# MELCOR Validation against Experiments on Hydrogen Distribution

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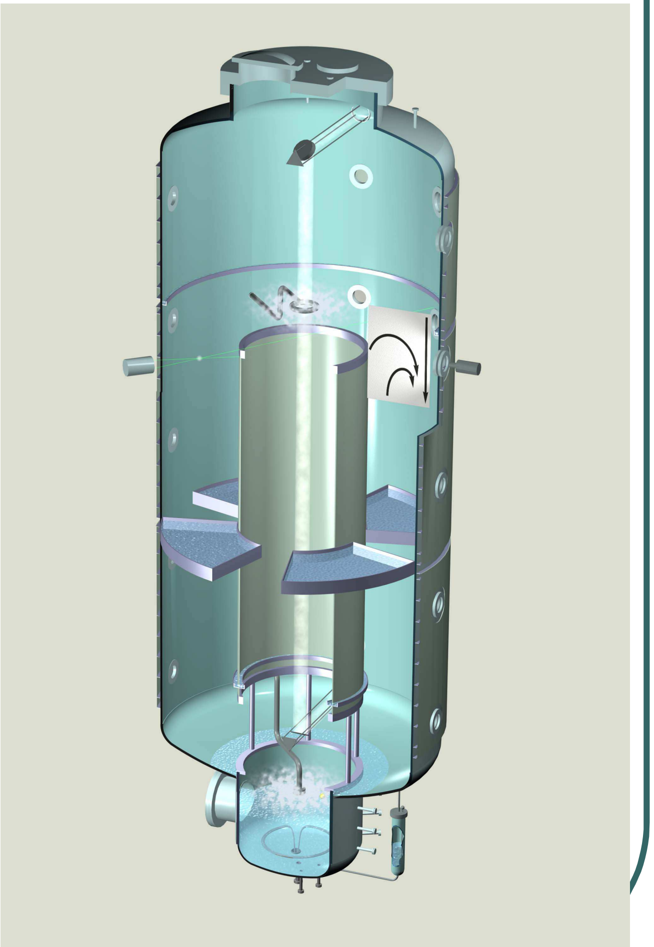
3rd European MELCOR User Group Meeting
Bologna, Italy, April 11-12, 2011

# Outline

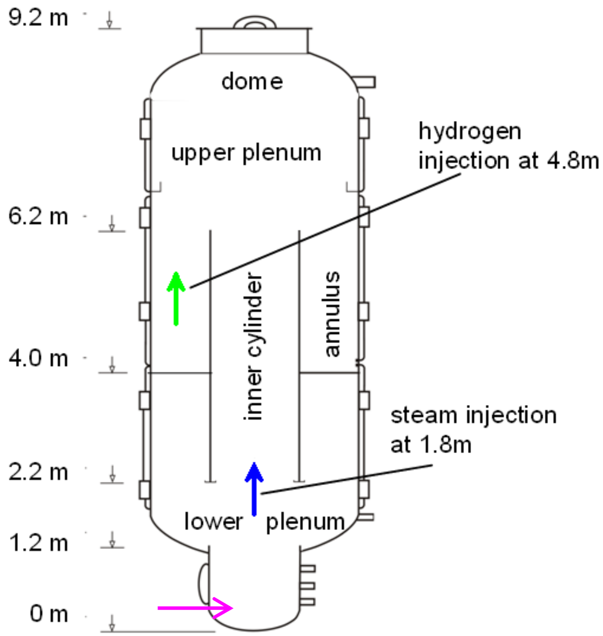
- OECD THAI HM2 Test Definition
- MELCOR Model Development
- MELCOR Simulations
  - Sensitivity Cases
- Conclusions

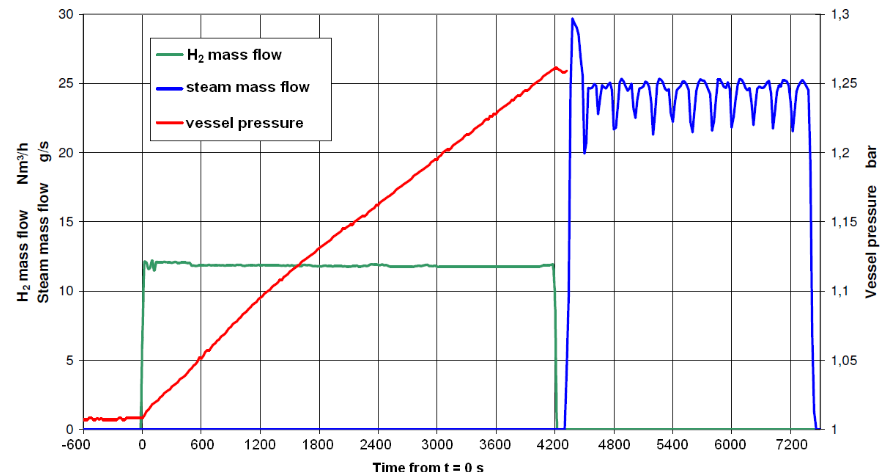
# OECD THAI HM2 Test

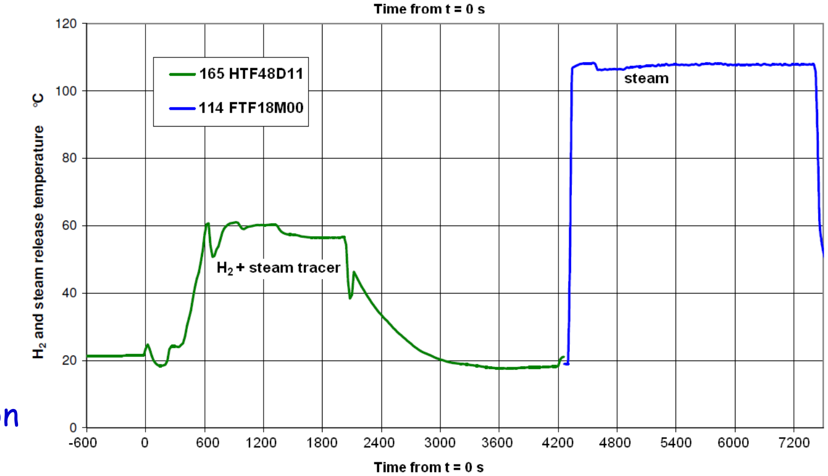
- HM test series objectives
  - Investigation of transferability of the experimental results performed with simulator – helium on hydrogen cases
  - Phenomenological objective of the HM tests was to investigate conditions for the hydrogen rich cloud erosion by steam and break up a light gas stratification
- HM2 test conduct
  - Filling of facility by nitrogen
  - Hydrogen injection – formation of light gas cloud
  - Steam injection
    - Steam plum stagnation inside of cylindrical structure
    - Erosion of light gas cloud – natural circulation
    - Atmosphere homogenization



# OECD THAI HM2 Test (2)




- Main Phases
  - Time < 0 s ⇨ Filling with nitrogen
  - 0 – 4200 s ⇨ H2 injection
  - 4320 – 6820 s ⇨ Steam injection – cloud erosion
  - Time > 6820 s ⇨ Steam inj. - Atm. homogenization

# MELCOR Model Development

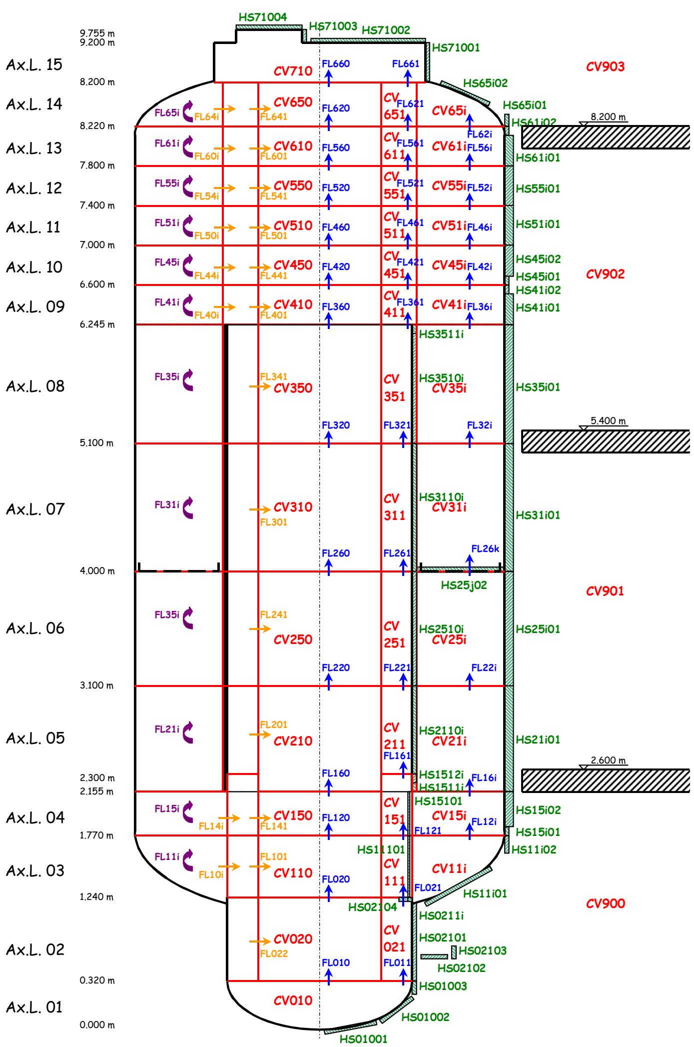
- Overview of improved (Open) model (comp. with original (Blind) one)

| Component | Original | Improved |
|---|---|---|
| Control Volumes | 133 | 181 |
| Flow Paths | 299 | 376 |
| Heat Structures | 225 | 245 |

- Only for MELCOR 1.8.6 due to absence of Film tracking networks
  - Too complicated system of HSs
- Modification of parameter **XMTFCi** - enhanced scaling constant of mass transfer in the condensation correlation - HSnnnnn400 (9)
  - Inner surface of inner cylindrical structure – resulted in possibility to model stagnation phase and agreement of pressure evolution in this phase
  - Inner surface of TTV – agreement of pressure evolution in phase of natural convection
- New screen for ATLAS prepared
- Model was converted to MELCOR 2.1 – possibility of FT and SPR

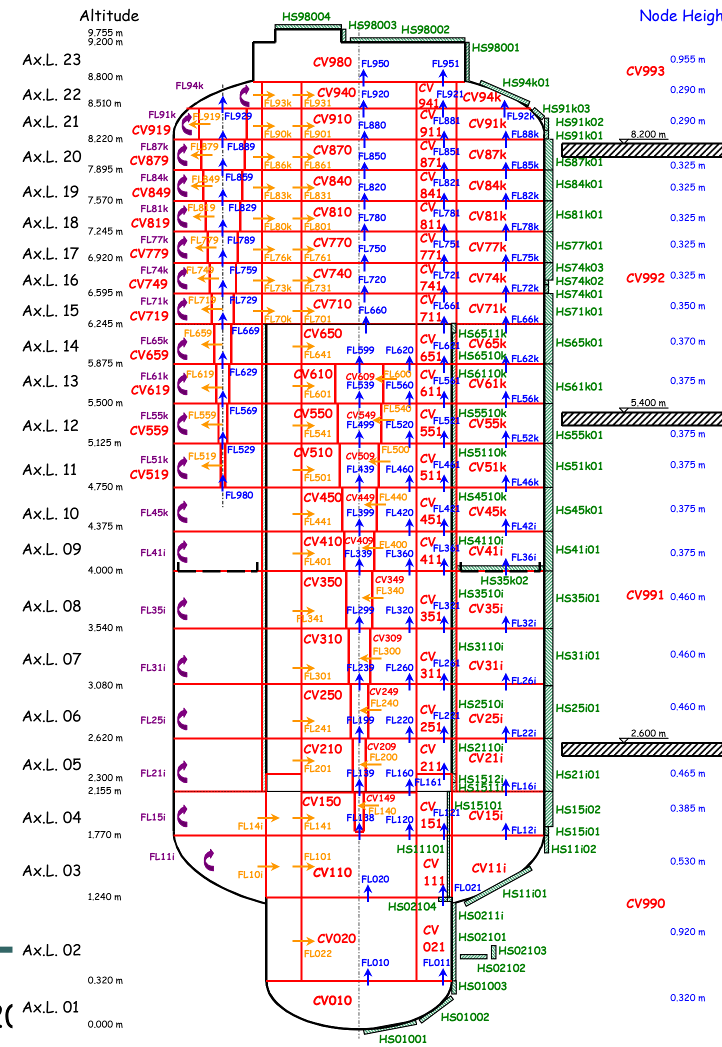
# MELCOR Model Development

## Comparison of Nodalizations



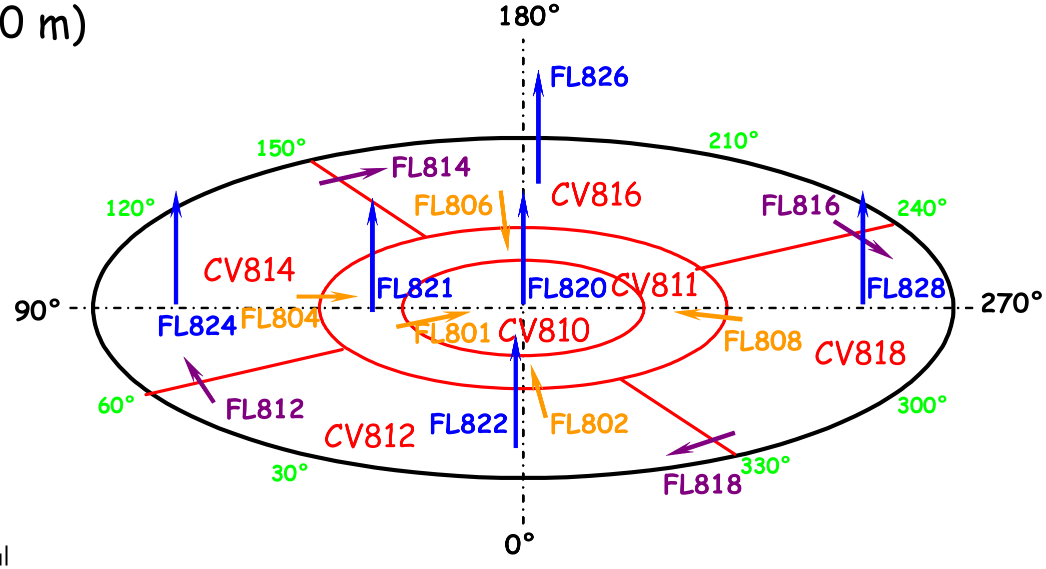

Blind

Open



# Radial Discretisation

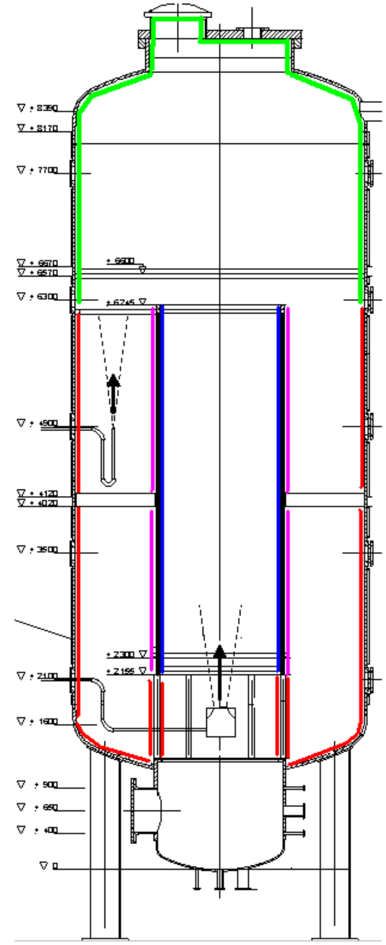
- Radial discretisation
  - Blind simulation
    - Levels 03 – 14 (8 azimuthal nodes)
  - Open simulation
    - Levels 03 – 09 (8 azimuthal nodes)
    - Levels 10 – 22 simplified periphery (4 azimuthal nodes instead of 8 in lower part)
- Ratio of flow areas of inside volume of cylindrical structure
  - 52.5 % to 47.5 % (R 0.500 m)




**CVnnn** – Control volume no. nnn
**FLnnn** – Flow path no. nnn – vertical
**FLnnn** – Flow path no. nnn – horizontal – radial
**FLnnn** – Flow path no. nnn – horizontal – peripheral

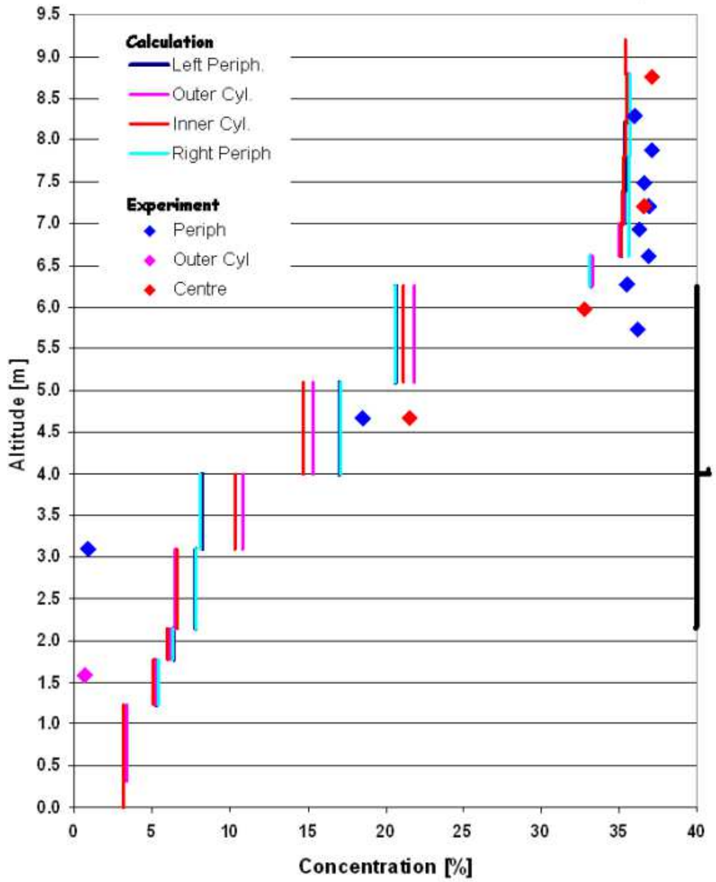
# MELCOR Model – Open Simul.
## Modification of parameter **XMTFCi**

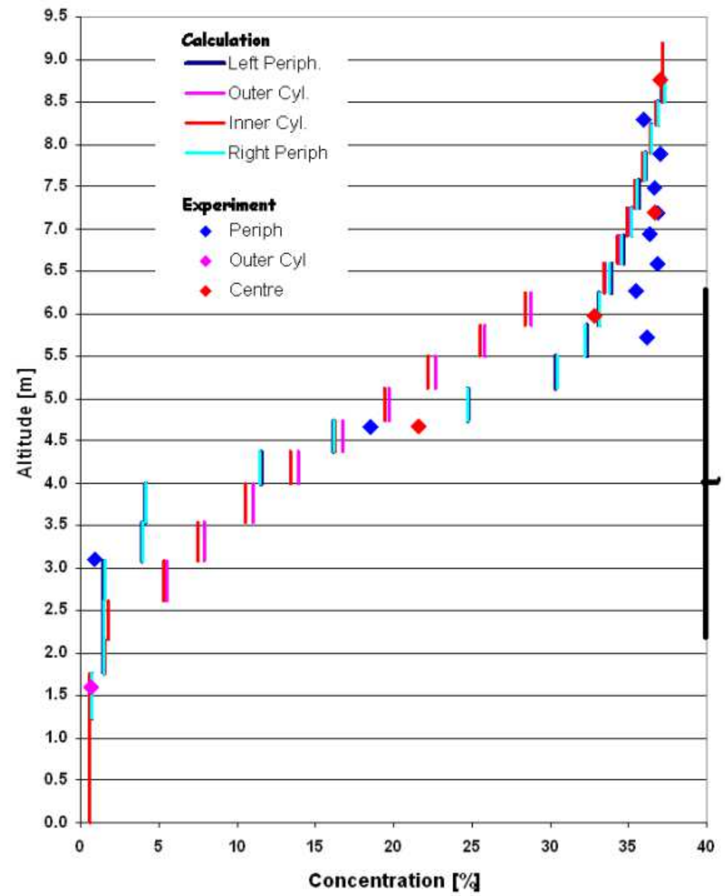
- Modification of parameter **XMTFCi** – values used in final simulation
  - XMTFCL = 2.00
  - XMTFCL = 3.02
  - XMTFCL = 4.00
  - XMTFCR = 5.00



# MELCOR 1.8.6 Final Simulation
## H2 Concentration – End of Injection

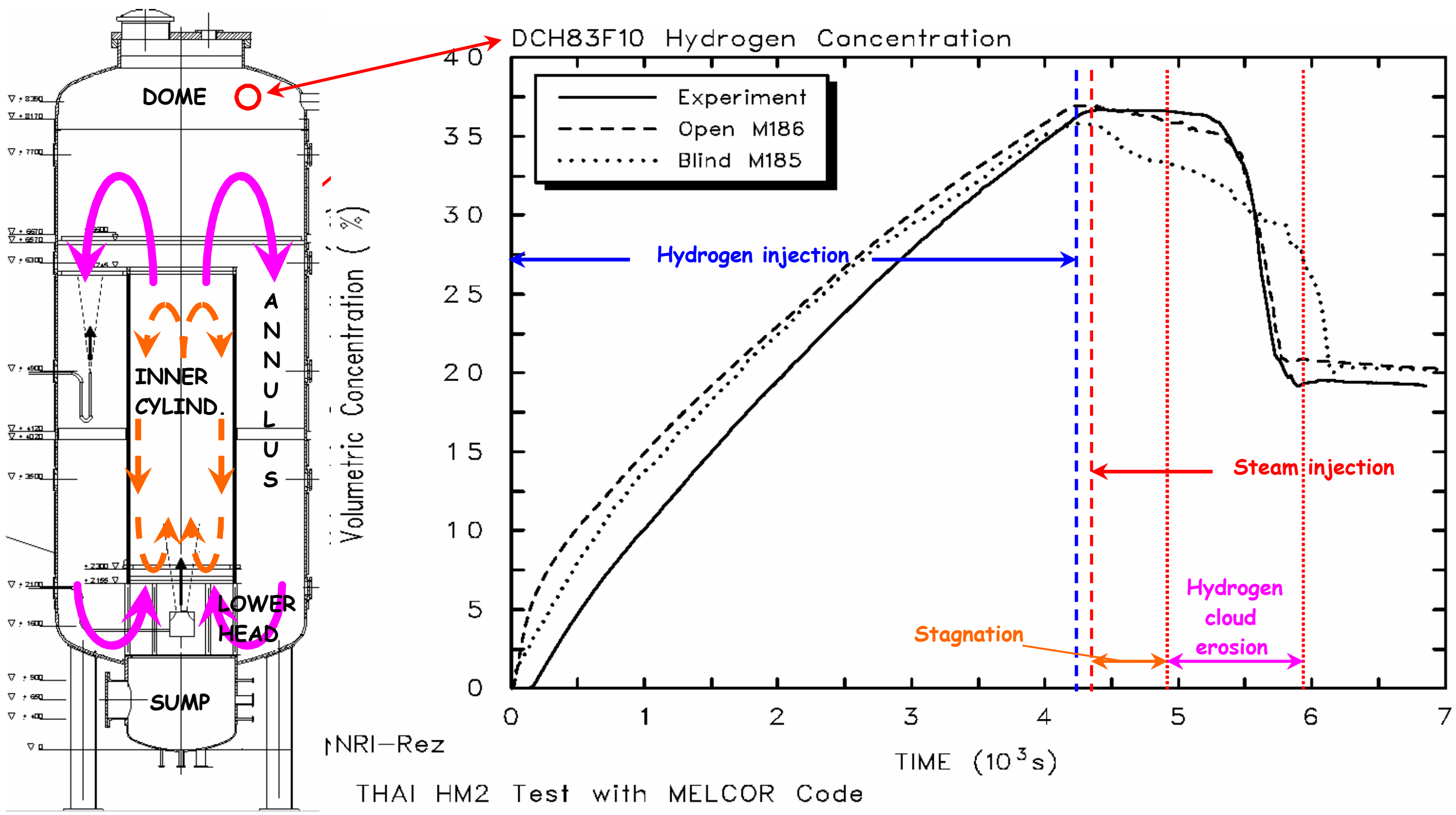
- Comparison of **Blind** **Open**



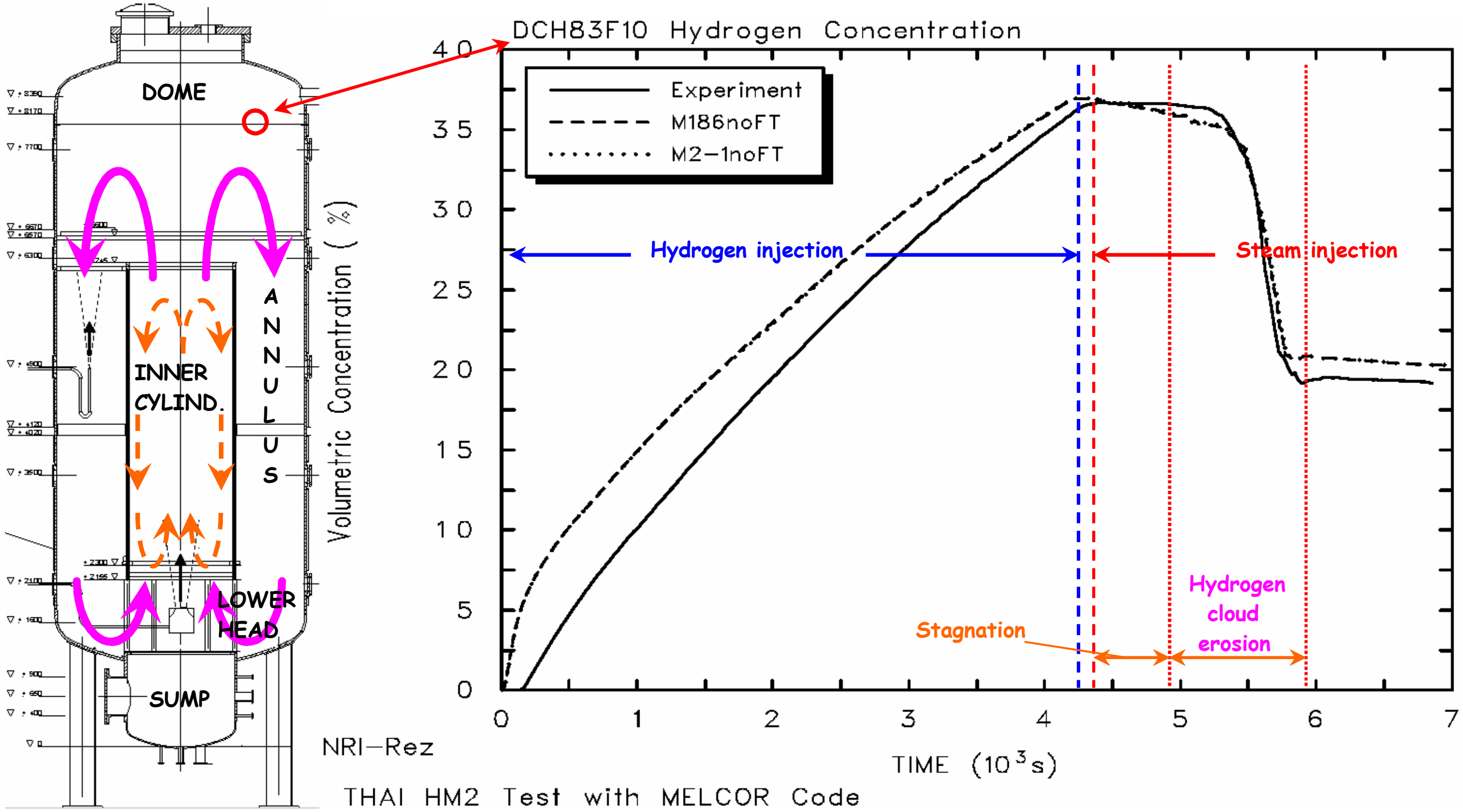
# MELCOR 1.8.6 Final Simulation
## Pressure and H2 Concentration

- Significant improvement of Open simulation in comparison with Blind simulation
  - Duration of stagnation phase
  - Timing of cloud dissolution



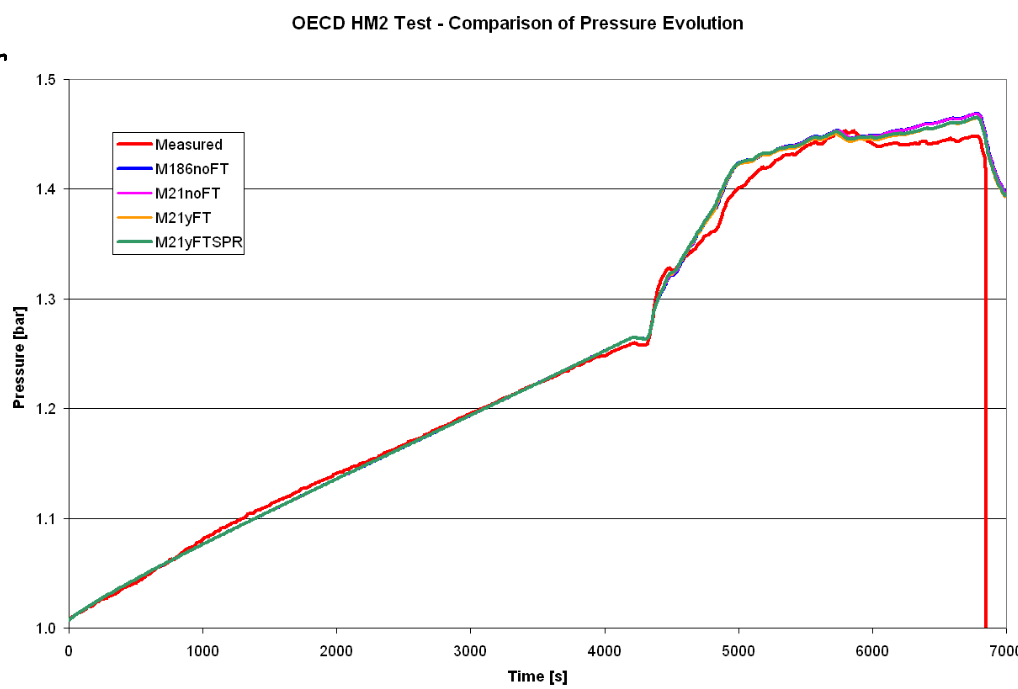
# M1.8.6 to M2.1 Comparison
## Pressure and H2 Concentration

- Practically identical results of M186 and M2.1 with identical inputs
  - Results of simulation with M186 are visualized using ATLAS



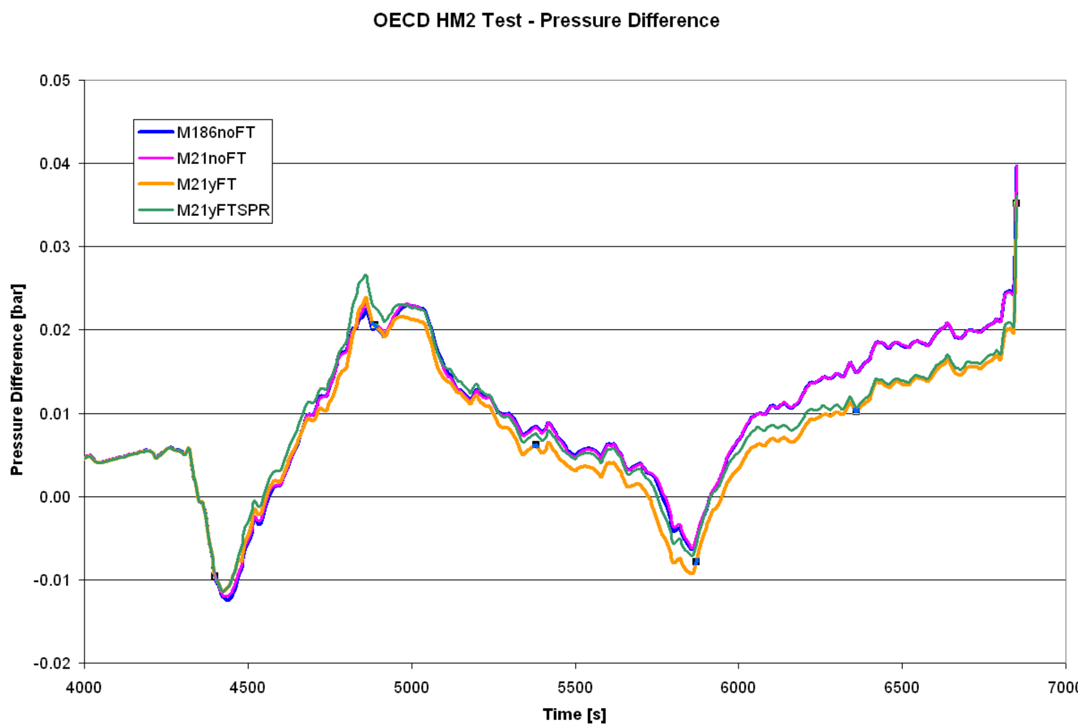
# M186 and M2.1 Simulations
# Impact of FT and SPR (1)

- Observations from input conversion
  - HSs in M2.1 input have to be in order of condensate drainage (starting from top to bottom of drainage HS chain)
  - Each of HSs has to have a definition of drainage, including the last one which is drained into pool of associated CV
- Cases compared
  - **M186noFT**– no film tracking model + no spraying by condensate
  - **M21noFT** – no film tracking model + no spraying by condensate
  - **M21yFT** – film tracking model + no spraying by condensate
  - **M21yFTSPR** – film tracking model + spraying by condensate
- Very similar results of all cases
  - All cases have identical definition of XMTFCi parameters



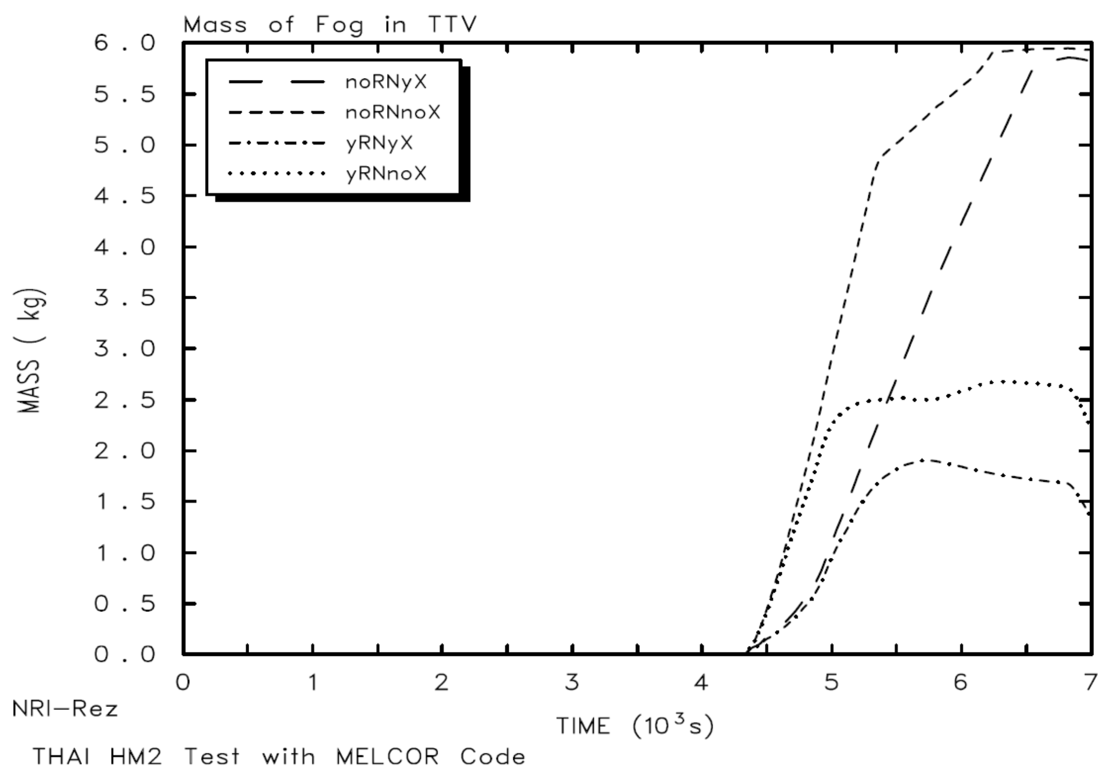
# M186 and M2.1 Simulations
## Impact of FP and SPR (2)

- Cases compared
  - M186noFT– no film tracking model + no spraying by condensate
  - M21noFT – no film tracking model + no spraying by condensate
  - M21yFT – film tracking model + no spraying by condensate
  - M21yFTSPR – film tracking model + spraying by condensate
- Very similar results of all cases
  - Neglect of FT and SPR definition in M186 did not influenced predicted results significantly
    - Confirmation of assumption from blind simulation
  - Practically identical results of M186noFT and M21noFT
  - Spraying of ATM by condensate has negligible impact
    - Slightly higher pressure, probably due to different ATM flow pattern (ATLAS cannot be applied for post-processing in M2.1)
  - Film tracking seems be a little more important in this exercise



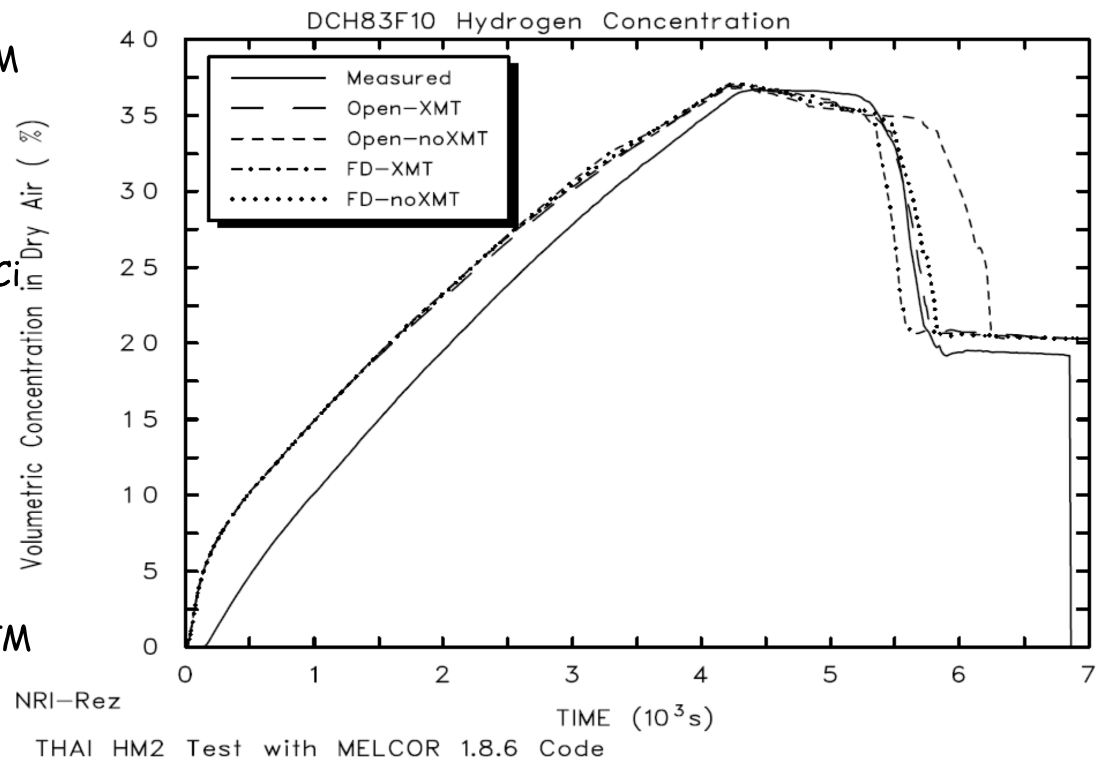
# M186 Simulations
# Impact of RN Package

- Very similar results of all cases
  - All cases have identical definition of XMTFCi parameters
  - **What is effect of RN Package?**
- Cases compared (all M186)
  - **noRNyX** – noRN+DCH + XMTFCi
  - **noRNnoX** – noRN+DCH + noXMTFCi
  - **yRNyX** – RN+DCH + XMTFCi
  - **yRNnoX** – RN+DCH + noXMTFCi
- Results differ mainly based on application of XMTFCi
  - Neglectable impact of RN + DCH application to steam mass in TTV
  - Some impact on fog mass, but no influence of pressure
    - It only influence distribution of condensate among aerosols (fog) and on wall (HS)



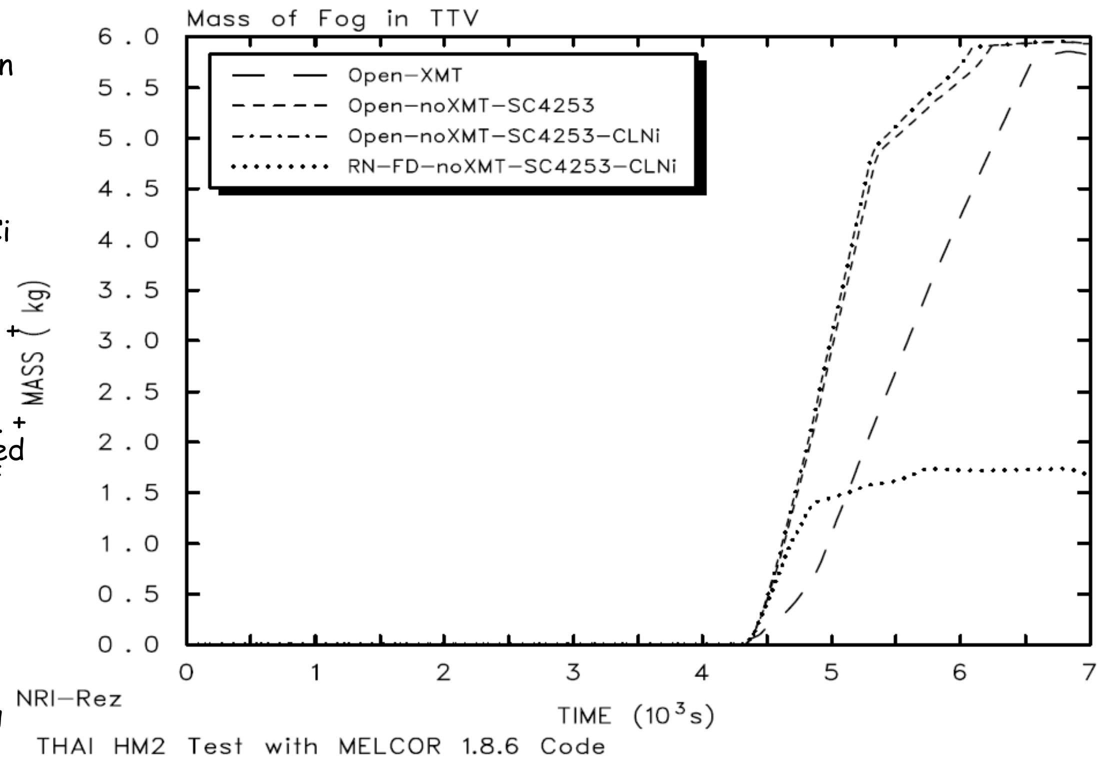
# M186 Simulations
# Impact of Max. Fog Density

- ISP-47 test included measurement of fog density
  - Max measured value < 40g/m$^3$, but M default is 100g/m$^3$
  - **What is effect of FD?**
- Cases compared (all M186)
  - **Open-XMT** – 100g/m$^3$ + XMTFCi
  - **Open-noXMT** – 100g/m$^3$ + noXMTFCi
  - **FD-XMT** – 30g/m$^3$ + XMTFCi
  - **FD-noXMT** – 30g/m$^3$ + noXMTFCi
- Results differ mainly during cloud erosion phase
  - Fog density limit influence total density of ATM ⇨ influence of hydrostatic head (steam jet has greater buoyant forces)
  - Lower FD limit results in lighter ATM ⇨ more intensive penetration of buoyant plume into H2 rich cloud
    - Earlier cloud dissolution
  - Comparable impact of XMTFCi and FD on timing of cloud dissolution, but not on pressure



# M186 Simulations
# Impact of Re Limits in Film on HS

- SC4253 (5) and (6) define limits of Re for film on HS
  - Inconsistency between literature and UG found by T. Ševon (VTT) – see contribution to CSARP 2010
    SC4253(5) new value 30.0
    SC4253(6) new value 1800.0
- Cases compared (all M186)
  - Open-XMT – final simulation with XMTFCi
  - Open-noXMT-SC4253 – noXMTFCi + modified SC4253
  - Open-noXMT-SC4253-CLNi – noXMTFCi + modified SC4253 + modified charact. dimensions of HS (inner surfaces)
  - RN-FD-noXMT-SC4253-CLNi – RN pack. + reduced fog density + noXMTFCi + modified SC4253 + modified charact. dimensions of HS (inner surfaces)
- Results differ mainly during cloud erosion phase
  - Cases 2 and 3 has high mass of steam and fog ⇨ high pressure and too slow cloud erosion
  - Case 4 has high mass of steam but low fog and case 1 has low steam and high fog ⇨correct timing of cloud erosion



# Summary and Conclusions

- Application of MELCOR confirmed possibility to predict THAI HM2 test correctly if
  - Appropriate nodalization scheme used to model
    - Hydrogen stratification – axial discretisation very important
    - Hydrogen cloud erosion by steam
  - Knowledge of facility, experimental conditions, and code
    - Need to enhance steam condensation for successful prediction of pressure evolution and flow regimes in facility
      - Under laminar or transition natural convection conditions
    - Modeling of H2 and steam jet CVs seems to be needed, although its replacement by movement source location predicted relatively acceptable hydrogen distribution, but it results in temporary deviations
      - Immediate start of hydrogen presence in case with moved source location vers. delayed hydrogen presence in case with jet CVs
      - Model with jet CVs predicted better agreement in
        - H2 distribution in lower levels and timing of phases
- Identification of condensate spraying model malfunction in M186 YT
  - BUG Report No. 172 (April 2008) – solved in M186 YU

# Acknowledgments


- The effort included in this paper was performed with the support of the CR Ministry of Industry and Trade project, and the partnership in the OECD THAI project is funded by the CR Ministry of Education, Youth, and Sports.
- Author acknowledges partners in the OECD THAI project for their approval of this contribution

# End of Presentation

**Thank You for Your Attention**