

# CALCULATING STEAM-WATER FLOWS AT LARGE NON-CONDENSIBLE GAS CONCENTRATION WITH SEVERE ACCIDENT CODE ASTEC V2.2

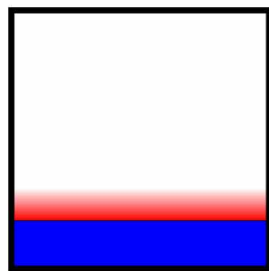
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# Presentation Outline

- Introduction and modelling specificities
- First Experiment : Pool evaporation
- Second Experiment : Global scale behaviour of a test reactor accident in cold shutdown conditions
- Conclusions

# Introduction

- Flows with high concentration of non-condensable gas are a common occurrence in nuclear facilities, often associated with low pressure, low temperature and low velocities conditions :
  - Spent fuel pools
  - Open reactor conditions during cold shutdown (planned reactor shutdown for fuel rod changing or maintenance on steam generators for example)...
- These applications are a growing issue for safety analysis (low power situations but few safety systems available)
- Challenging numerical issue for system codes such as ASTEC v2.2 (interfacial heat transfer evaluation)



□  $f_v=0$

■  $f_v=1$

■  $\alpha=0$

In the example, **global** vapour molar fraction  $f_v$  is very low (close to 0) while **local** value is close to 1 at the interface.

Considering global concentration is not appropriate:

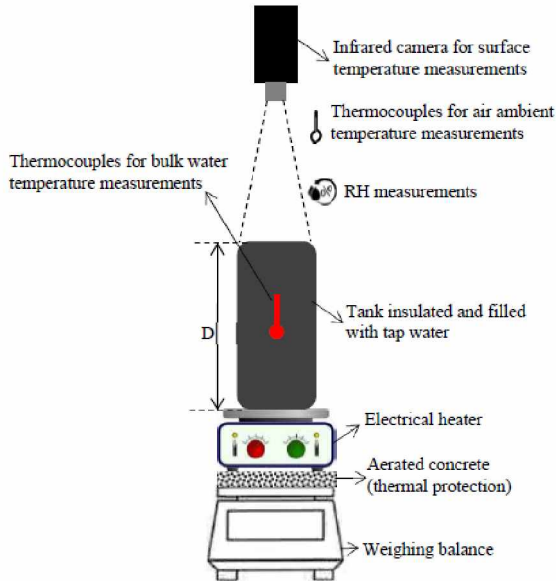
- Numerical issues (due to properties evaluation)
- Results accuracy?

## Introduction

- Several changes in ASTEC v2.2 towards calculating this kind of applications
    - Default momentum equation system changed from a one fluid model with a drift correlation to a two fluid model
      - Better representation of low velocities out of equilibrium two phase flows
    - Improvement of the interfacial heat transfer evaluation with presence of non-condensable gas
      - The local vapour composition at liquid-gas interface is used instead of the global one (as large volumes are considered, the global vapour fraction may not be representative of interface conditions)
- Solves numerical issues and improves results accuracy

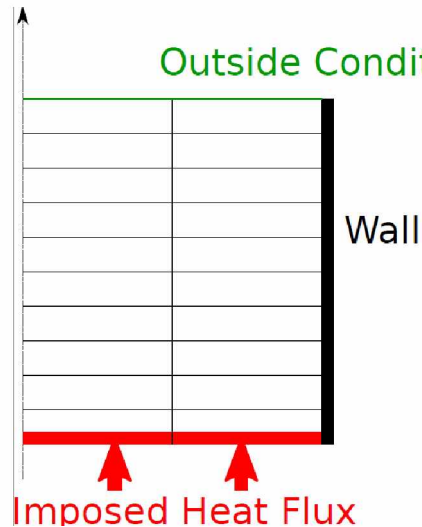
# First Experiment : Pool evaporation

## Experimental set-up and dataset



Martin and Migot, NURETH-18 (2019)

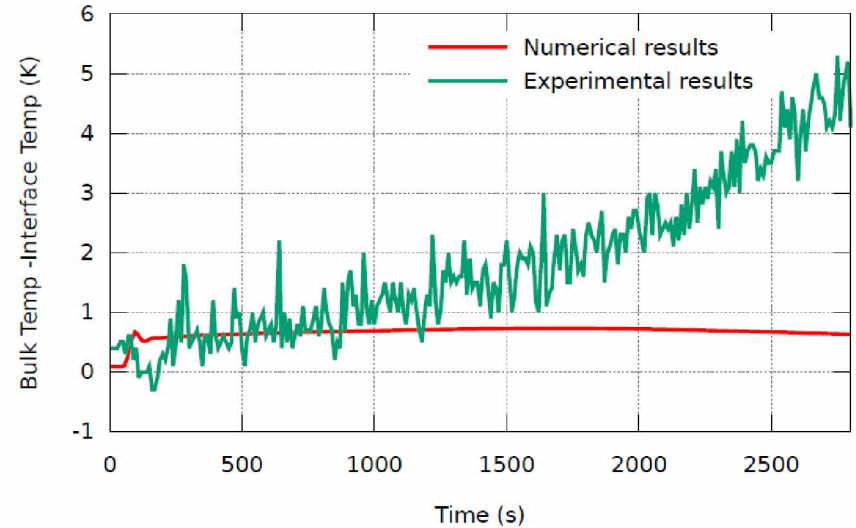
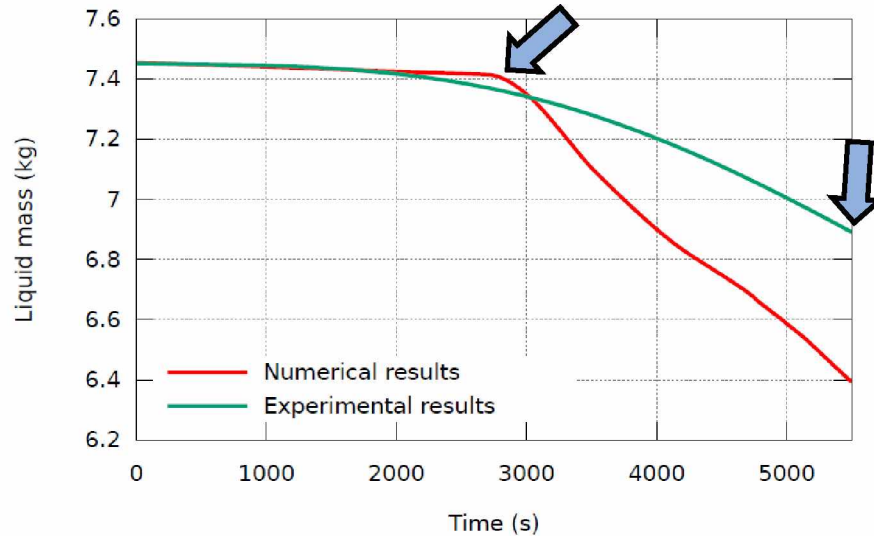
- 2D axi-symmetric mesh possible in ASTEC
- External adiabatic wall
- Heated wall at the bottom
- Fixed pressure boundary condition at the top



Data	Tank 5
Cross-section (m <sup>2</sup> )	0.056
Tank Depth (m)	0.18
Init. Water Mass (kg)	7.46
Init. Water Temp. (K)	295.75
Air Temp. (K)	296.85
Relative Humidity (%)	40

# First Experiment : Pool evaporation

## Results analysis



- Full boiling is achieved significantly earlier in the calculations ( $\sim 2800$  s vs  $\sim 5500$  s)
- Reduced temperature gradient compared with the experiments

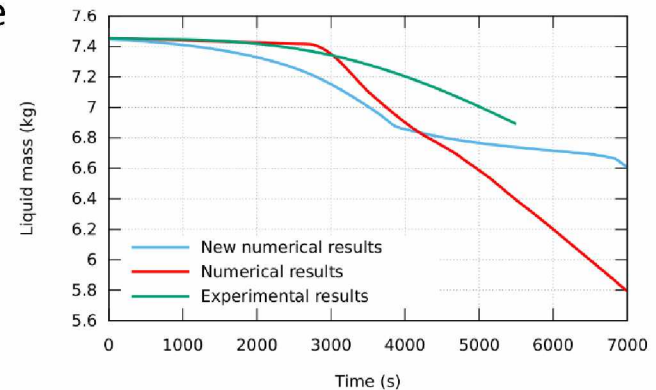
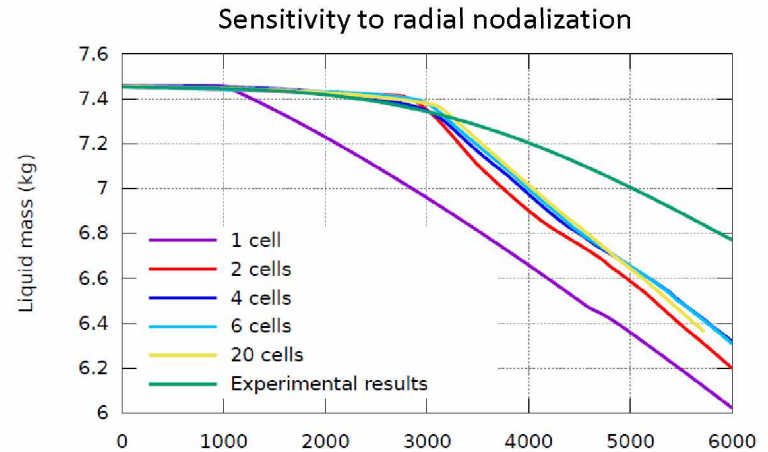
# First Experiment : Pool evaporation

## Mesh Effect

- Axial direction → convergence to mesh achieved for 10 cells
- Radial direction → clear effect of the 2D loop

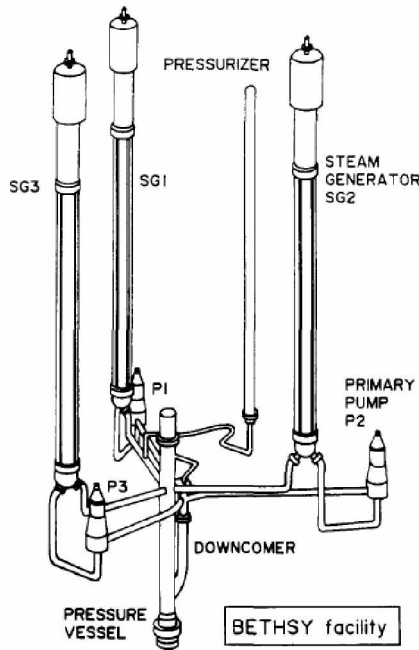
## Results improvement directions

- Modifications in regular friction between cells + pressure boundary condition → significant results difference → Investigations and assessment of these parameters needed
- Very sensitive to singular pressure drop definition
- Viscosity effect on the loop development (especially for more than 2 radial cells meshes)
- Real 2D thermal-hydraulic (1D flow in both directions for now)

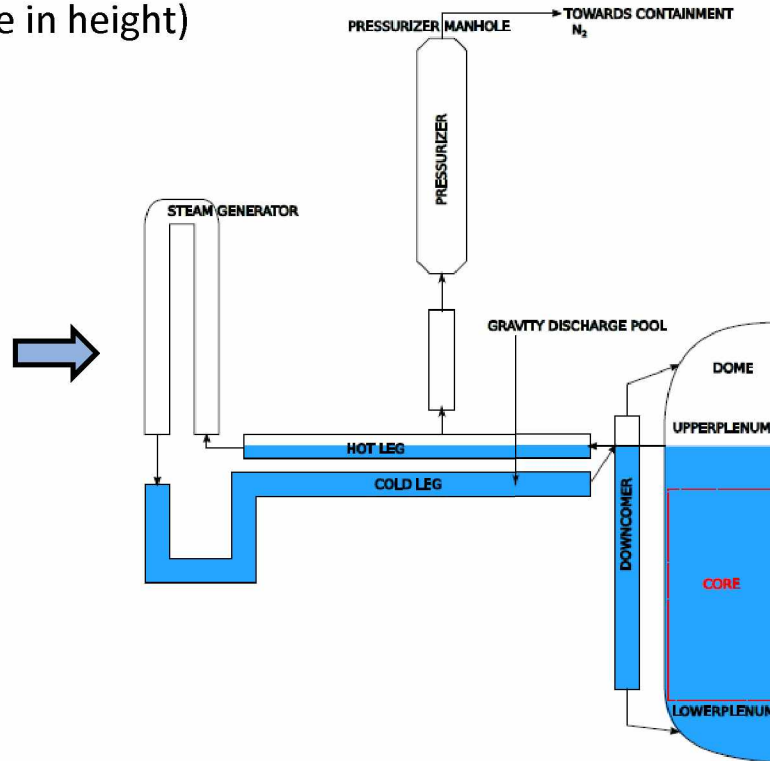


# Second Experiment : Cooling loss accident with open and partly drained reactor

Experimental set-up and scenario → BETHSY facility ⇔ French 900 MWe reactor (1/100 volume – full scale in height)



Dumont et al., NED (1994)



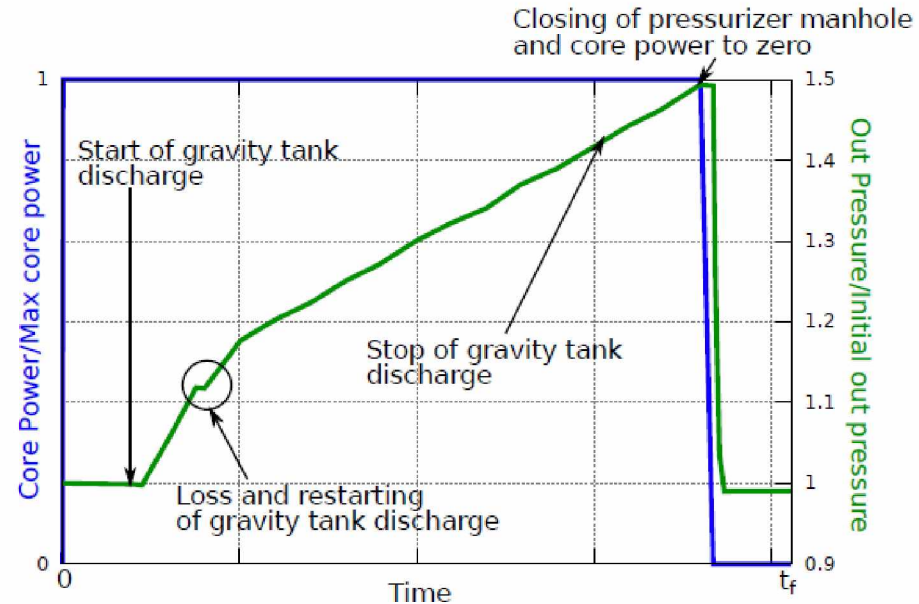
- No secondary system (isolated during experiments)
- No safety system except gravity led discharge tank
- **N<sub>2</sub>** used to represent air in the experiments
- Initial conditions : open at pressurizer manhole and partly drained reactor



## Second Experiment

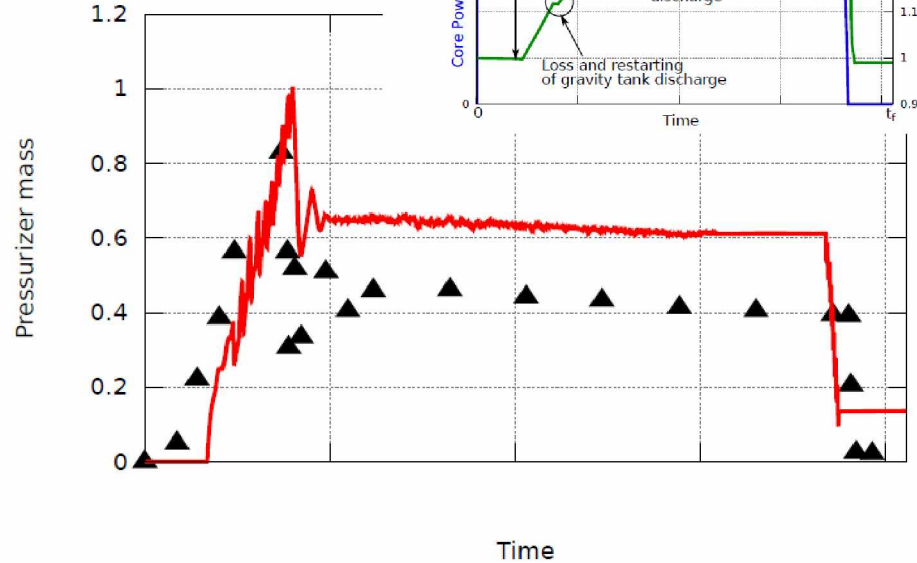
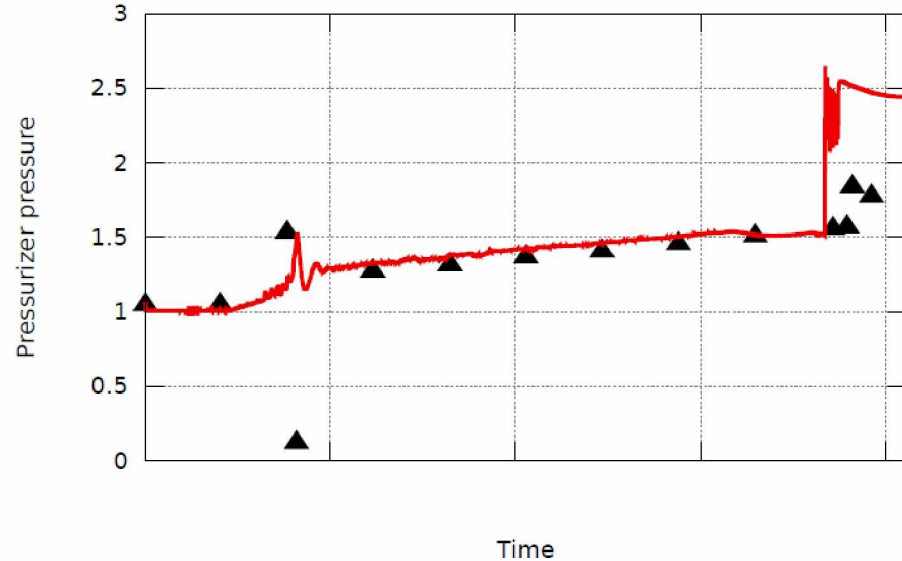
- Initial state reached through first calculation
  - From a full of water state, system is drained till initial water mass and level is reached
  - First calculation stopped when stabilised steady state is reached

- Scenario for the transient sequence
  - Loss of cooling → core power is increased
  - Counter-pressure in the containment is increased during the test
  - Gravity led discharge pool availability varies



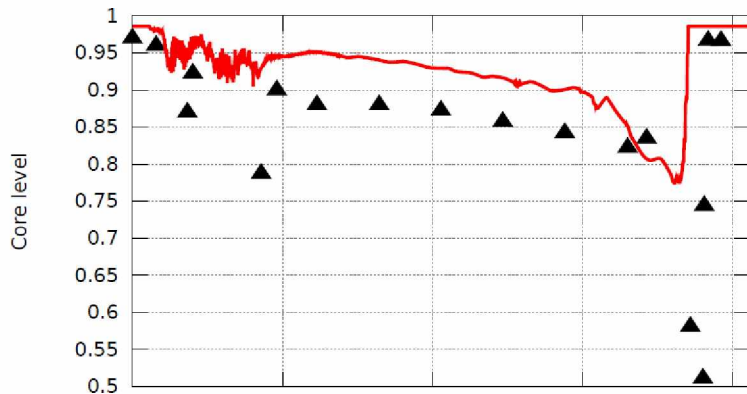
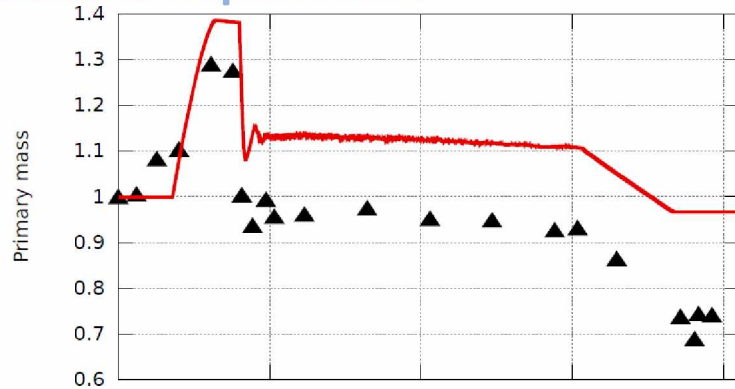
# Second Experiment

## Results analysis : Pressurizer behaviour

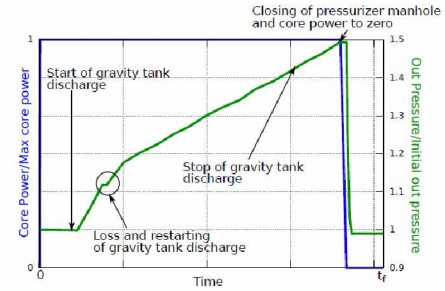


- Retention of water in the pressurizer was an important point in the experiment and is correctly predicted by the calculation
- However, globally, over-estimation of water amount remaining in the pressurizer

## Second Experiment



Time



- Global behaviour follows the experimental trend
- Too much water in the primary system (although same liquid mass discharged through manhole and same injected mass) → evaporation process seems under-estimated
- Uncertainties concerning the upper plenum area (above the core) → 1D representation / here pool evaporation like area

## Conclusions

- It is possible to perform ASTEC v2.2 calculations with high quantity of non-condensable gas, low pressure and temperature conditions and low velocities (far from severe accidents system codes usual working conditions)
- It is also possible to calculate natural convection loop in 2D-axisymmetric mesh with ASTEC v2.2 although lack in current modelling have been highlighted through First Experiment calculation (pool evaporation study)
- Though improvements are still needed global behaviour on reactor scale experiment is satisfactory
  - Studies of reactor accident in cold shutdown state can be considered with ASTEC v2.2