ID137

A Multi-Zone Model for Hydrogen Accumulation and Ventilation in Enclosures

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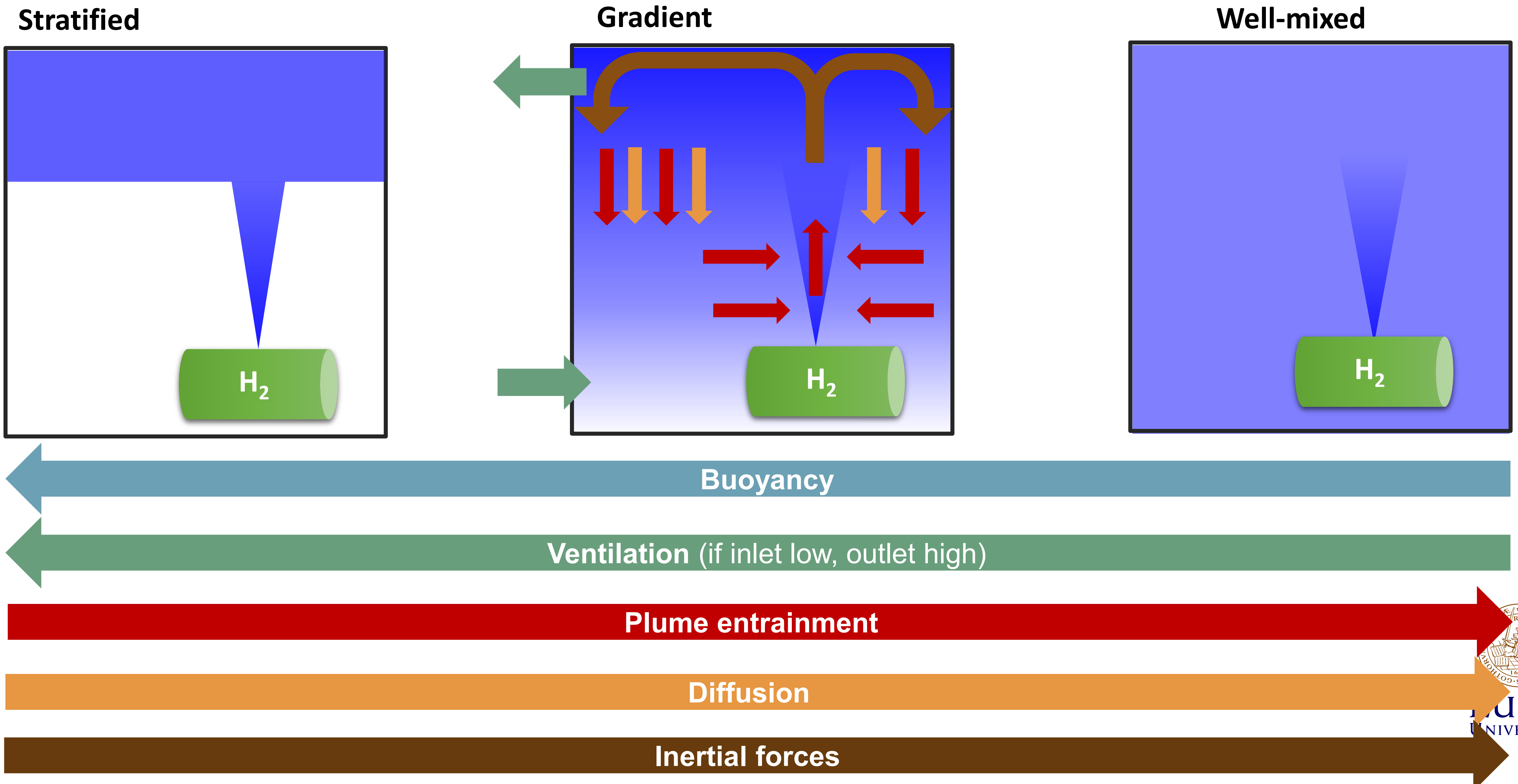
Competing phenomena in accumulation



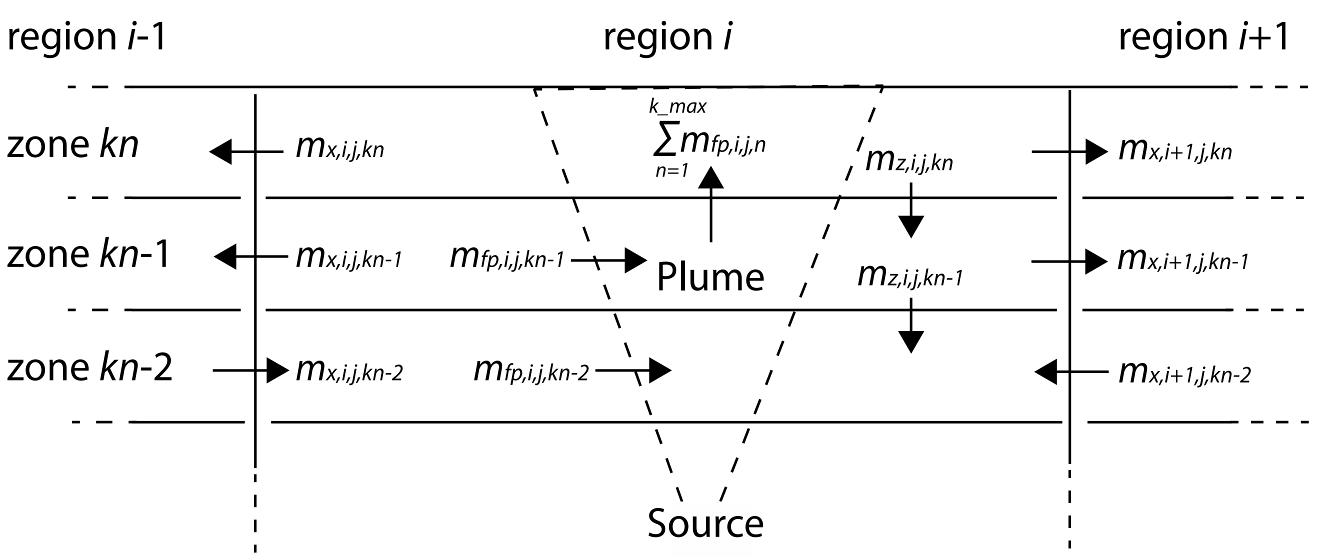
Why not only using CFD?

- Vent size optimization requires many repeated runs
- CFD-models generally have requirements on number of grid cells over the (notational) nozzle.
- … but ventilation is typically based on a very small leak (e.g. 0.1 mm^2) and even using notational nozzles and grid stretching/refinement the run-times can be long.

Aim

- To develop a general model for hydrogen accumulation with short runtime to allow for ventilation optimization
- Perform some initial validation

Proposed model – Multi-zone concept (from Suzuki et al. [11])



Governing equations (explicit)

- Mass conservation
- Hydrostatic pressure due to density difference
- Diffusion (Fick's law)
- Empirical plume model

$$Q(z) = \frac{6\epsilon}{5}\left(\frac{9\pi^2\epsilon}{10}\right)^{1/3} B_o^{1/3}(z+z_o)^{5/3}$$

```
&MESH IJK= 3, 3, 10, XB=0,2.6,0,2.6,0,2.45 /
&TIME T_END=2000 /
&MISC TMPA=20 /
&SOUR XYZ=1.3,1.3,0, diameter=0.015, velocity=0.3395 /
&PROP mass=0.004, density=0.167 /
&VENT XYZ=0,2.4,2.3, direction=left, area=0.025, v_flow=0 /
&VENT XYZ=2.6,0.2,0.1, direction=right, area=0.0102 /
&TAIL /
```

Note! Based on a buoyant plume, but even at 500 bar, a 0.1 mm^2 leak becomes buoyant after 0.09 m.

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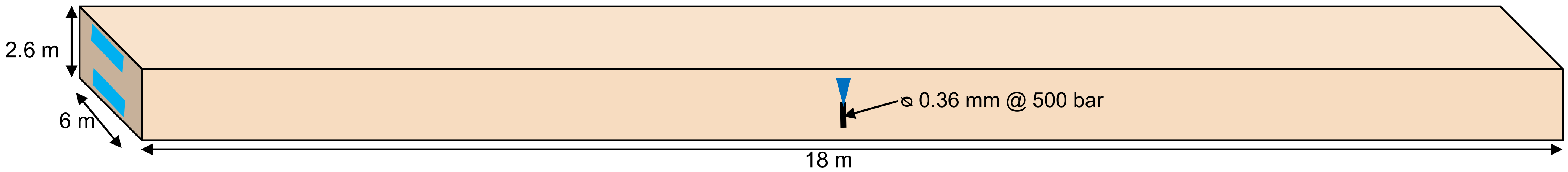
Model freely available, link in paper

Example



Validation – Set 1 (Helium, laminar)

Set 1A – Liang et al. [16]

Top vent: None (except leaks)
Floor vent: ⌀5.7 cm

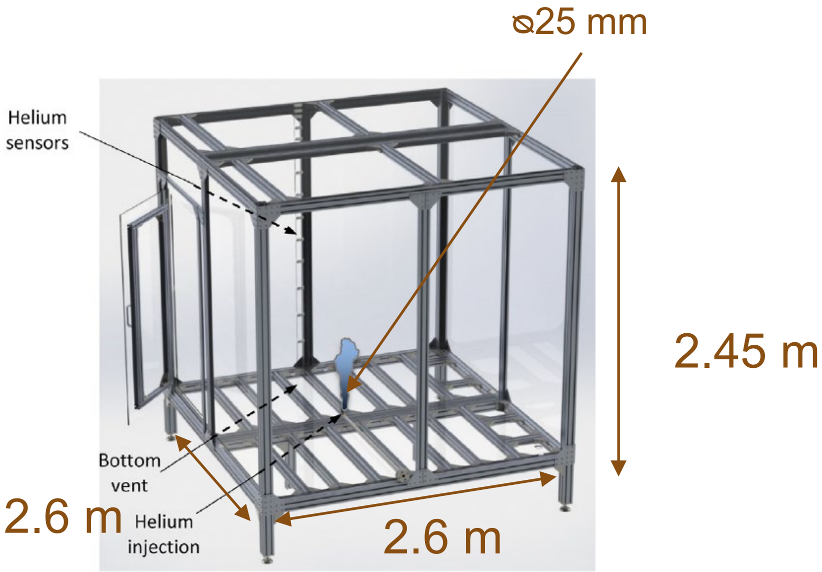


Fig. 1 – Schematic of 16.6 m^3 polycarbonate enclosure.

Set 1B – Liang et al. [17]

Top vent: ⌀11.4 cm
Floor vent: ⌀11.4 cm

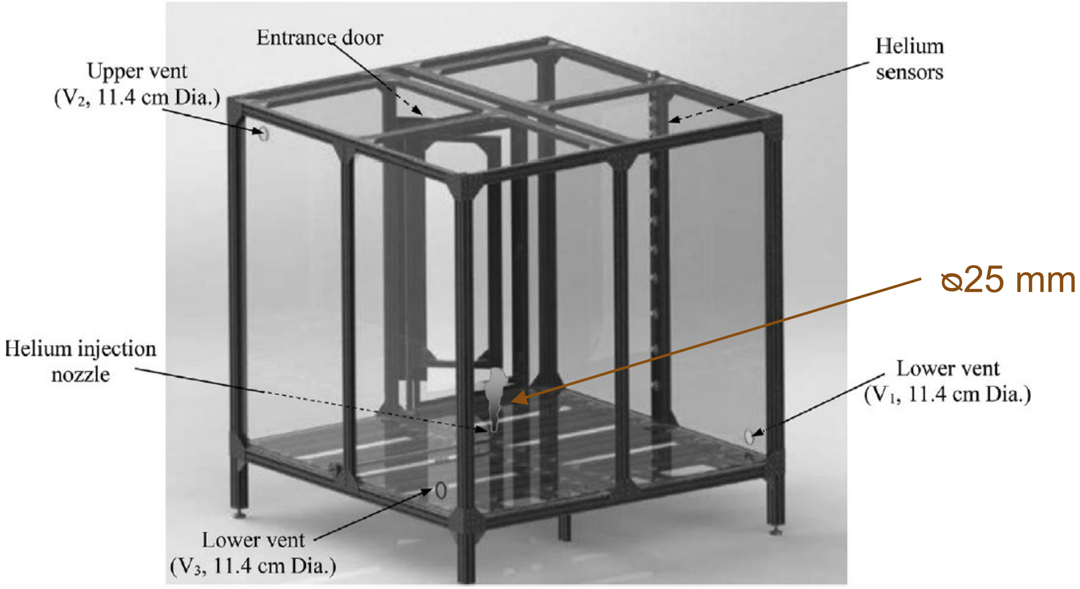


Fig. 1 – 3D drawing of 16.6 m^3 polycarbonate enclosure.

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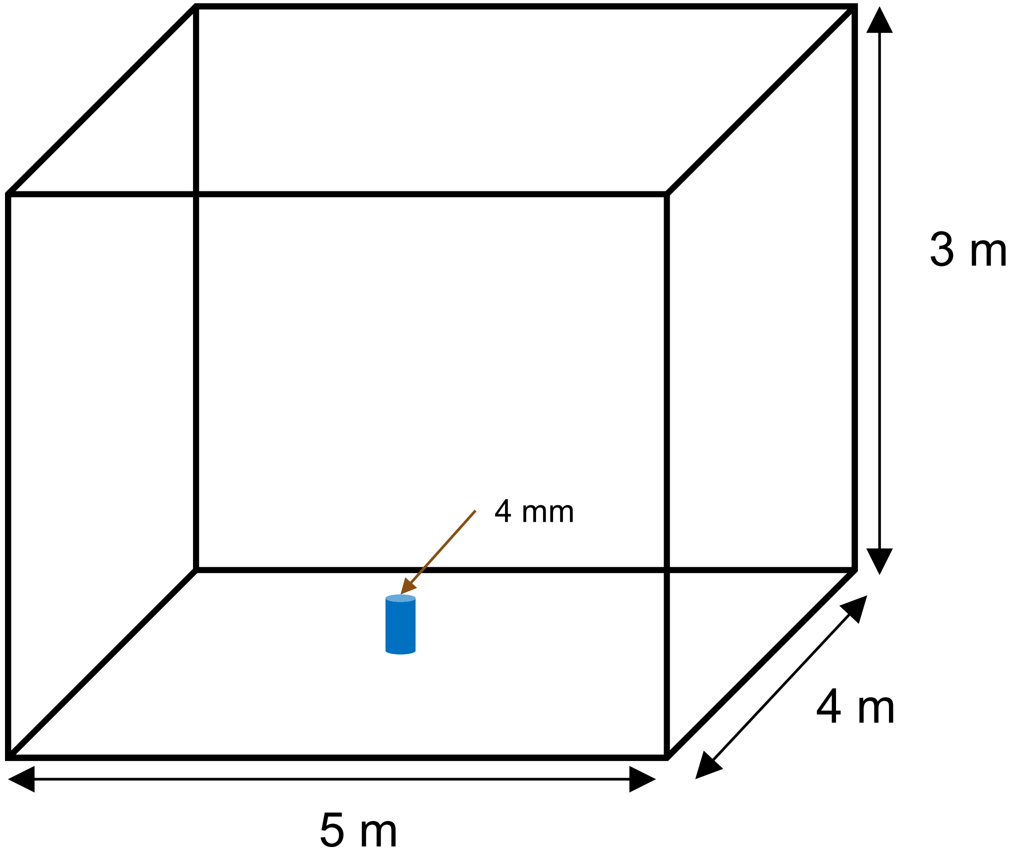
Validation – Set 2 (Hydrogen, turbulent)

- Brzezińska [18]



Validation matrix

Test	Set	Gas	Room volume	Nozzle diameter	Mass flow	Floor vent diam.	Top vent diam.	Source height above floor	Reynolds number	Richardson number	Ref
			[m^3]	[mm]	[g/s]	[cm]	[cm]	[m]	[-]	[-]	
1	1A	He	16.6	25	0.0028	5.7	-	0	15	5427	[16]
2	1A	He	16.6	25	0.0698	5.7	-	0	363	9	[16]
3	1B	He	16.6	25	0.0140	11.4	11.4	0.1	73	217	[17]
4	1B	He	16.6	25	0.0140	11.4	11.4	1	73	217	[17]
5	1B	He	16.6	25	0.0140	11.4	11.4	1.7	73	217	[17]
6	2	H_2	60	4	0.137	-	-	0	27740	0.0015	[18]

Mesh: 3x3x10 cells (LxWxH)

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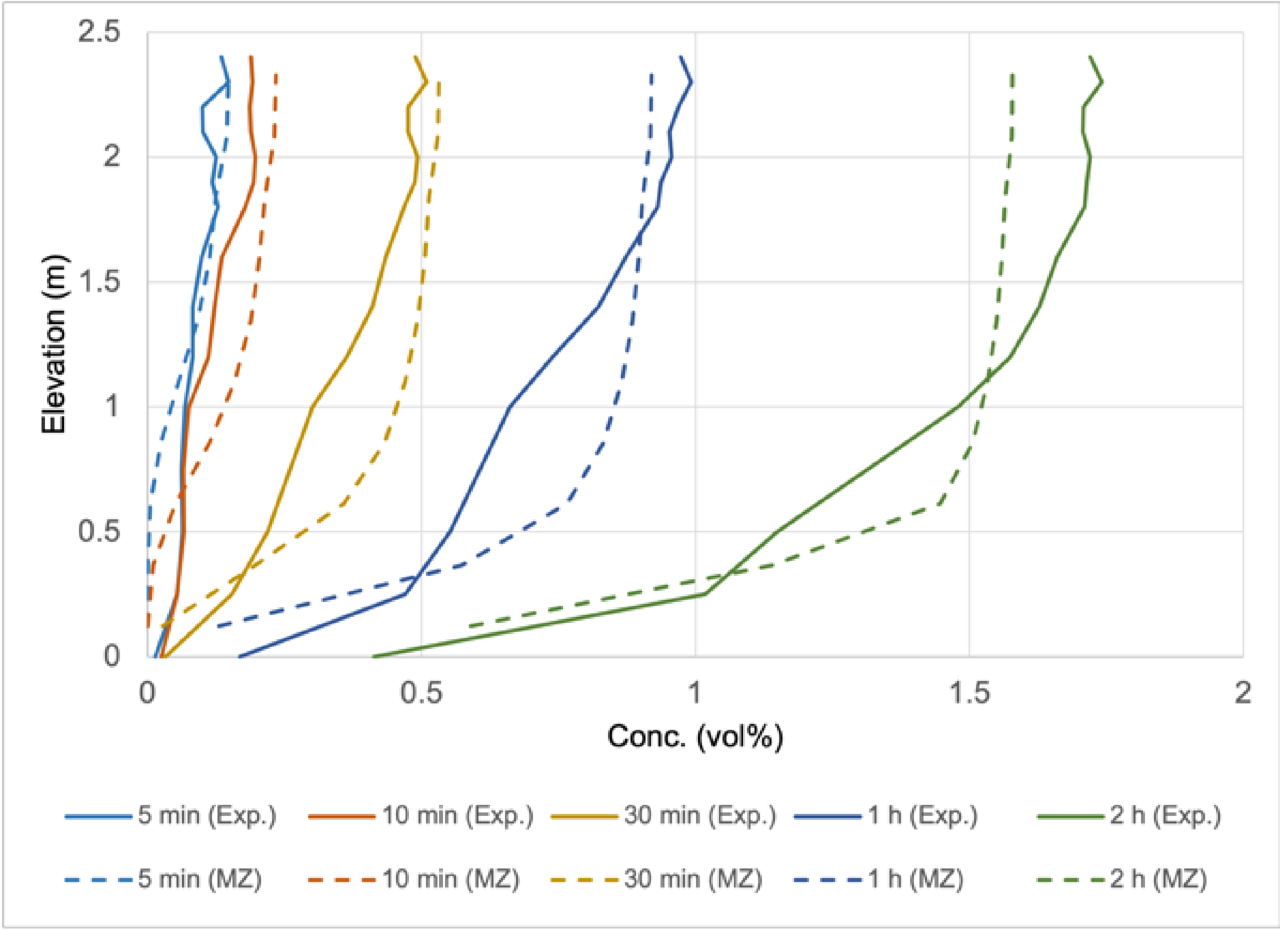
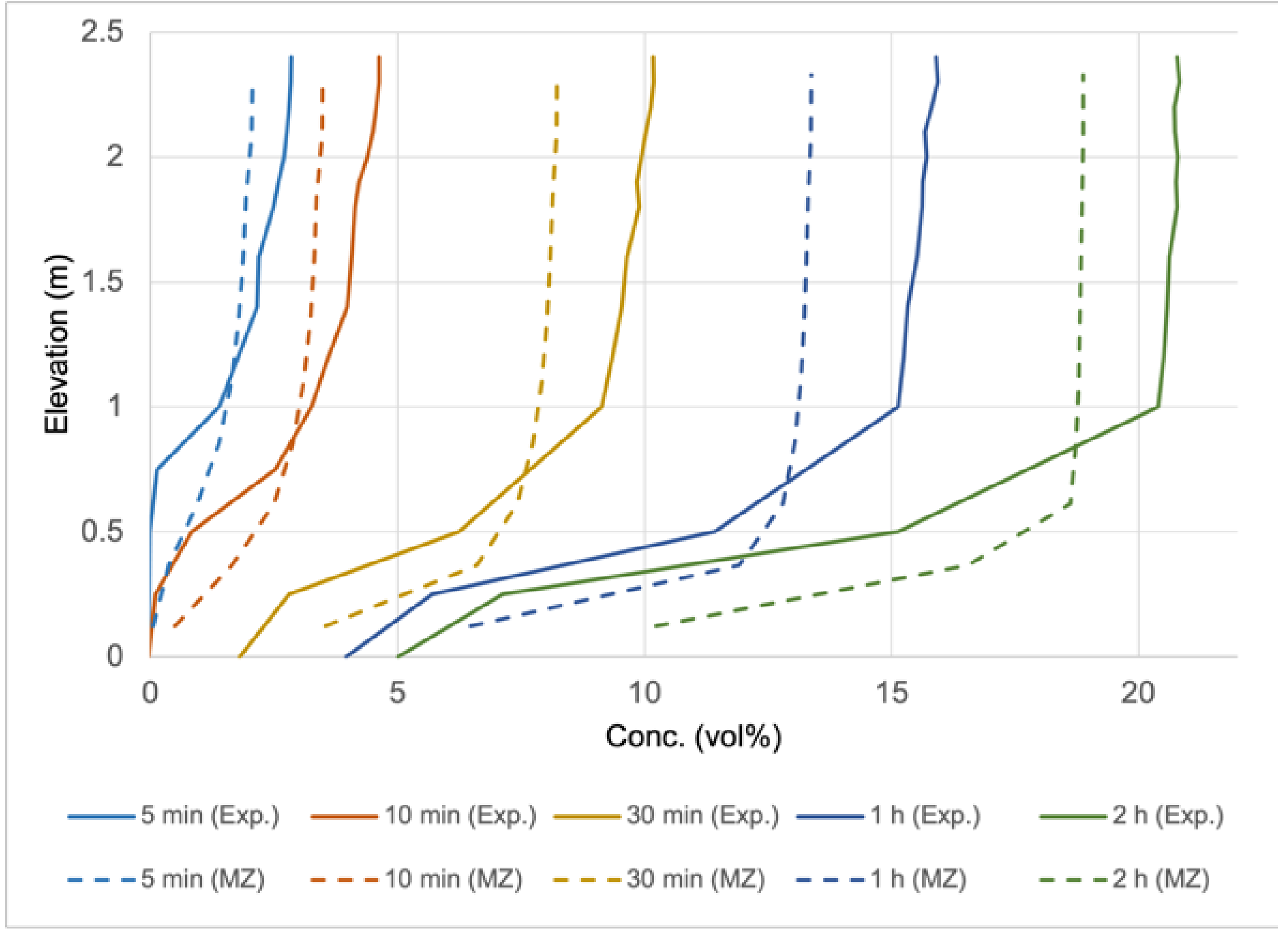
Results 1A – No vent, He, laminar



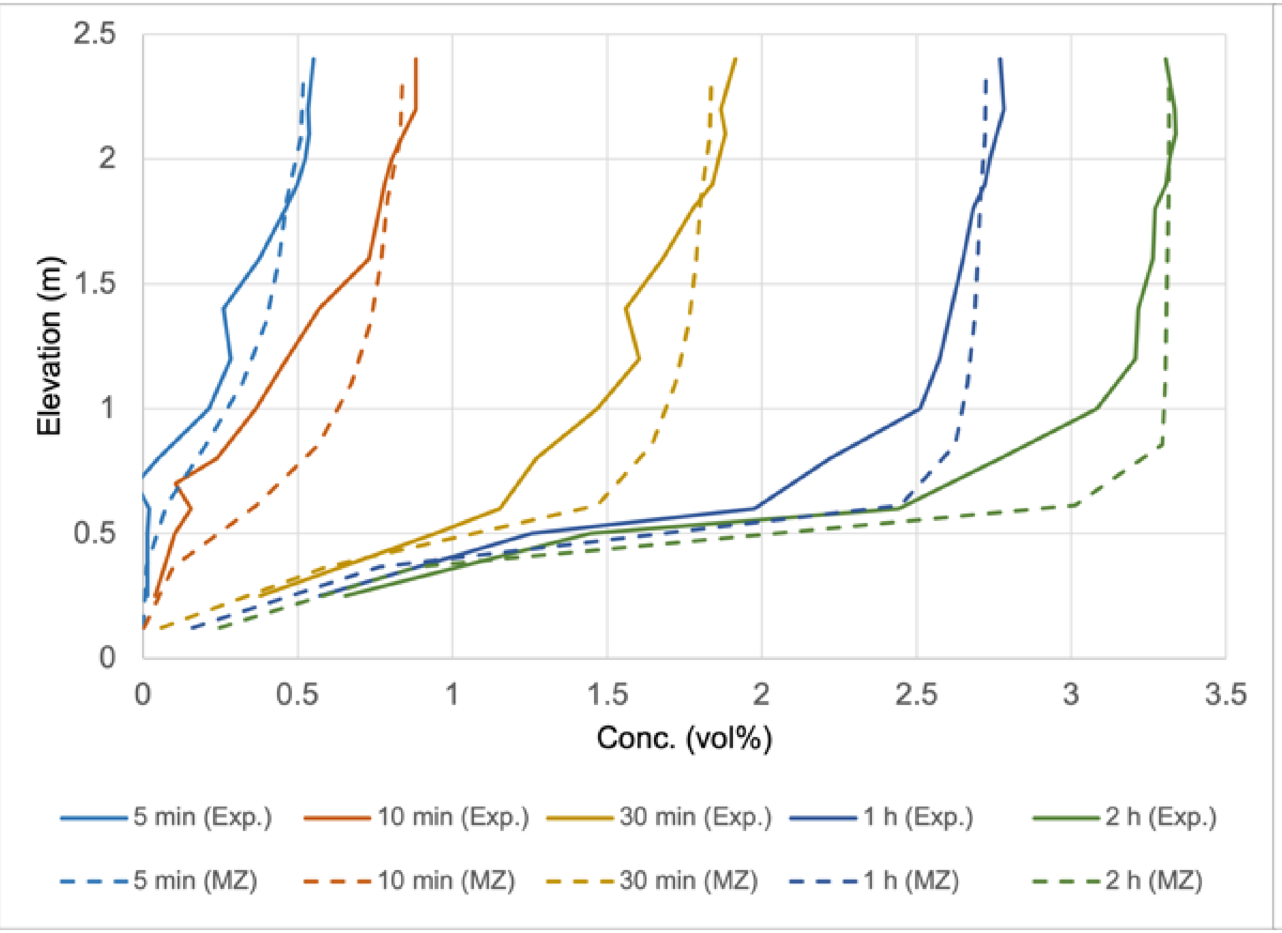
0.0028 g/s, Re= 15, H=0



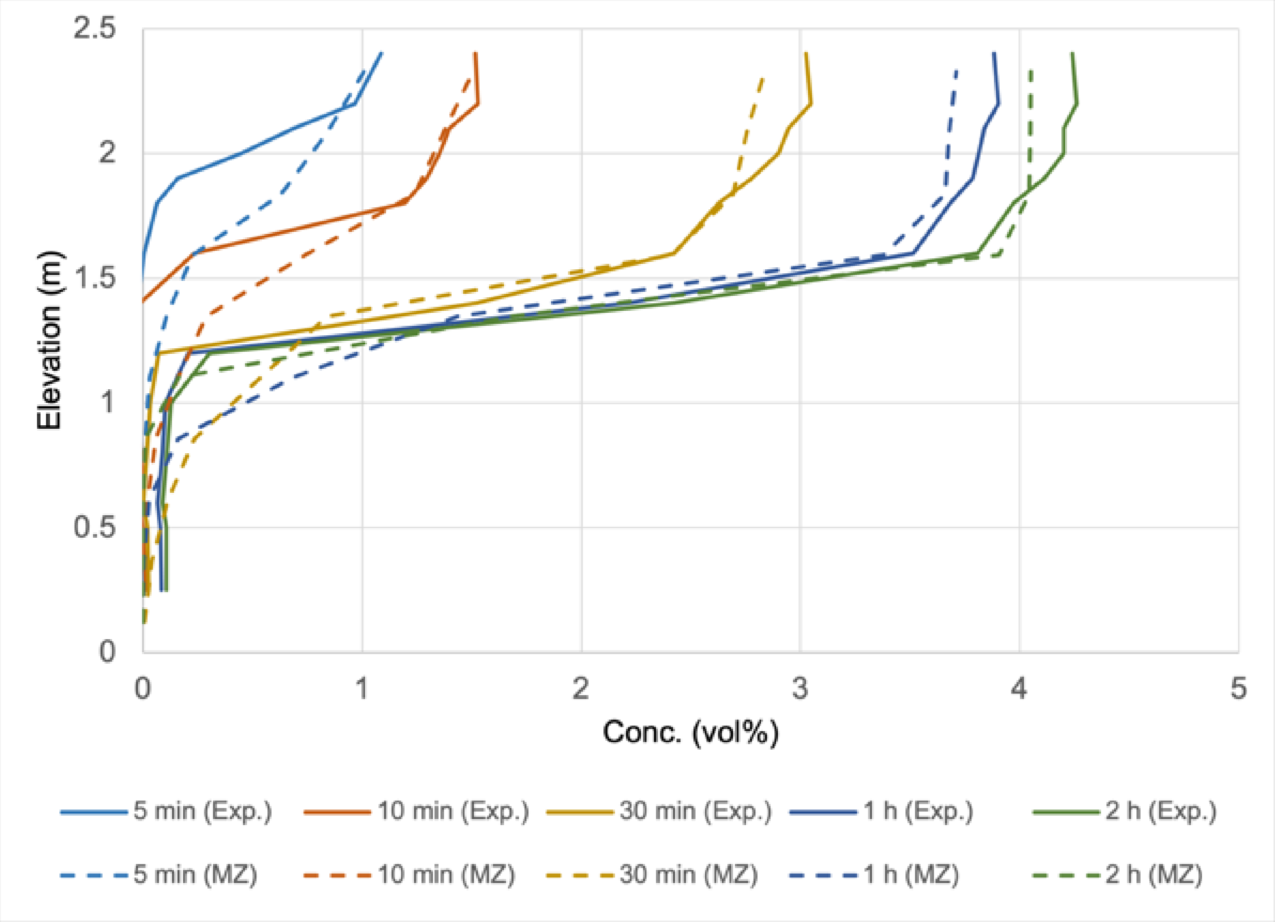
0.0698 g/s, Re= 363, H=0

Results 1B – Ventilated, He, laminar

Profiles



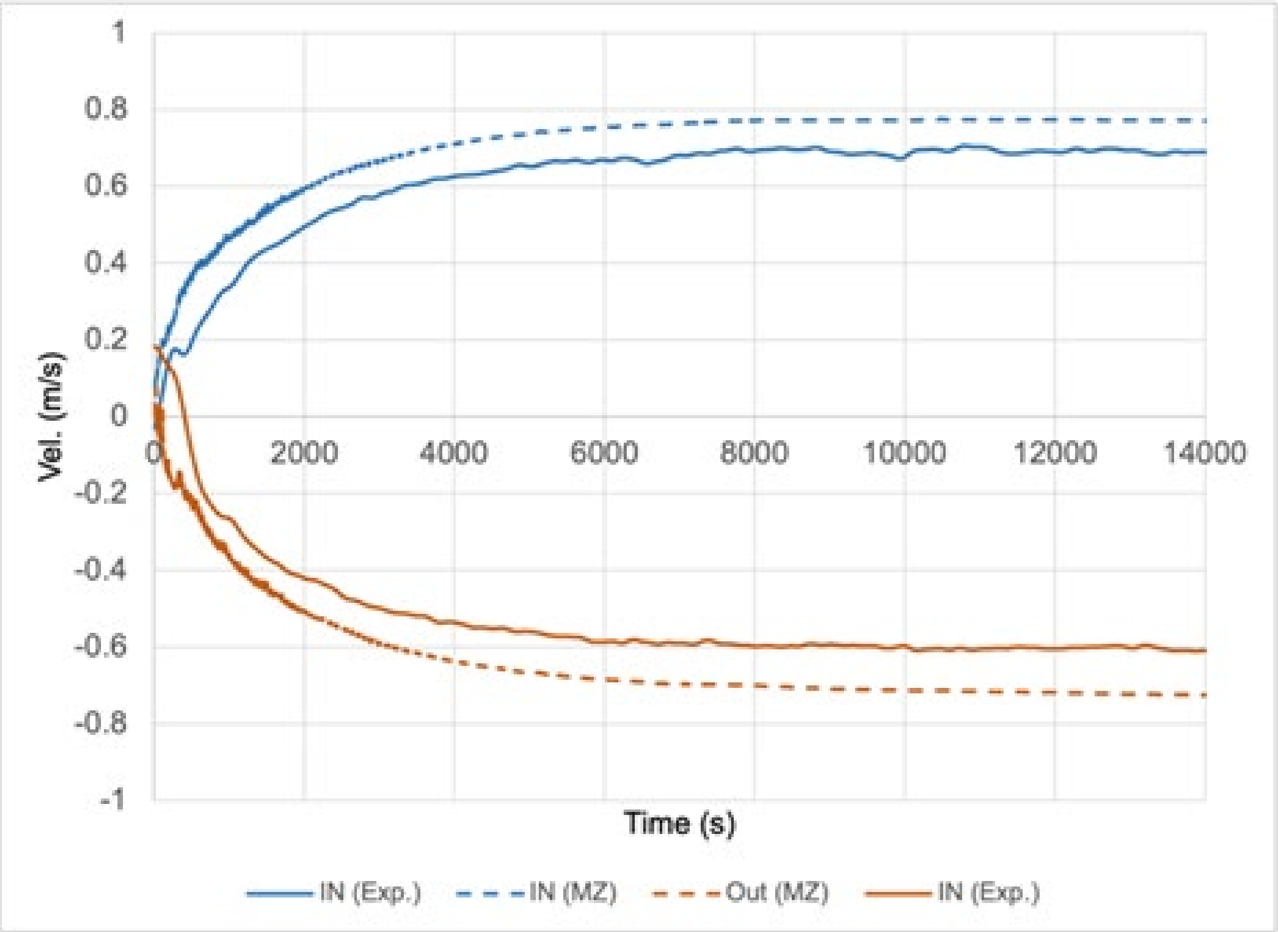
0.0140 g/s, Re= 73, **H=0 m**



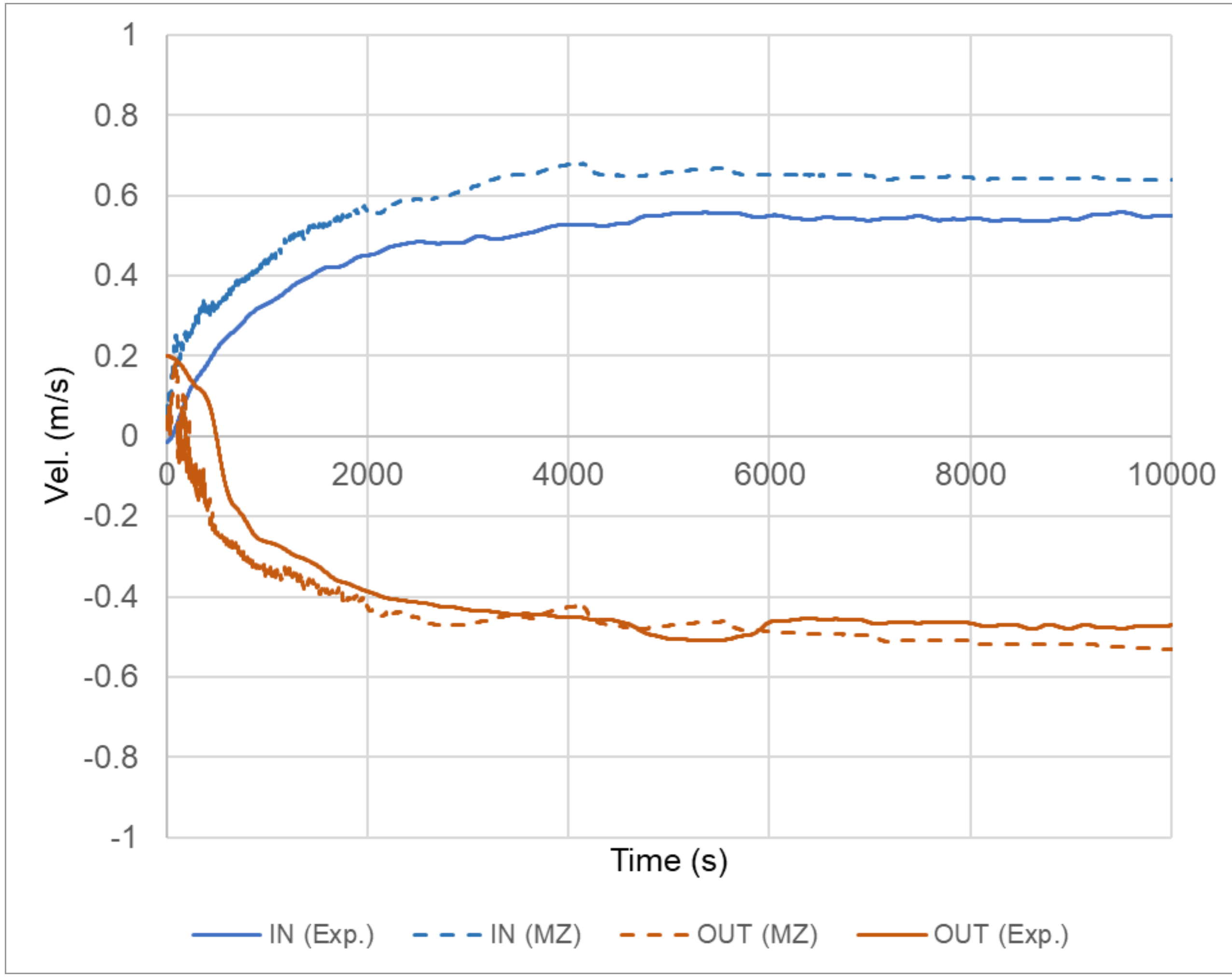
0.0140 g/s, Re= 73, **H=1 m**

Results 1B – Ventilated, He, laminar

Vent flows

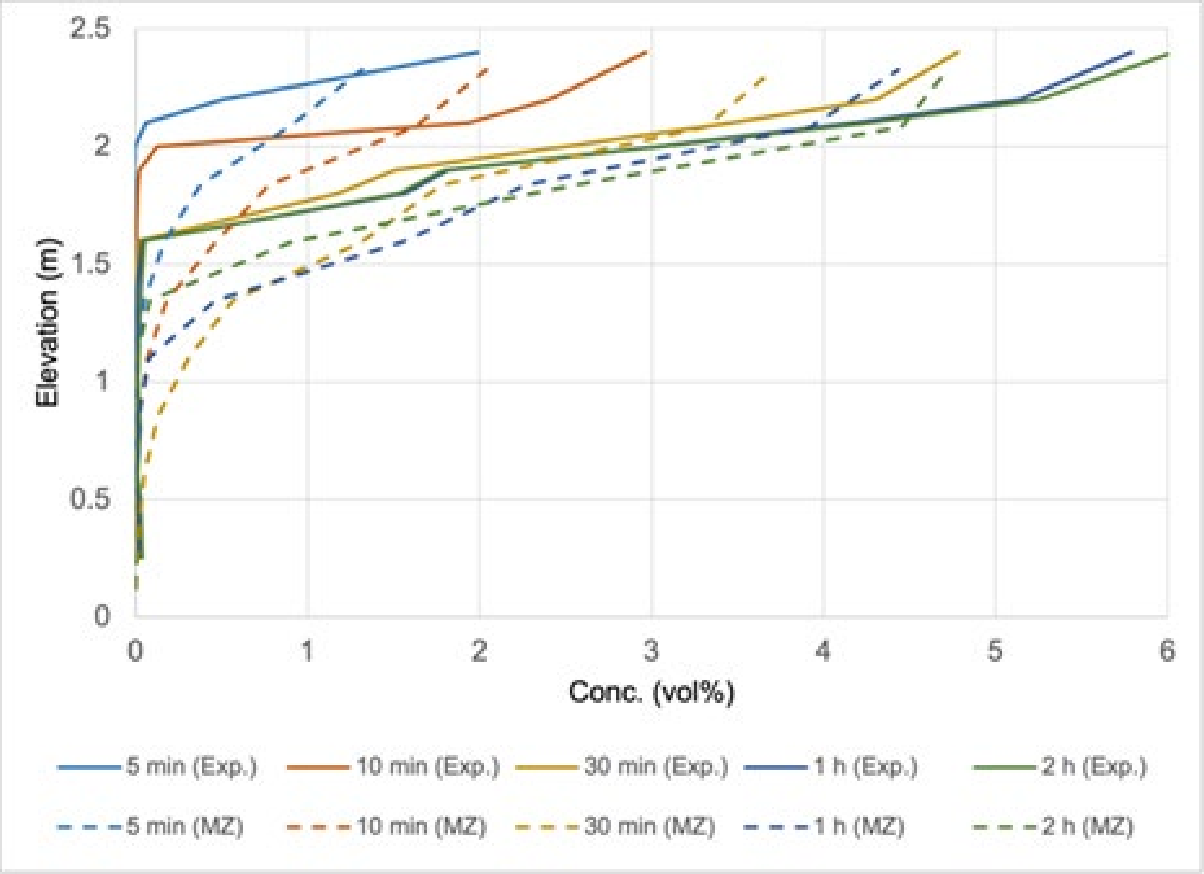


0.0140 g/s, Re= 73, **H=0 m**

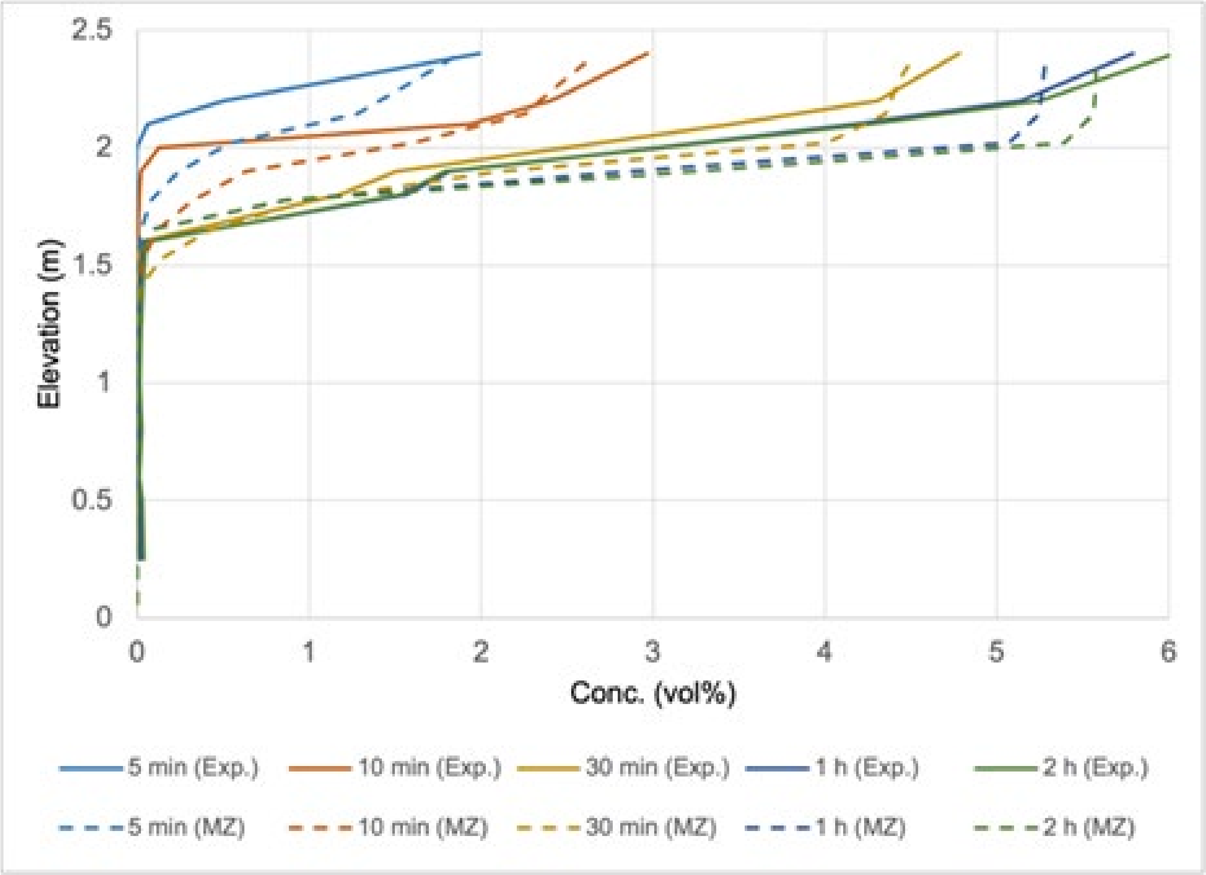


0.0140 g/s, Re= 73, **H=1 m**

Results 1B – Ventilated, He, laminar (cont.)

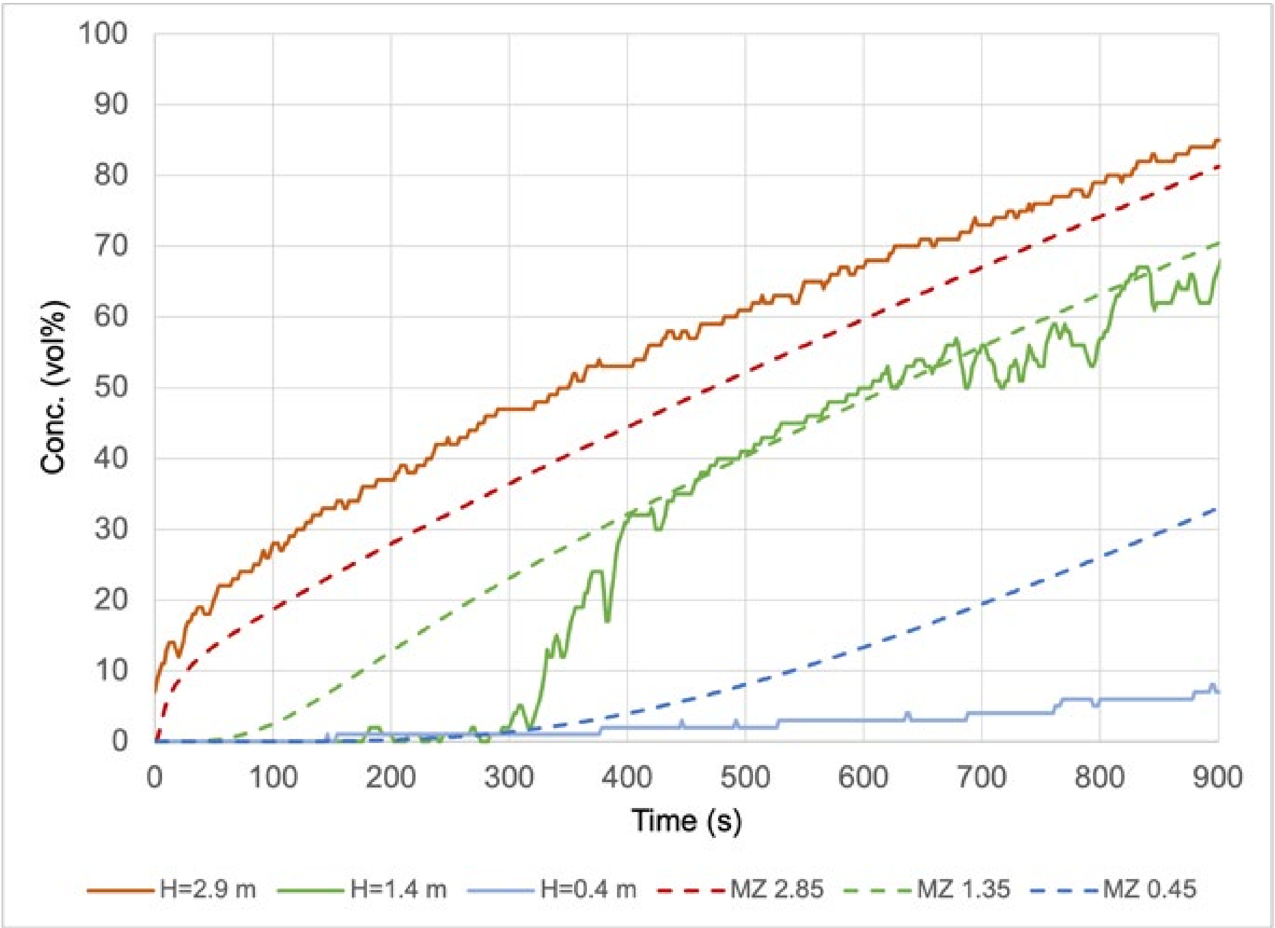


0.0140 g/s, Re= 73, **H=1.7 m**, **N_z=10**



0.0140 g/s, Re= 73, H=1.7 m, **N_z=20**

Results 2 – No vent, H_2, turbulent



0.137 g/s, Re= 27740, H=0

Future work

- **More validation!**
- **Variation in plume/jet-model & grid resolution**
- **Implementation of wind-pressure**
- **Add possibility for criteria based on maximum deflagration pressure following Makarov et al. [19]**
- **Test in QRA-framework**
  - Probability of enclosure damage with variation in leak size and location

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Conclusions & Acknowledgement

- A model for hydrogen accumulation with short run-time has been developed.
- The model give reasonable agreement with experiments, but further validation and development is needed
- Feel free to download the software and try for yourself

The kind contribution of experimental data provided by Zhe Liang (Rita) and colleagues at Canadian Nuclear Laboratories (CNL) in Canada as well as Dorota Brzezińska at Lodz University of Technology in Poland is acknowledged

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