Modeling of Phébus FPT-1 experiment in EU MUSA project

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VTT – beyond the obvious

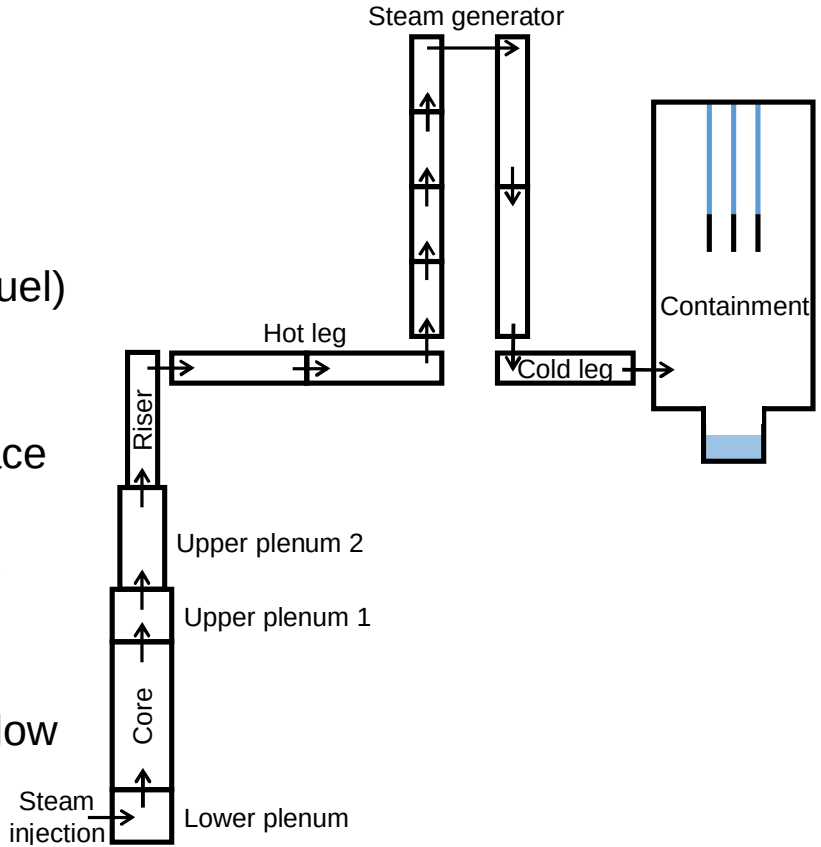
MUSA has received funding from the Euratom research and training programme 2014–2018 under grant agreement No 847441.

Introduction

- Phébus FPT-1 experiment performed by IRSN in 1996
- 1 m long fuel bundle, 20 fuel rods, and Ag-In-Cd control rod
- Heated up by fission power
- Released fission products transported through hot leg, steam generator tube, and cold leg, to containment
- MELCOR model developed by VTT in EU MUSA project (Management and Uncertainties of Severe Accidents)
- MELCOR 2.2 revision 18019
- Presenting results of a reference case calculation
- The model will be used in uncertainty analyses

Nodalization

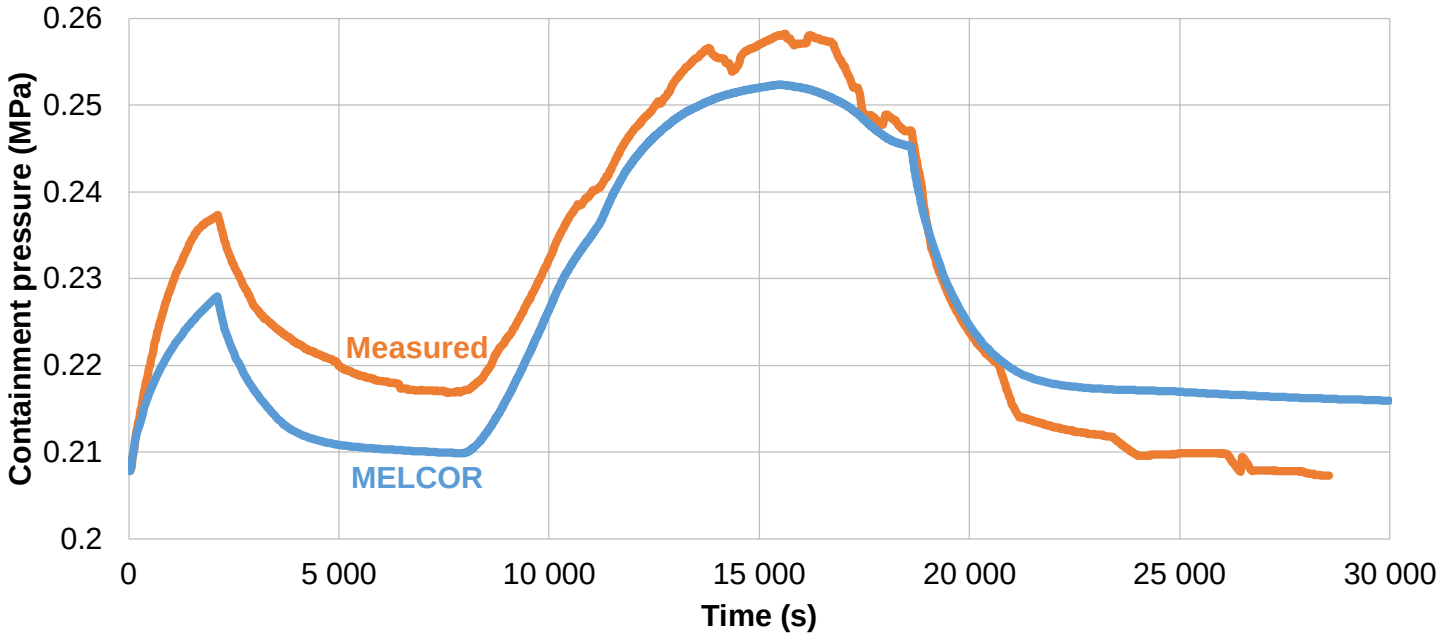
- Core model:
  - 2 rings, 14 axial levels (11 levels for active fuel)
- Thermal-hydraulics:
  - 15 control volumes
  - 35 heat structures with specified outer surface temperatures
- Code crashing due to very high pressure in lower plenum
  - Avoided by increasing sensitivity coefficient 1505 (1) (minimum porosity for calculating flow resistance) from default 0.0001 to 0.01



Radionuclides

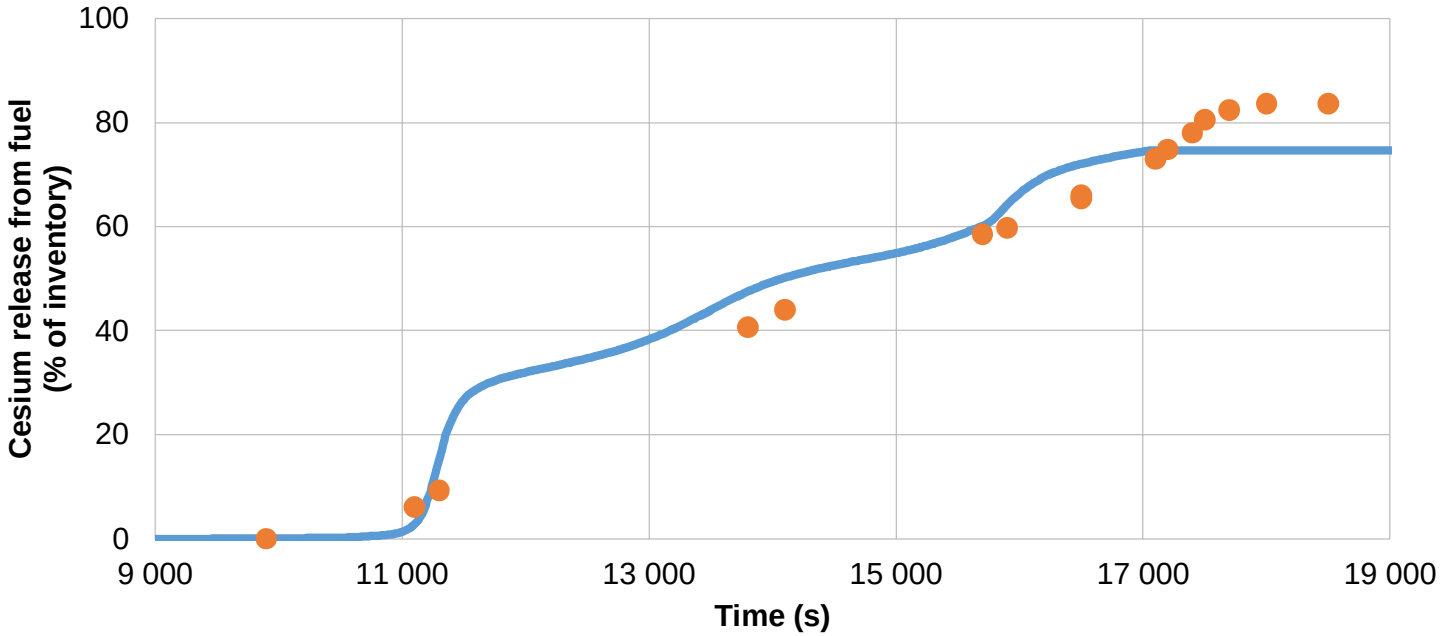
- Almost all iodine as CsI, very little I_2
- Cs modeled as CsOH (92 %) and CsI (8 %)
- Cs_2MoO_4 not modeled
  - Would require lot of manual work because not part of MELCOR's default inventories
- No fission products in fuel–cladding gap
  - Measurements do not show any release at the time when cladding failed

Pressure



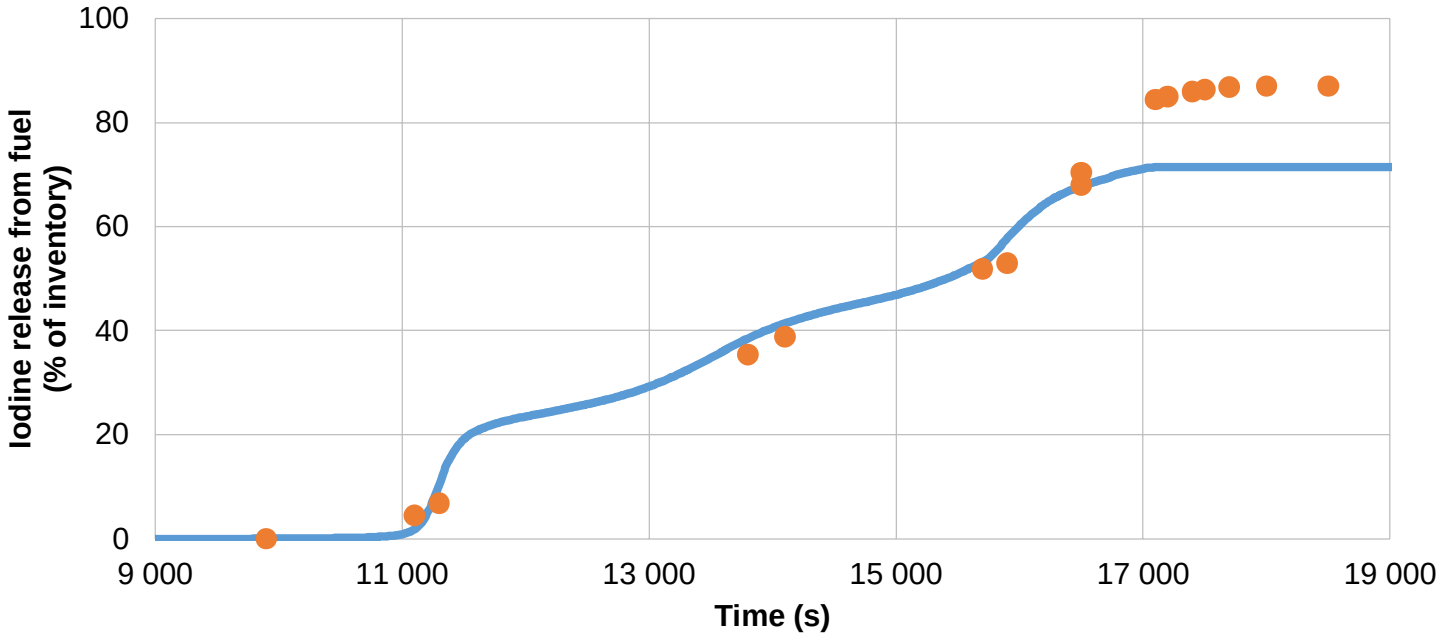
Ref. [1]

Cesium release from fuel:
Very small underestimation



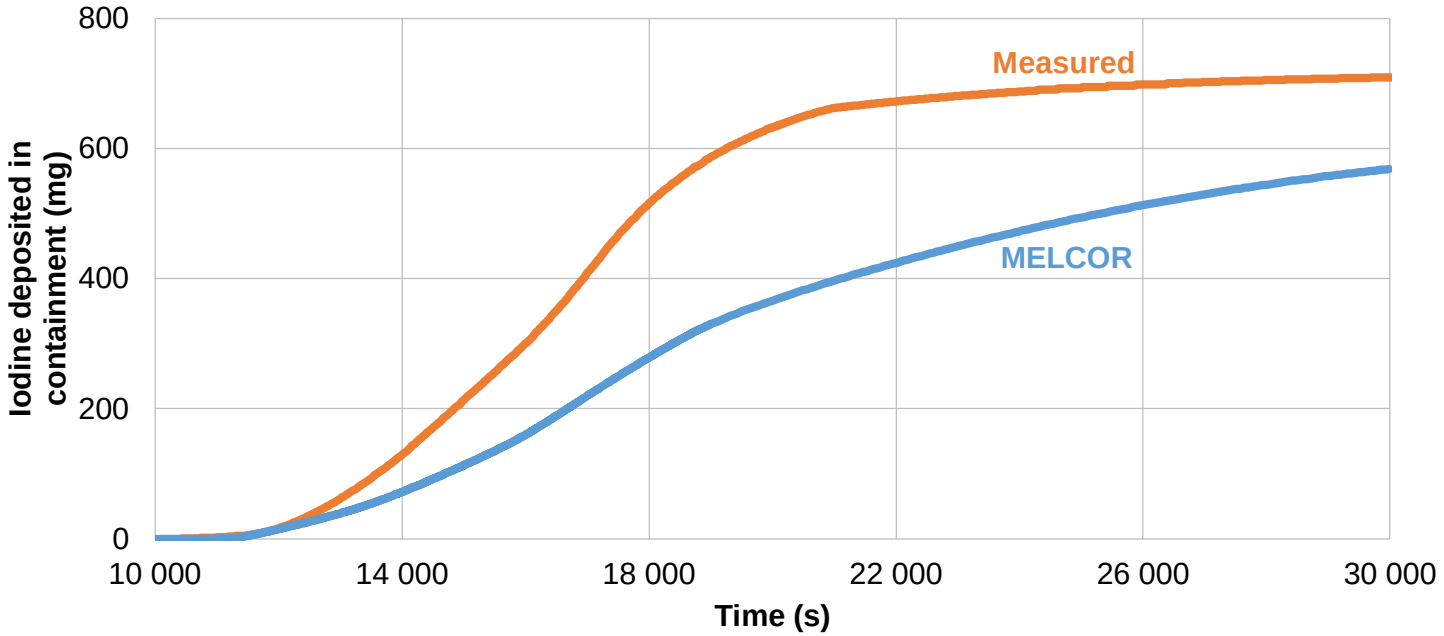
Ref. [2]

Iodine release from fuel
Small underestimation



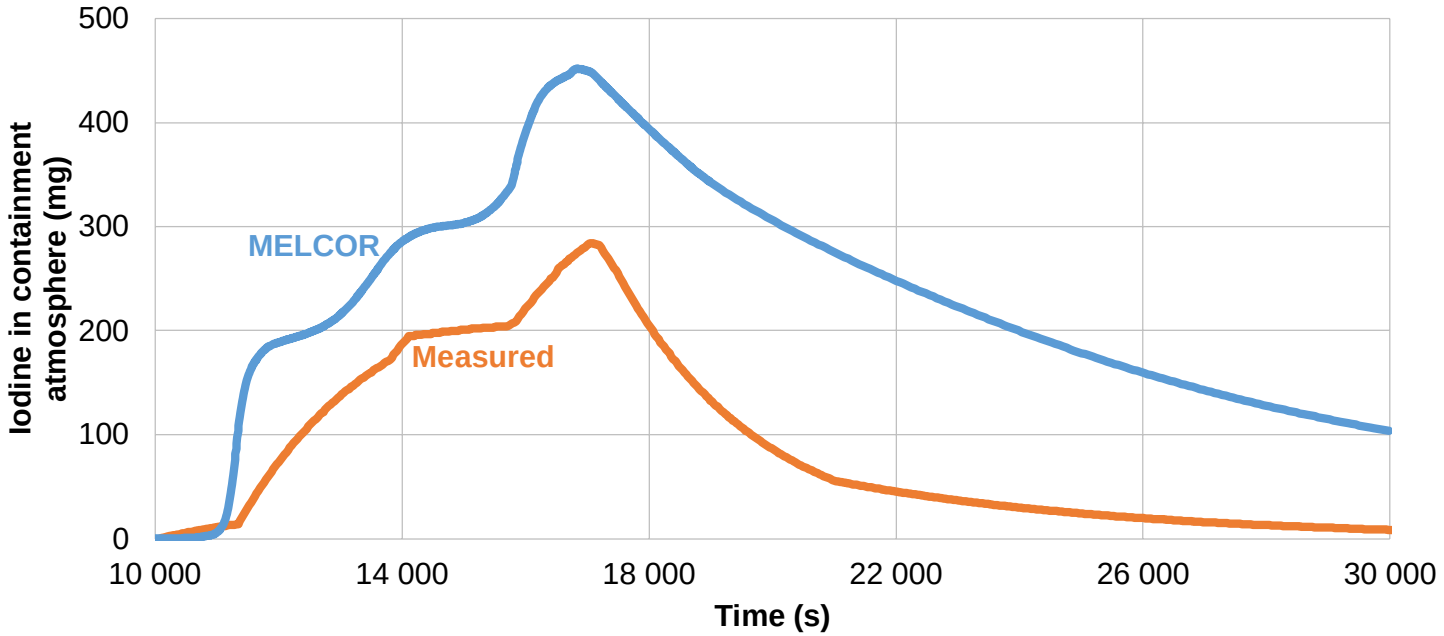
Ref. [3]

Iodine deposition in containment: Underestimated



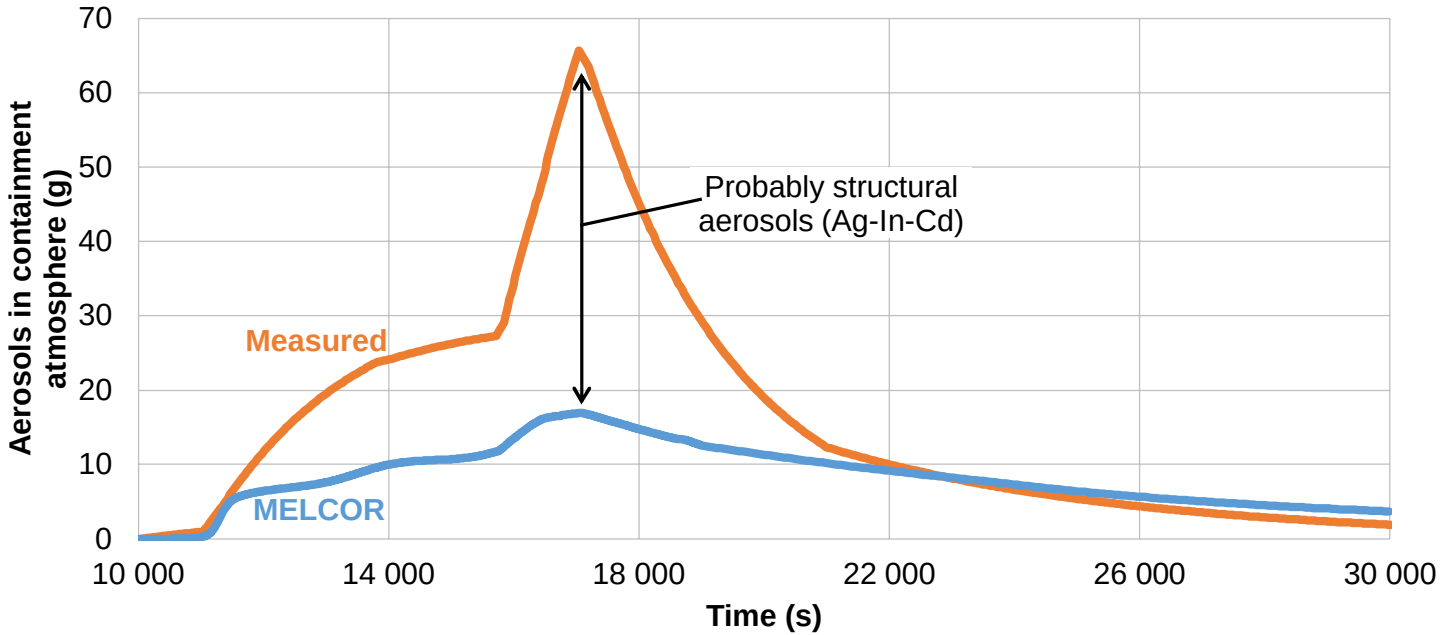
Ref. [4]

Iodine in containment atmosphere: Overestimated



Ref. [4]

Airborne aerosols in containment: Grossly underestimated



Ref. [3]

Attempts to activate the Ag-In-Cd release model

- Activated control rod silver release model with COR_CR
- Defined new elements and classes in DCH: Ag-CR, In-CR, and Cd-CR, and specified their masses
- Mapped control rod poison to RN classes with RN1_CRCL
- Changed control rod poison release multiplier to 1.0 with SC 7100
- Defined vapor pressure curves, diffusivities and molecular weights of the Ag-In-Cd classes with SCs 7110, 7111, and 7120

- The model runs without errors, but Ag-In-Cd is not released from Core to RN package

Conclusions

- Cs and I release from fuel calculated well
- Deposition in circuit and in containment somewhat underestimated
- Activating control rod silver release model not successful
- Relatively fast calculation: about 40 minutes of CPU time
- Satisfactory starting point for uncertainty analyses

- Thanks to IRSN for sharing the Phébus results

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References of measurement data

[1] Gyenes, G., Ammirabile, L., 2011. Containment analysis on the PHEBUS FPT-0, FPT-1 and FPT-2 experiments. Nuclear Engineering and Design 241, 854–864.

[2] Dubourg, R., Faure-Geors, H., Nicaise, G., Barrachin, M., 2005. Fission product release in the first two PHEBUS tests FPT0 and FPT1. Nuclear Engineering and Design 235, 2183–2208.

[3] Clément, B. et al., 2005. Thematic network for a Phebus FPT1 international standard problem (THENPHEBISP). Nuclear Engineering and Design 235, 347–357.

[4] Bosland, L., Weber, G., Klein-Hessling, W., Girault, N. & Clement, B., 2012. Modeling and Interpretation of Iodine Behavior in PHEBUS FPT-1 Containment with ASTEC and COCOSYS Codes. Nuclear Technology 177, 36–62.