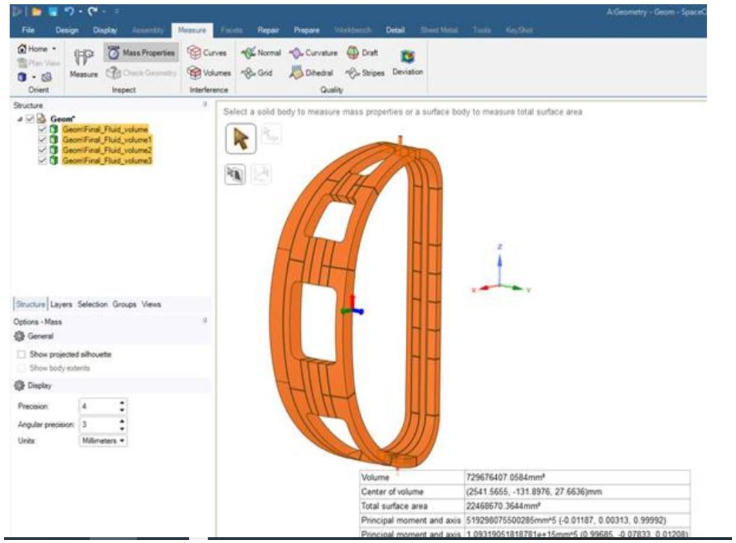
Status of the work

Status:

- Draft model of the VV loop in OSCAR-Fusion V1.3 (credits: C. Gasparrini)
- In-vessel: Accurate Wet surfaces of the VV-IVC (credits: E. Martelli)
- Neutron-activation reaction rates data collection (G. Mariano, R. Villari et al.)

Ongoing:

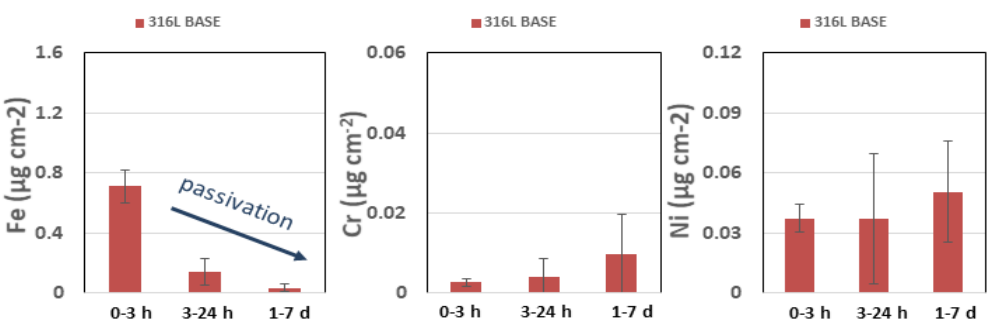
- Data collection on the out-bio-shield components. Geometrical and T-H data
- Pressure drops evaluation (credits: M. Molinari)
- Corrosion law definition
- Irradiation scenario definition
- Water chemistry implementation



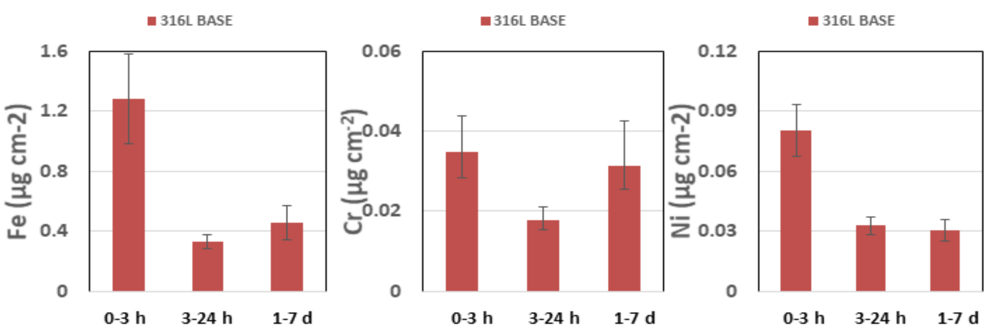
Challenges and Issues

- **Validation Domain:** OSCAR-Fusion is validated under PWR primary cooling loop T-H conditions (300°C, 155bar), far away from DTT-VV (60°C, 8bar).
- **Water Chemistry:** 8000ppm of B cannot be simulated in OSCAR-Fusion.

Ultrapure water immersion tests at 80 °C, $pH_T = 6.3$



Borated water (8000 ppm B) immersion tests at 80 °C, $pH_T = 3.6$



C. Gasparrini et al., IEEE Transactions on Plasma Science

Release metals from 316L and TIG welds samples exposed to UPW and borated water H_3BO_3 (8000 ppm in B) at 80°C, h: stands for hours, d: for days

A significant increase of Fe and Cr releases was observed in borated water compared to UPW.

Challenges and Issues (cont'd)

- **Radiolysis:** OSCAR-Fusion does not take into account radiolysis phenomena.

$$H_2O\ + radiation \rightarrow radicals + molecules$$

  - radiation: γ, n, α from $^{10}B(n,\alpha)\ ^{7}Li$
  - radicals: e.g. OH, HO_2 etc.
  - molecules: e.g.H_2O_2 etc.

- **Radiolysis depends on:**
  - Radiation intensity;
  - Linear Energy Transfer (LET=dE/dx)
  - Temperature
  - Presence of oxidant species in the circuit

- **In DTT VV-circuit:**
  - **High B concentration with 95% enrichment in B-10: α particles have high LET;**
  - **High temperature helps recombination of radicals: we have very low temperatures in DTT.**

Conclusions and Outlook

- A **draft model** of the VV loop has been produced in OSCAR-Fusion;
- The OVC part has to be revised and implemented together with a real operation scenario;
- Data collection on **manufacturing, geometrical and thermal-hydraulic data** is ongoing;
- Experimental data produced by C. Gasparrini will be used to refine **corrosion laws** for high levels of B;
- Parametric studies on **water chemistry** will be performed using OSCAR-Fusion.

Thank you for your attention

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