Hydrogen Convection & Distribution

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EMUG2025

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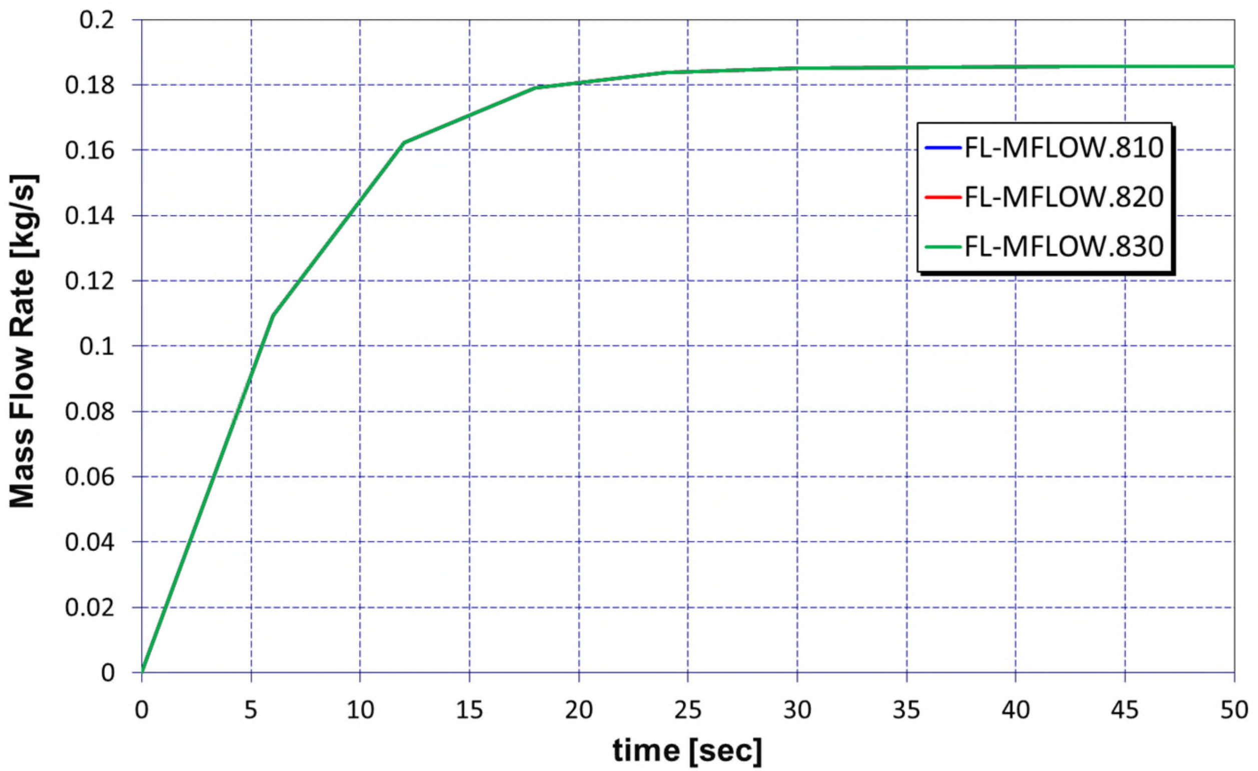
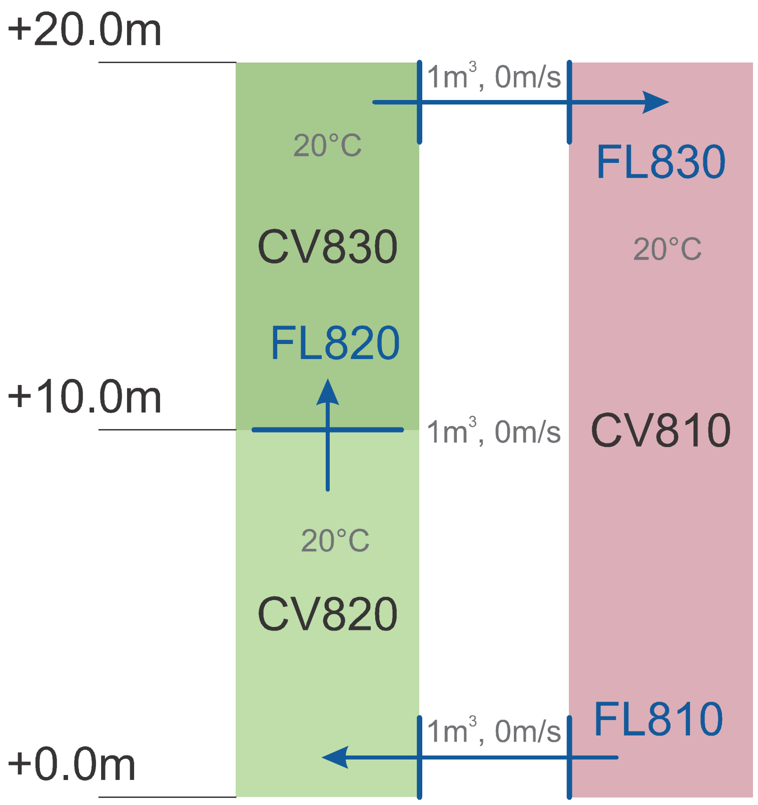
Introduction

Flow Paths Loops 1

- **Different hydrostatic pressures over 1 or 2 CVs**
- **Pressure difference CV810 - CV820 → mass flow**

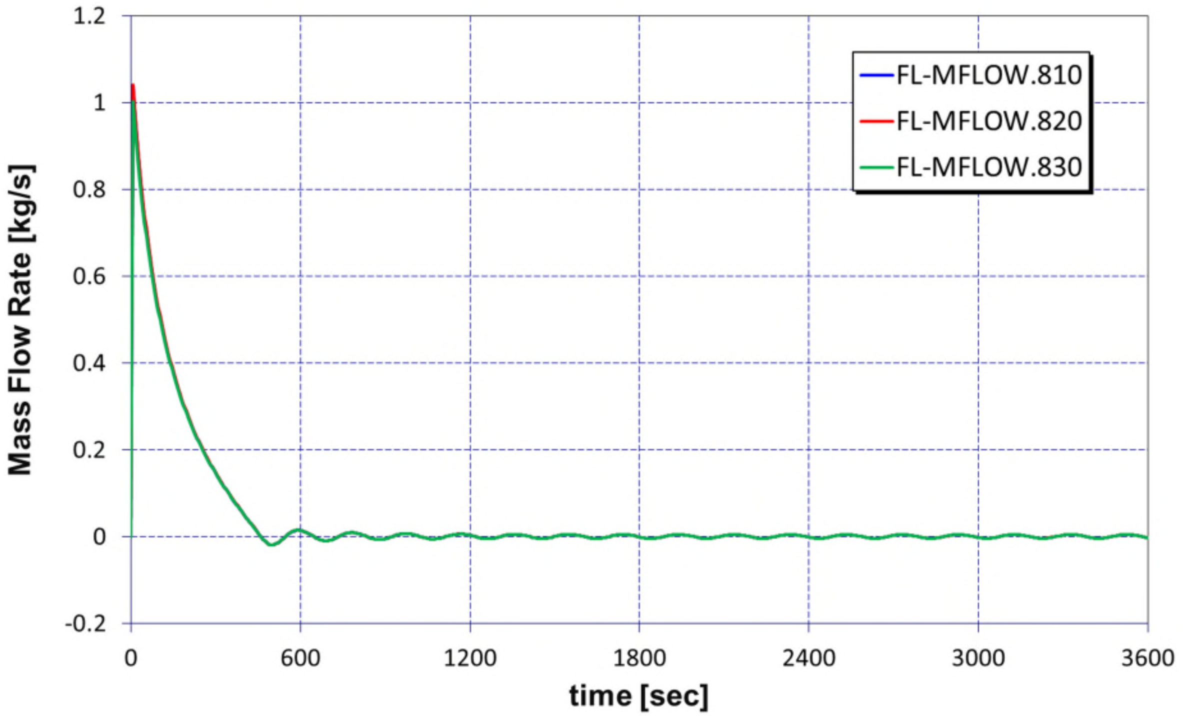


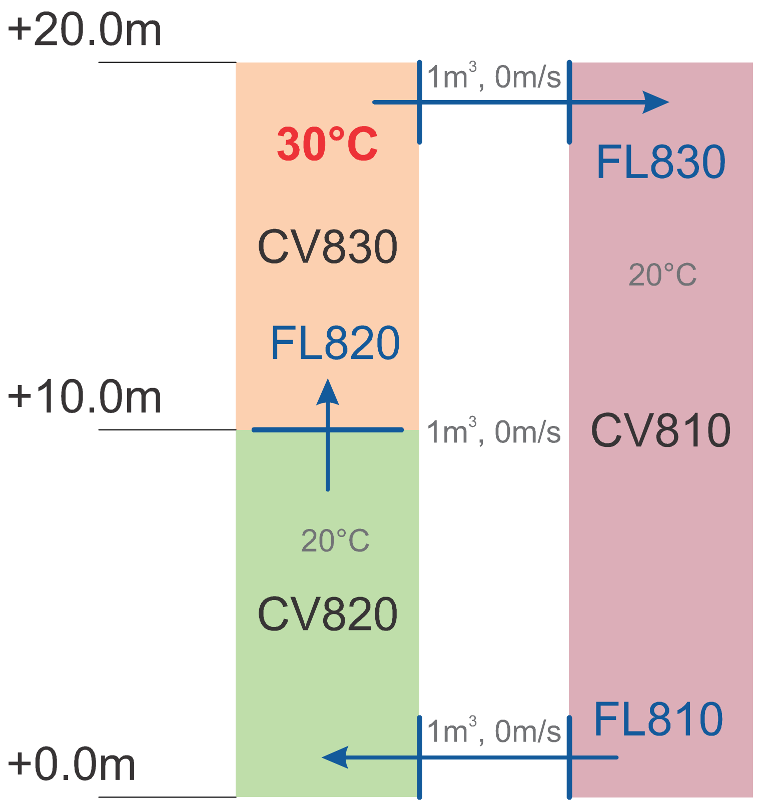


Introduction

Flow Paths Loops 2

- **2 distinct stable states, one fully mixed, one with temperature gradient**
  (CV810 =22.7C CV820 = 21.6C CV830 = 23.4C)
- **DeltaT ~ 2K can compensate hydrostatic pressure error**

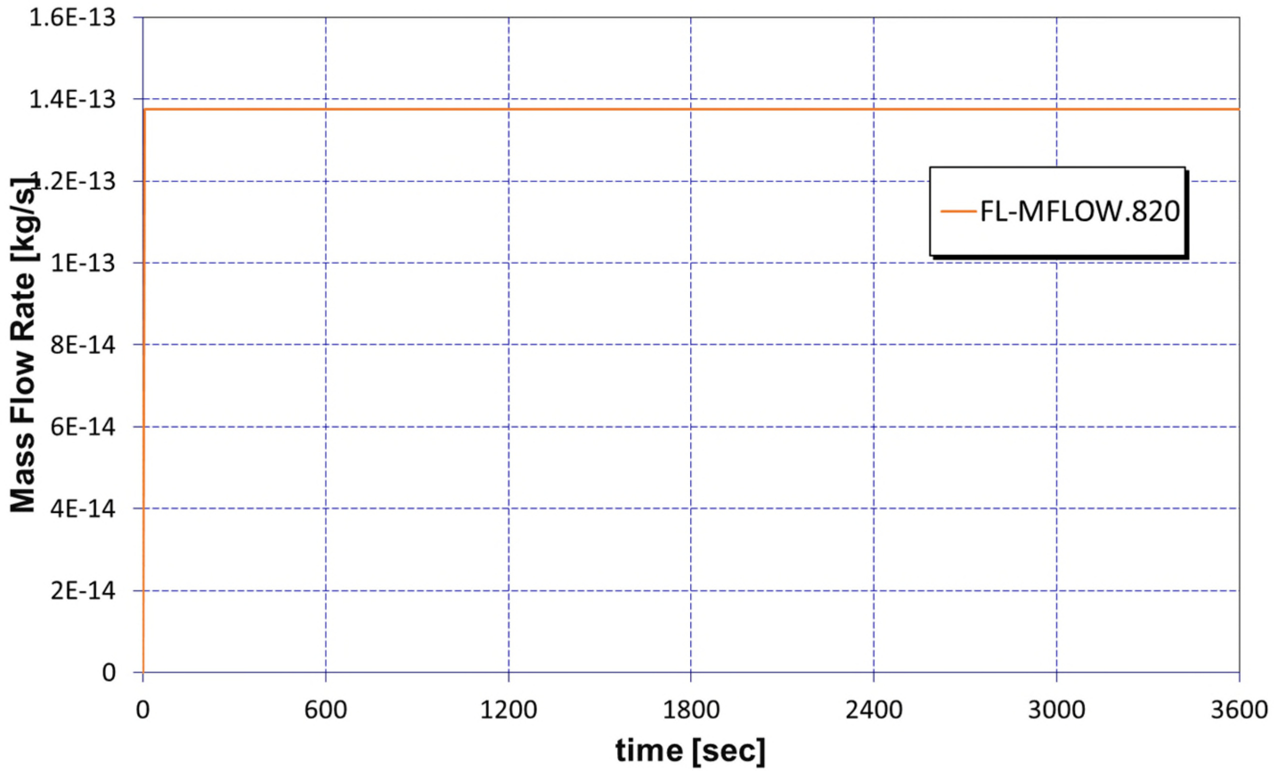


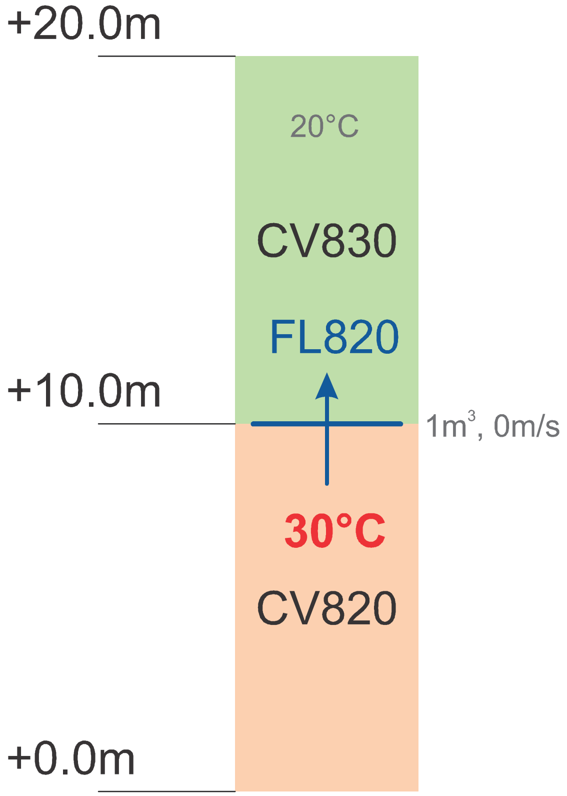


Introduction

Flow Paths Loops 3

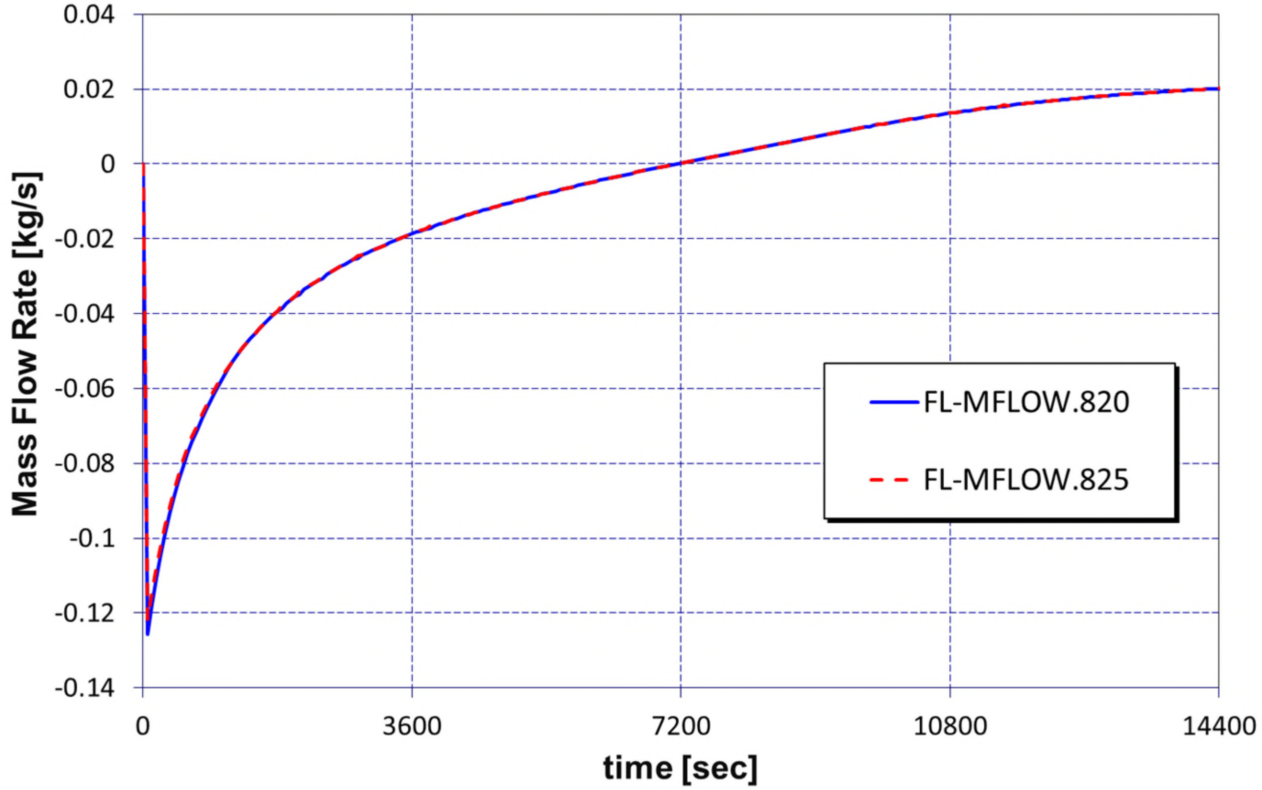
- **Stacked CV with only one FL connection**
  - can not relax inversion “weather”   FL-MFLOW(FL820) = 0.0
  - can be reason for breakdown of MELCOR timesteps

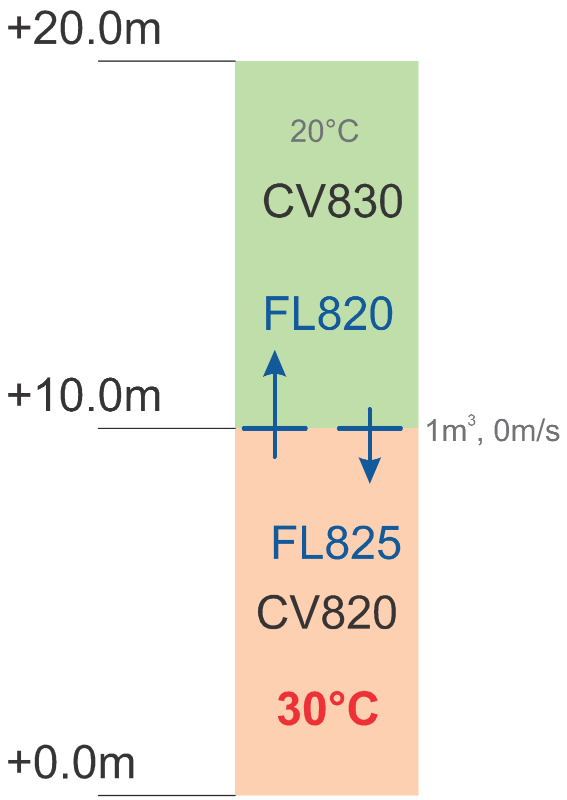




Introduction
Flow Paths Loops 4

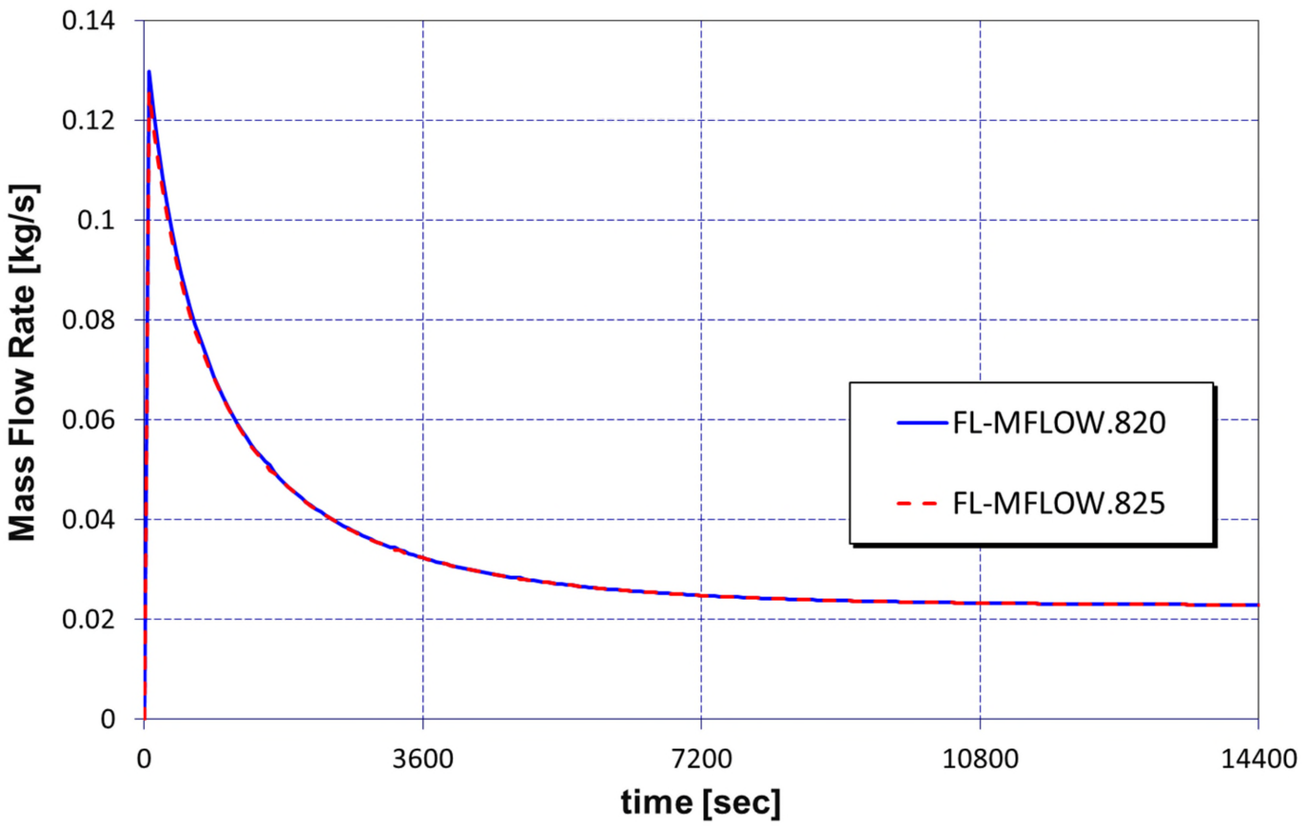
- **Stacked CV with two FL connections (inversion “weather”)**
  - 10 cm symmetry breaking (zfm/zto, FL_JLF/FL_JLT)

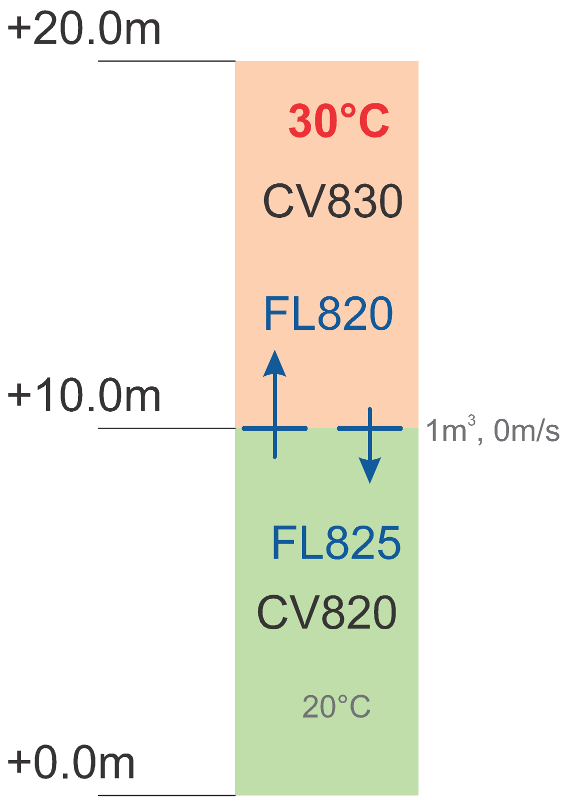




Introduction
Flow Paths Loops 4

- **Stacked CV with two FL connections (non-inversion “weather”)**
  - 10 cm symmetry breaking (zfm/zto, FL_JLF/FL_JLT)
  - Zero Flow expected





Introduction

Flow Paths Loops 4

- **Stacked CV with two FL connections (non-inversion "weather")**
  - **2m symmetry** breaking (zfm/zto, FL_JLF/FL_JLT)
  - Strong symmetry breaking of flow paths **can** sometimes help
  - But can also **negatively affect numeric**

```
C:\WINDOWS\system32\cmd.exe
COMMAND-LINE ARGUMENTS:

 Opening user input file MELGEN_page8.inp
Records of Restart File: R33.RST
 NCYCLE=         0 TIME= 0.00000E+00
        RESTART REQUESTED FROM LAST AVAILABLE CYCLE
Restart requested from NCYCLE=      -1 Read from NCYCLE=       0
 Calculation End Time (sec)->   14400.0000000000
 RESTART REQUESTED FROM LAST AVAILABLE CYCLE
*****DEFAULT EOS: Built-in Water !*****
HTML: CREATING HTML OUTPUT FILE ().....
 Listing written TIME=  0.00000E+00 CYCLE=         0
 CYCLE= 0 T= 0.000000E+00 DT(INC)= 1.000000E-03 CPU= 0.000000E+00 NCR=0,0
 CYCLE= 100 T= 2.206217E+00 DT(INC)= 4.149500E-10 CPU= 4.062500E-01 NCR=0,0
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 CYCLE= 400 T= 2.206217E+00 DT(INC)= 5.144400E-10 CPU= 1.937500E+00 NCR=0,0
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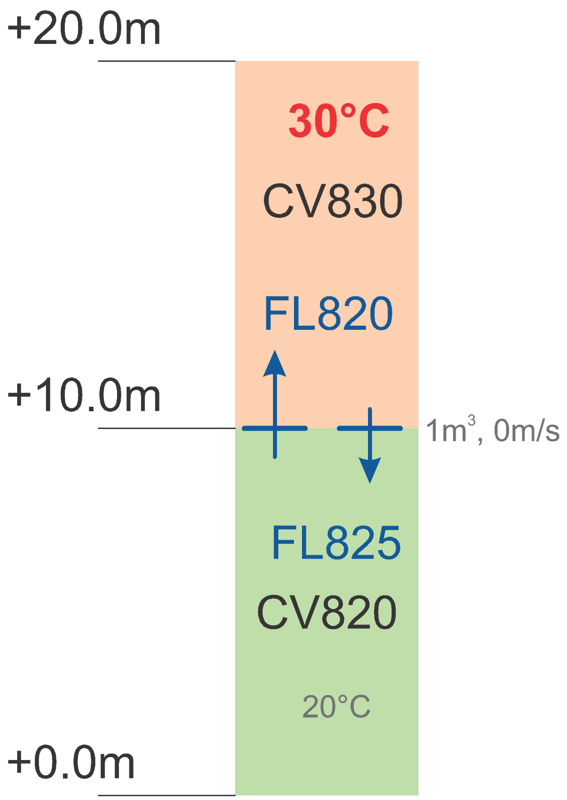


Introduction

Flow Paths Loops - Summary

- **Loop-FL-structures can lead to non-physical results**
  - CV with different elevations
  - low relative differences between CV (density, temperature, composition)
  - CVs with large interface areas, relative to volume
  - FL with low flow resistance / low flow velocities
  - connections with long momentum length (fllen)

Modelling gas convection in containment dome via splitting the open space into multiple CVH volumes

→ LP codes have a tendency of over-predicting convection mixing

→ More Control Volumes may not make the result better

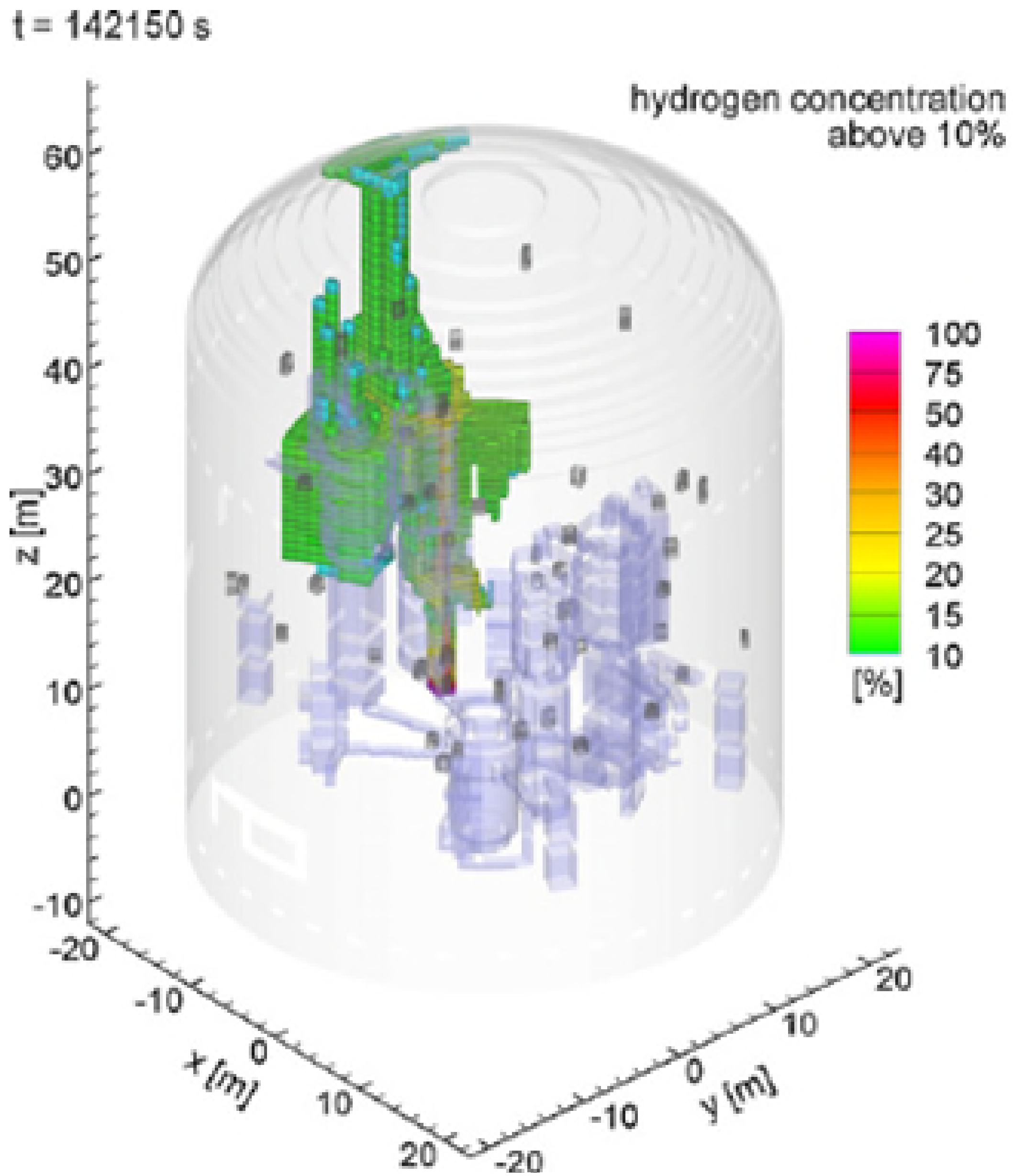
Not a MELCOR-specific issue, but affects all lumped-parameter codes

What we want to model in LP

Plume formation in Dome

- **(fast) Hydrogen release from primary loop**
- **Plume rising through the steam generator towers**
- **Ascending to the containment dome**
- **Short-term stratified layering in upper containment**
- **Long-term mixing within the containment**
  - Diffusion
  - Convection flows

How to nodalize the containment dome

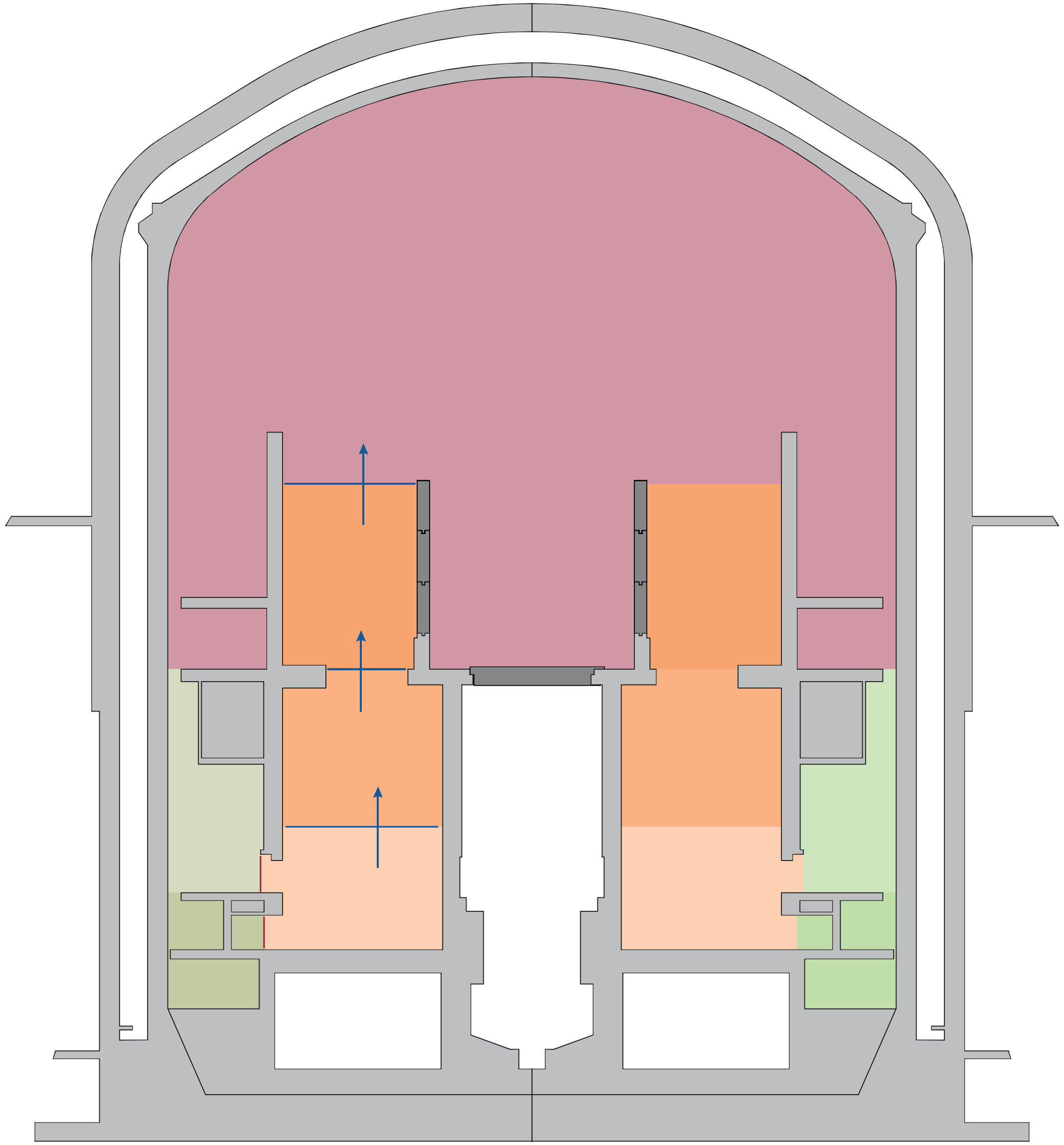


Computational validation of the EPR™ combustible gas control system - ScienceDirect

Approach 1 - Just prepare for CFD

- **One large volume for the containment dome**
  - Be aware that this nodalization will be weak
  - Use the results as starting conditions for CFD simulations

- **Approach employed in the licensing of EPR reactors**
  - MAAP for containment source term
  - COCOSYS for overall containment response
  - ANSYS CFX for hydrogen cloud formation in dome



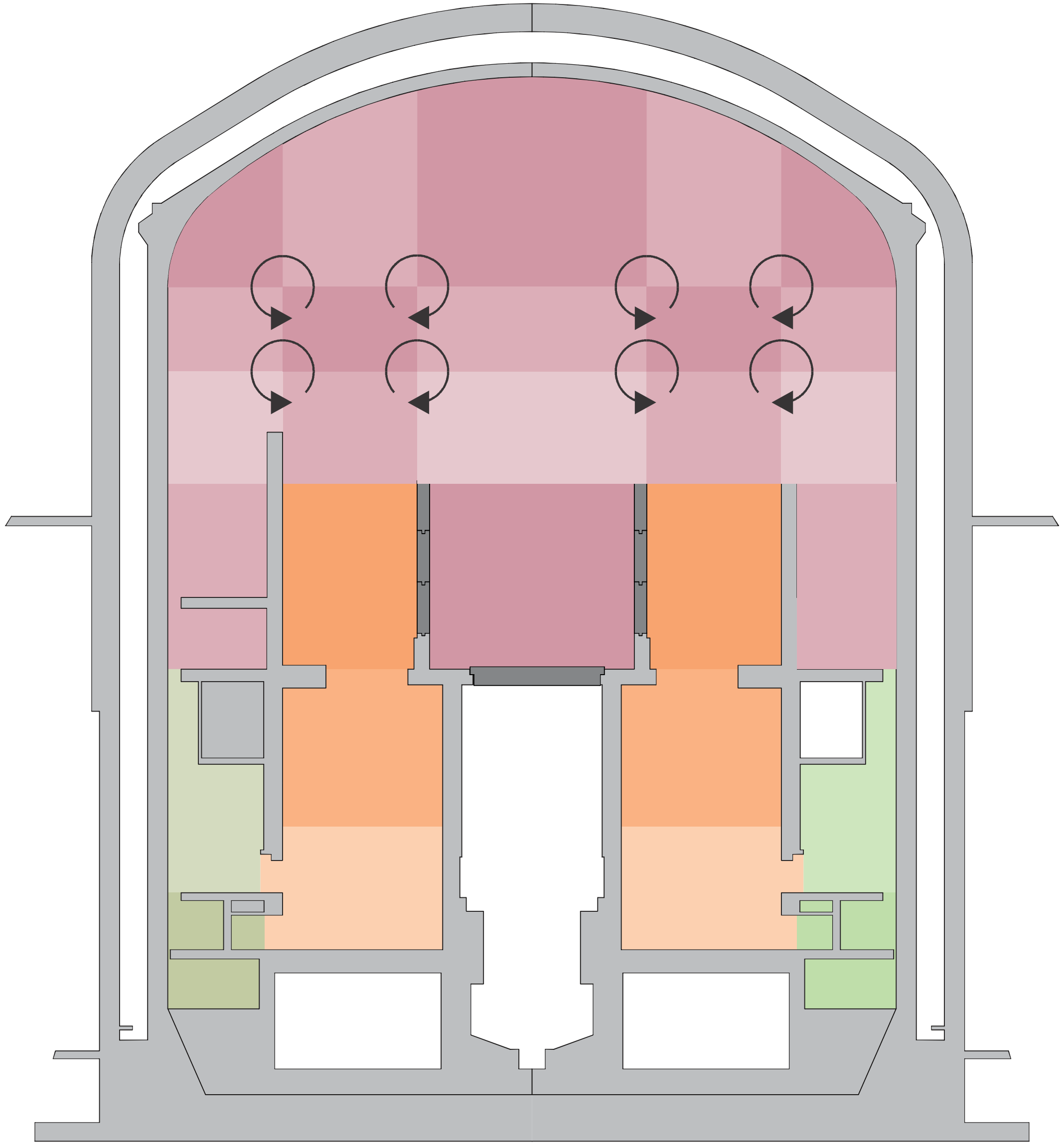
Approach 2 - More CVs

- **Separating the dome into multiple CVH**
  - large interfaces
  - low flow resistance between volumes
  - complex loop flows

  → Risk of homogenization by unnatural flows

- **Some CVH splitting can increase inhomogeneity of dome**

- **With more and more CV, a lumped-parameter code**
  - **will not** converge to a CFD code, but
  - Resembles a single CV model more and more

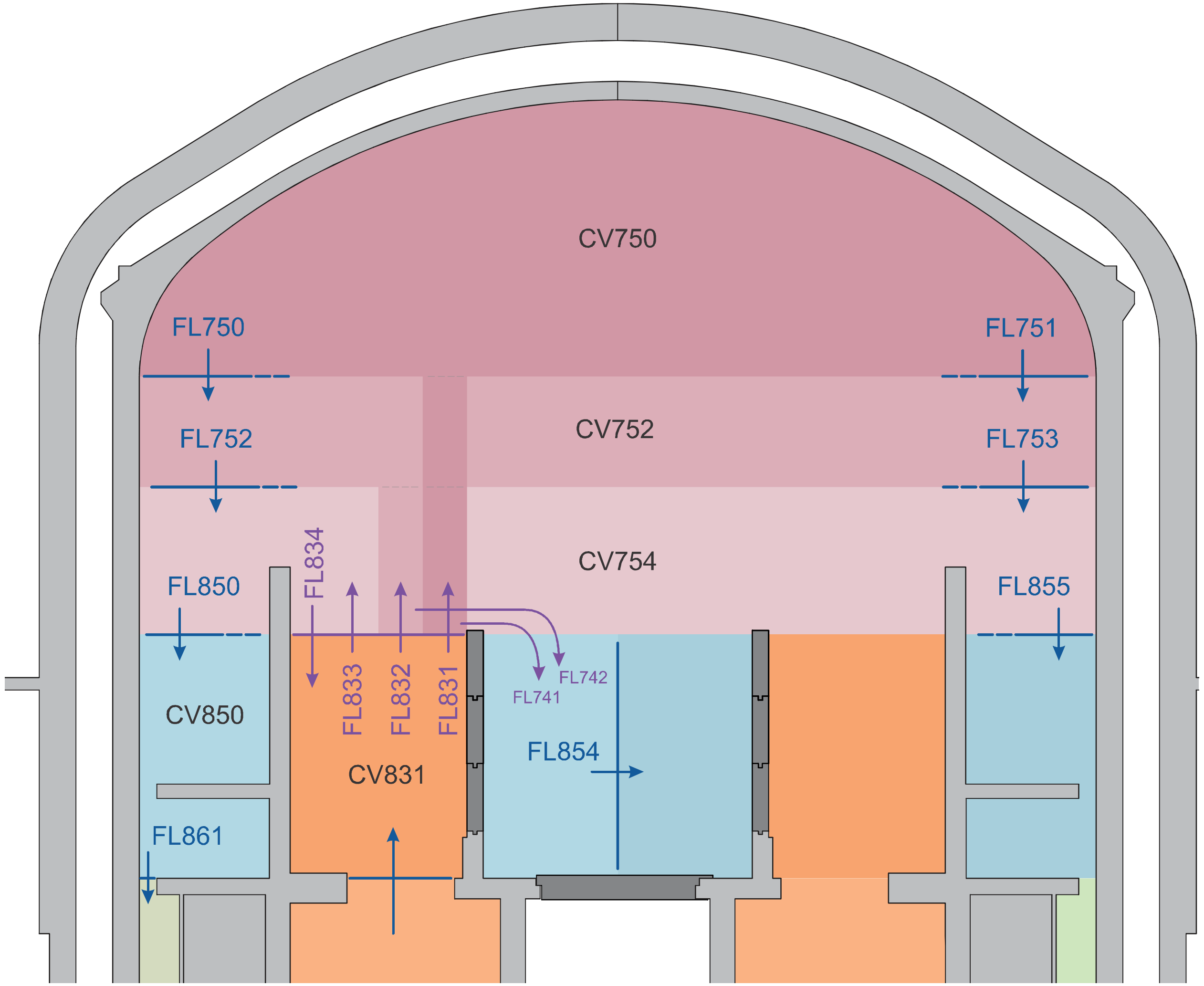


Approach 3 - Functional Nodalization

- **Splitting dome in 4 layers**
  - 1 layer as service floor
  - 3 layers as domes above the SG towers
  - Upper dome CVs have a “finger” down to SG tower ceiling → avoid unnatural chimney effect

- **SG ceiling representation**
  - only-forward CF-controlled FL831-834
  - Add gas rising from SG tower to the lowest dome layer having < gas density than in the SG tower
  - If no flow upward through SG tower top, then open downward flow path FL834
  - Dome layer “finger” need condensate drainage (CF-controlled FL741 / FL742)

- **Stacked dome layers**
  - Interconnected by 2 FL (e.g. FL750 / FL751) to allow for relaxation of inversion “weather”
  - One FL is equipped with valve function



Functional Nodalization - Pros & Cons

- Avert many lumped-parameter code issues for convection flow
- Recreate expected gas convection flow pattern
- Convection flow pattern must be known in advance
- Risk to enforce an unnatural flow pattern
- Model is not universal anymore

Thank you

AMHYCO Engineering correlation for Framatome PAR

AMHYCO 2020.10 – 2025.3

EMUG 2025
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Framatome
2025-04-07

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New PAR Correlation for Framatome PAR

- **Since 1980 – AREVA correlation, developed by Siemens & Framatome NP / AREVA / Framatome**
  H_2, CO, O_2, but uncertainty in low Oxygen, and no CO Poisoning
- **WP3/4 – preliminary AMHYCO correlation as used for simulations**
  (generic plate-type PAR, with bounding poisoning criteria)
- **General overhaul of Framatome PAR correlation and validation on THAI**
  (FRG-internal report / non-public due to restrictions due to THAI)
- **Publication (NED) in preparation as standard reference**
  (PAR history, focusing on the physics, w.o. validation)
- **THAI-THEMIS 6th Review Meeting presentation**
  (example of THAI validation, cut correlation to not spread preliminary results)
- **As Chapter in WP5 Deliverable 5.1**
  (longer version with implementation Guide, w.o. validation)

Unfortunately, the presentation of the Hydrogen mitigation part must be delayed up to the CSARP&MCAP meeting