ANSA - Analytical severe accident research

Objectives of the project and outline of the presentation

National competence in the area of severe accidents is further improved and the tools and methods in use will be validated in their intended purposes.

1. Fukushima accident analyses
2. Hydrogen behaviour in the containment
3. Passive safety features
4. Pool scrubbing
5. Environmental consequences

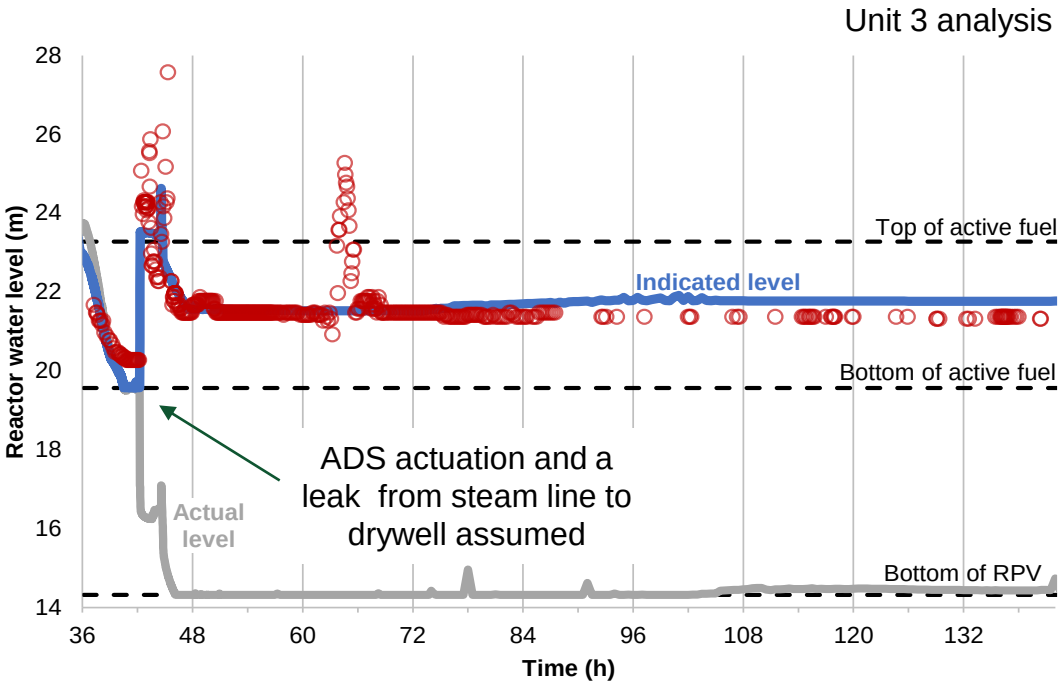
Motivation for the Fukushima accident analyses

The Fukushima accident provides a unique opportunity for obtaining more information about the progress of severe accidents and their prevention and mitigation.

- The third versions of VTT's MELCOR models for the Fukushima unit 2 and unit 3 accidents were developed
  - Detailed plant data from the OECD BSAF-2 project implemented
    - Remaining uncertainties related to physical and chemical models and nodalization in MELCOR and uncertain boundary conditions
  - Reactor water level measurement system added
- Calculations reproduce the measured pressures well

Reactor water level measurement system

- Based on measuring the pressure difference between two water-filled pipelines connected to the reactor
- The measurements were distorted by boiling of water in the measurement system



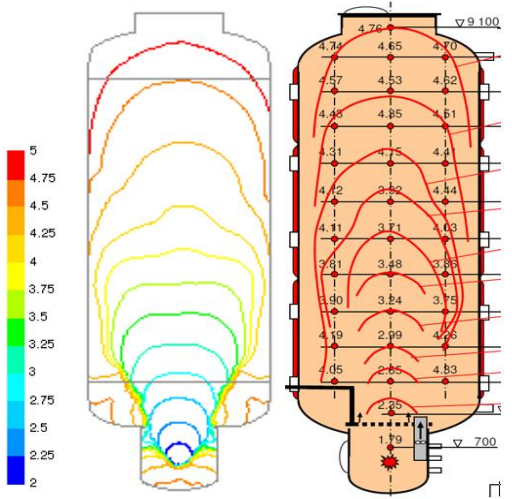
Hydrogen behaviour in the containment: migration

Containment is the last safety barrier preventing the release of fission products and therefore ensuring the integrity of the containment is extremely important.

- Hydrogen combustion constitutes a risk to containment integrity
- First should be assessed hydrogen migration to estimate the timing for the formation and composition of a flammable mixture
  - OpenFOAM model has been developed to study the efficiency of natural convection in eroding light gas stratification
  - A benchmark exercise on THAI TH-32 experiment
    - Preliminary results are in a good agreement

Hydrogen behaviour in the containment: combustion of lean hydrogen mixtures

- Lean hydrogen mixtures are actually more probable
  - Their analyses are less conclusive
- VTT's model has been developed further and extended to ultra-lean hydrogen concentrations
  - Close to the limit of flammability
- Tested by computing eight THAI combustion experiments
  - Volume fraction of hydrogen 7 - 11.8 %
- Wrinkling characteristics of flames have been studied further



Computational (left) and experimental (right) first flame arrival times

Passive safety features: crucible type core catcher

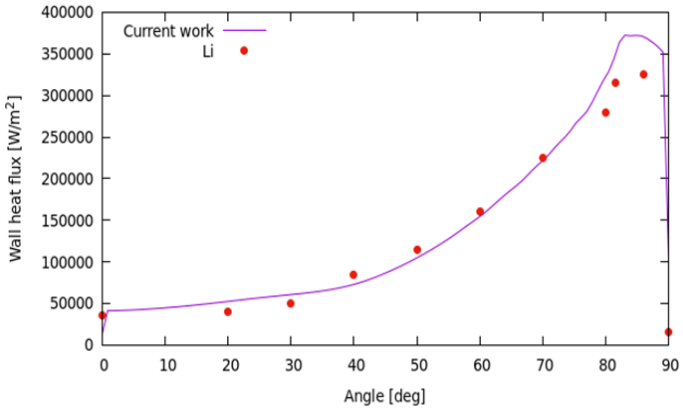
Proper functioning of the passive safety features under all circumstances will be ensured after validating the models against suitable experiments and developing reliable modelling practices.

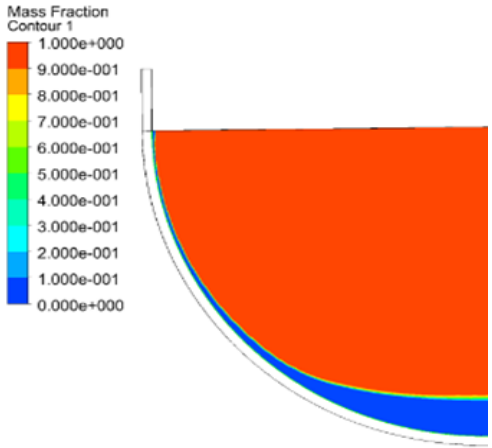
- OpenFOAM model capable of simulating heat transfer in an externally cooled, homogeneous molten corium pool was developed and validated simulating a SIMECO-2 experiment
- Results were compared to a pre-test analysis by Li (2016)

Li, Y, 2016. CFD Pre-test Analysis of SIMECO-2 Experiment. Stockholm: KTH Royal Institute of Technology. 77 p.

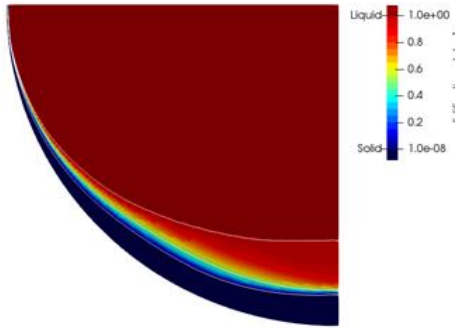
Results were in a good agreement

- Most notable differences
  - Enhanced heat transfer in the upper part of the pool
  - Thicker mushy zone resulted by OpenFOAM





Li (2016)

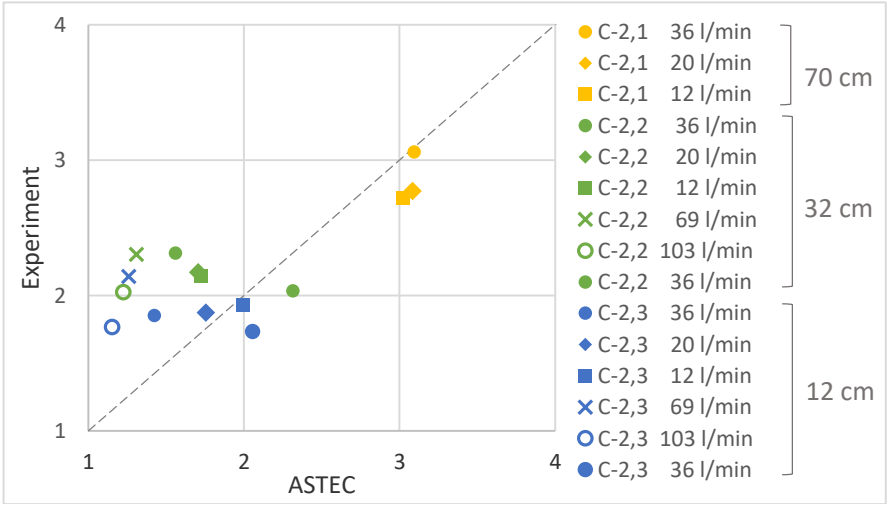


OpenFoam

Pool scrubbing

The final objective of SAM is to minimize the potential source term to the environment. Pool scrubbing is an important mechanism in mitigating fission product release from the containment.

- Experiments performed in the frame of MANTRA project provide excellent validation data for the integral codes
- Experiments for CsI aerosol and CH_3I considering the effect of NaOH and $Na_2S_2O_3$ were analysed with ASTEC



Comparison of DF for CsI aerosol (NaOH added to the pool).

Summary of pool scrubbing analyses

CsI

- ASTEC results seem to be very sensitive to particle size
  - The effect is larger on globular regime
- At jet regime, the behaviour of analytical DF results is reverse to experimental results when considering the effect of inlet flow rate
- The effect of NaOH seems to be negligible

CH_3I

- Experimental and analytical DF results were in a good agreement for a pure water pool
- In the experiments was observed that $Na_2S_2O_3$ could enhance trapping of CH_3I
  - This effect could not be reproduced in the model

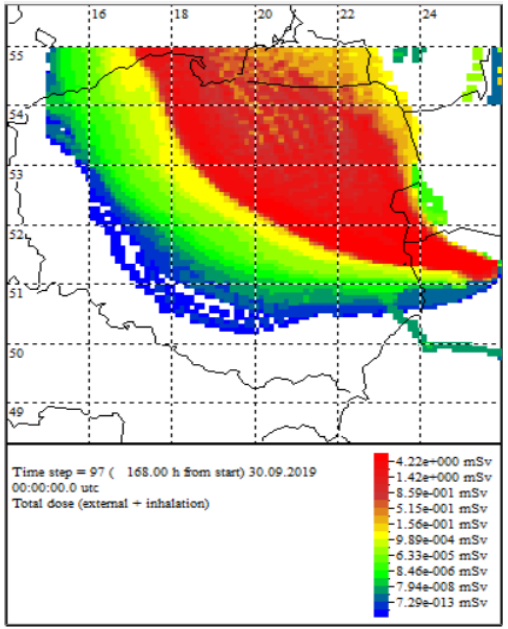
Environmental consequences

Understanding of dispersion and exposure phenomena are needed for all-encompassing nuclear safety

- The physical phenomena are complicated, and they can be modelled by codes featuring various levels of sophistication
- A lot of verification and validation effort is needed to check the reliability of the codes being developed
- International code benchmark BARCO (Benchmarking on Assessment of Radiological COnsequences) was participated to compare VTT's in-house codes VALMA and ARANO with well-known international code packages

BARCO scenario and results

- Hypothetical release from the Ukrainian Rivne NPP
  - Two VVER-440/213 and two VVER-1000/320 reactors operating
- ARANO and VALMA results were well within the range of the ‘bunch’ of other result values
  - ARANO predicted higher maximum doses than VALMA
    - VALMA uses the realistic spread of wind direction



Total dose produced by VALMA.

VTT

beyond

the obvious

Anna Korpinen
anna.korpinen@vtt.fi
+35840 159 1156

@VTTFinland

www.vtt.fi