NUMERICAL STUDY OF IN-VESSEL CORIUM RETENTION IN A BWR REACTOR

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Introduction

• This work is a part of the project “In-Vessel Melt Retention Severe Accident Management Strategy for Existing and Future NPPs”- IVMR, under H2020 grant agreement No 662157;
• IVMR started in June 2015, for a duration of 4 years. It involves 23 partners from 14 European countries.
Introduction - What is IVMR all about?

- Review existing approach for in-vessel retention
- Improve it by providing new experimental data and justifying less conservative assumptions
- Extend it to various designs
- Investigate possible innovations for in-vessel retention
Introduction – IVMR activities

June 2015
- Corium molten pool experiments (WP3)
- Simulant molten pool experiments (WP3)
- External cooling experiments (WP4)

Methodology Synthesis (WP2)

2016-2017
- Review of innovations for optimization of IVMR (WP5)
- Improvement of models (WP2)

CFD applied to molten stratified pools (WP2)
CFD applied to external cooling (WP2)
Assessment of mechanical resistance of ablated wall (WP2)

2017-2018

May 2019
- Updated & harmonized Methodology
- Updated Reactor Calculations (WP2)

IVMR
Introduction – Reactor Calculations

- 4 sub-groups: VVER 440, VVER1000, BWR, PWR

Codes:
- Integral codes: ASTEC, ATHLET-CD, MAAP, MELCOR, RELAP/SCDAPSIM
- Dedicated codes: PROCOR, Apros
The Reactor

Scheme of typical BWR-5 reactor

Scheme of MARK II containment
Brief Description Of The Modelled BWR

- BWR-5 Mark II Containment;
- Vessel (carbon steel with internal sst cladding) total height 20.8 m, diameter 5.30 m and thickness 13 -18 cm;
- 2029 MWt;
- Total mass of UO2 fuel = 91.2 tons;
- Total mass of Zr = 26.4 tons.
Ex-vessel & finite element mesh of LH are integrated into the model.
Ex-Vessel Model

Reference mesh points for the results “1”, “6” & “10”
General Modelling/Scenario Info

- RELAP/SCDAPSIM mod 3.4;
- LB LOCA with SBO;
- HTC – calculated by RELAP5;
- Reactor cavity flooded before meltdown;
- LH mesh of 140 finite elements.
Ex-Vessel Cooling Conditions

- Event of LB LOCA + total failure of all emergency core cooling systems (reactor scram is activated) was assumed. Two ex-vessel cooling scenarios were analyzed:
  - Sufficient wall cooling scenario, where LH is cooled with constant water flow (~15 kg/s);
  - Insufficient wall cooling scenario, where the reactor cavity is filled with water before meltdown and no more water is supplied after cavity is full (gradual boil-off).
Main Results (LOCA + SBO)
Main Results – “Sufficient Cooling”
Main Results – “Sufficient Cooling”
Main Results – “Sufficient Cooling”
Main Results – “Insufficient Cooling”

![Graphs showing relocated material mass and debris height over time.](image-url)
Main Results – “Insufficient Cooling”
Main Results – “Insufficient Cooling”
Conclusions

• The water flow needed to maintain the water level in the ex-vessel model was found to be \( \sim 15 \text{ kg/s} \);

• The modelling results show that CHF is not reached in the analysed cases, i.e. with constant cold water flow or without water flow (only dry-out is observed).

• The heat transfer coefficient from external surface of the reactor vessel varies within the interval of 5000 – 7000 W/(m\(^2\)*K).
Thank you for your attention

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