Hyindoor

Pre normative research
on the indoor use of fuel cells and hydrogen systems

Passive and forced ventilation systems with one vent

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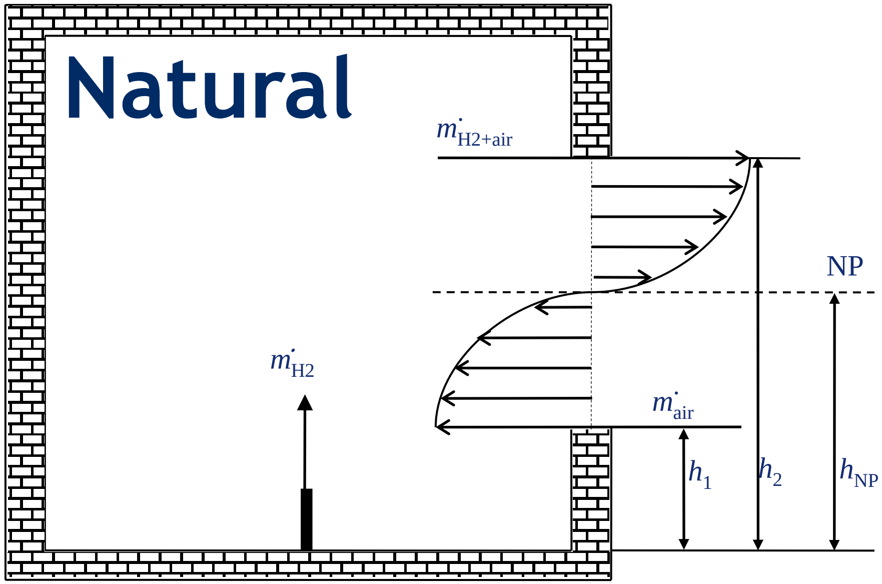
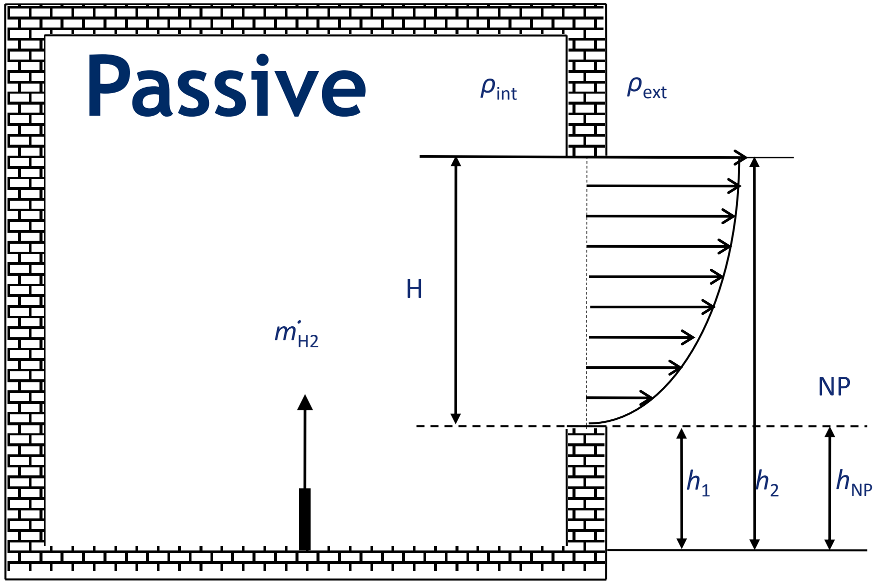
General strategies

- Vertically stretched vents (Height > Width) are more efficient than horizontally stretched of the same area
- Ventilation system with two vents at the different heights is more effective than a system with one vent of the same area. The larger difference in vent heights is, the more efficient is ventilation system
- Vents on the vertical walls are more efficient than vents in (horizontal) roof
- Multiple vents located at all sides of enclosure at different heights improve ventilation for all wind directions
- Obstruction (grills, rain covers), and horizontal ducts reduce vent efficiency

Natural and passive ventilation





- **Natural ventilation** equations for air ventilation in buildings are derived in the assumption of equality of flow in and out (neutral plane is at half vent height).
- **Passive ventilation**: neutral plane for lighter than air gases can be anywhere below half of a vent height.

Natural *versus* passive 1/2

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Natural ventilation:

$$X = \left[\frac{Q_0}{C_D A (g' H)^{1/2}} \right]^{2/3}$$

Passive ventilation:

$$X = f(X) \cdot \left[\frac{Q_0}{C_D A (g' H)^{1/2}} \right]^{2/3}$$

Difference:

$$f(X) = \left(\frac{9}{8} \right)^{1/3} \cdot \left\{ \left[1 - X \left(1 - \frac{\rho_{H_2}}{\rho_{air}} \right) \right]^{1/3} + (1 - X)^{2/3} \right\}$$

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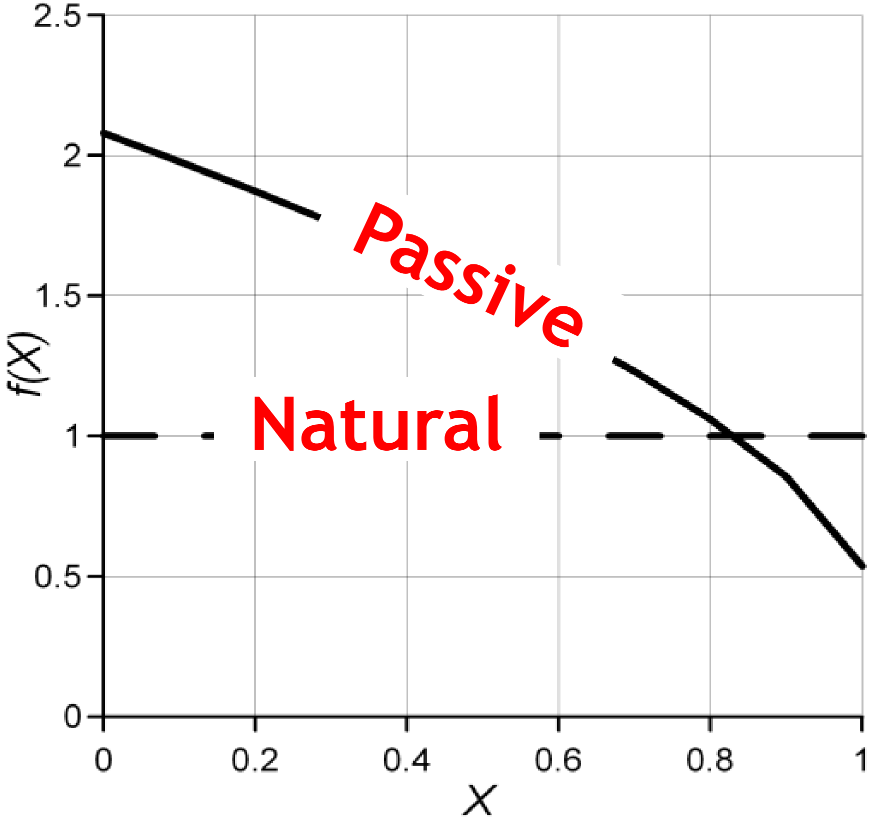
Natural *versus* passive 2/2

Difference: $$f(X) = \left(\frac{9}{8}\right)^{1/3} \cdot \left\{ \left[1 - X\left(1 - \frac{\rho_{H_2}}{\rho_{air}}\right)\right]^{1/3} + (1 - X)^{2/3} \right\}$$



Natural ventilation equation:

- Underestimate **x2 (lean)**
- Overestimate **x2 (rich)**

Validation tests

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- Experiments were carried out by CEA (France) within GAMELAN series of experiments using helium released into *HxWxD*=1.26x0.93x0.93 m enclosure.
- One vent located on a wall near the ceiling.
- Three different vent sizes were studied:
  - vent (a) *WxH*=90x18 cm,
  - vent (b) 18x18 cm,
  - vent (c) 90x3.5 cm.
- Helium was released upwards from a tube mounted in the centre of the enclosure 21 cm above the floor. Pipes with internal diameter of 5 mm and 21 mm had been used.

Predictions of maximum concentration 1/2

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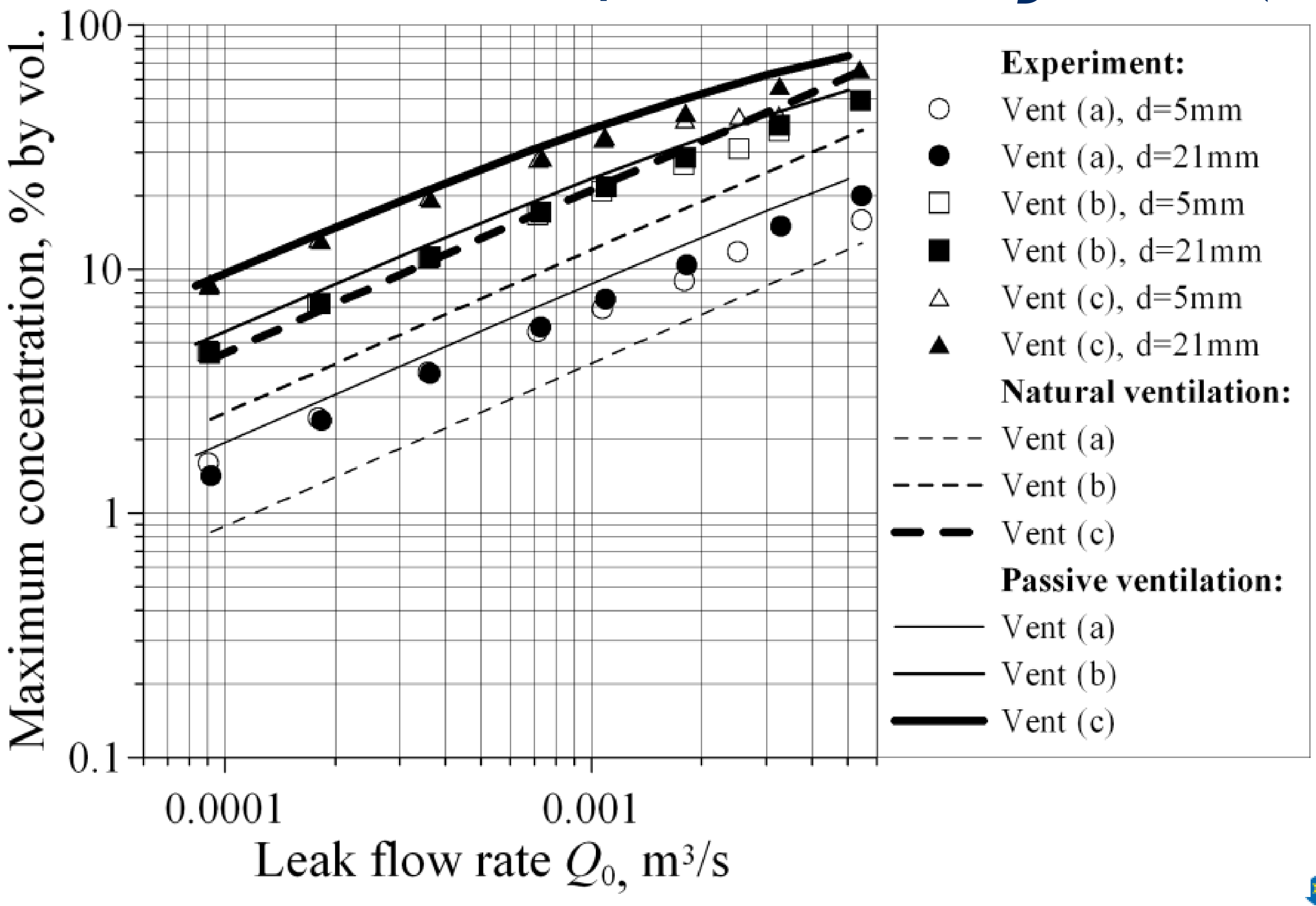
Natural ventilation equation with C_D=0.60 (dashed). **Passive** ventilation equation with C_D=0.60 (solid).



Predictions of maximum concentration 2/2

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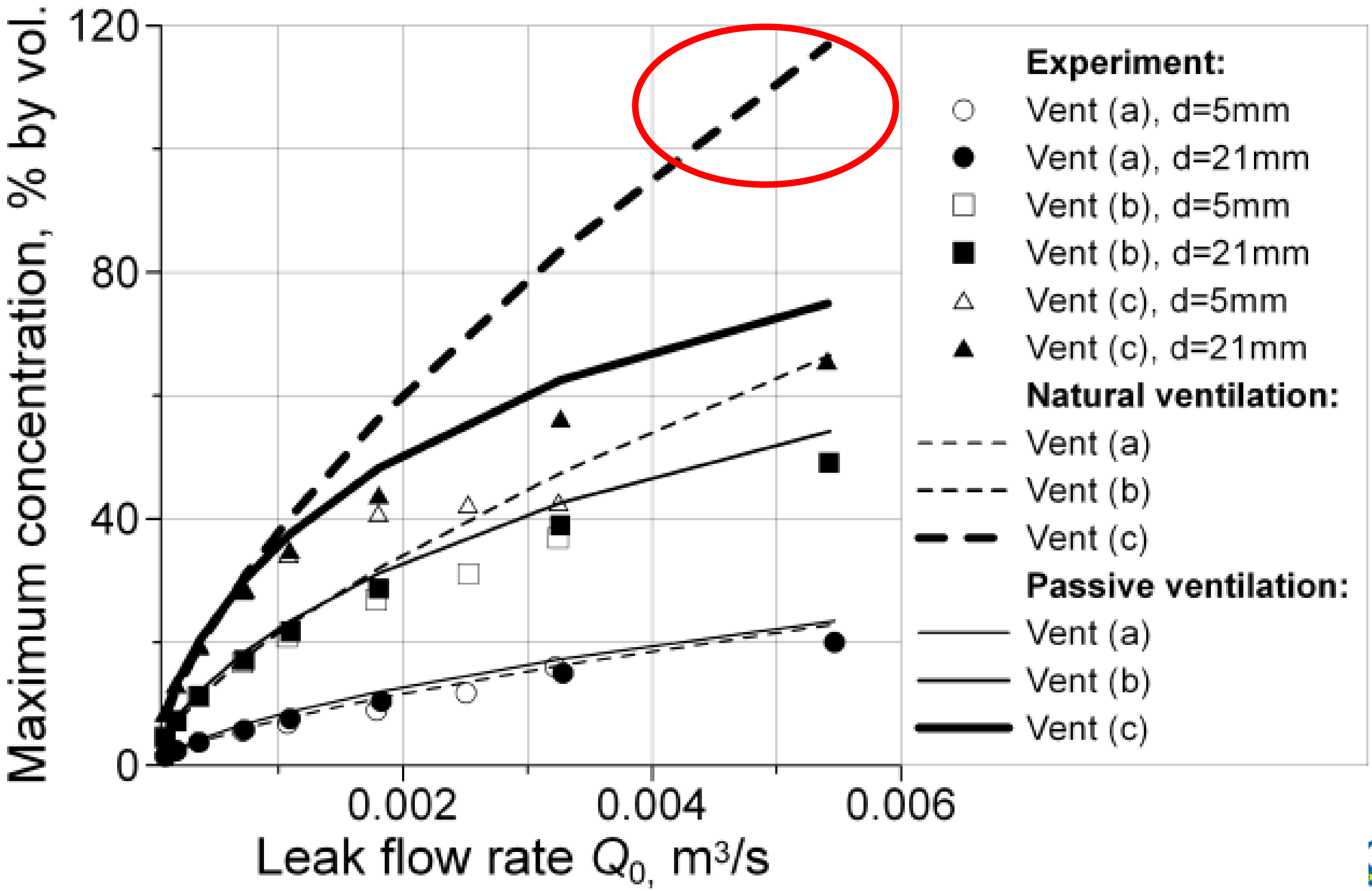
Natural ventilation equation with **“tuned” C_D=0.25.** Passive ventilation equation with C_D=0.60.



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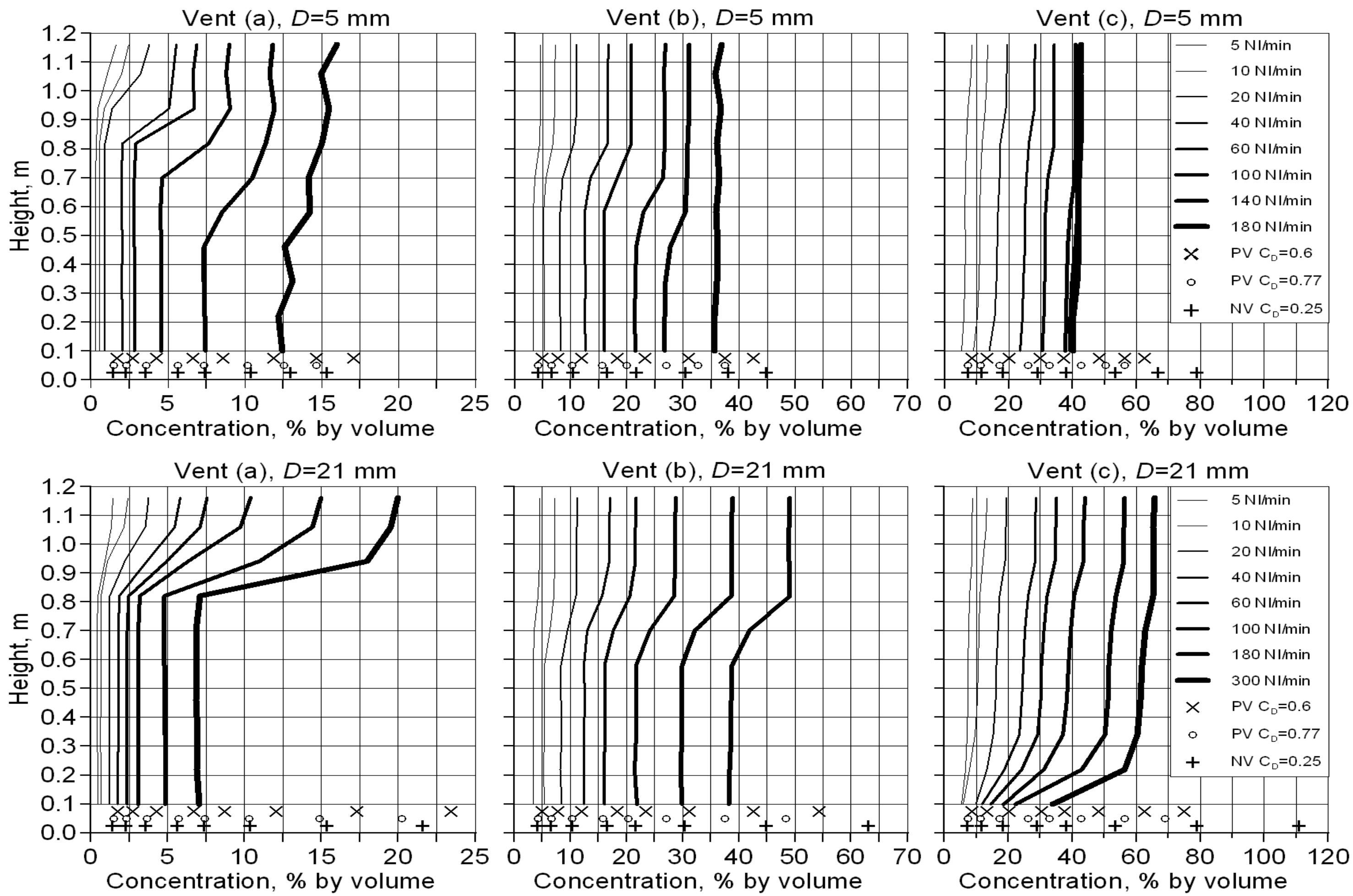
Comparison with GAMELAN experiments

Vent (a): HxW=18x90 cm; Vent (b):18x18 cm; Vent (c): 3.5x90 cm



Maximum concentration nomogram

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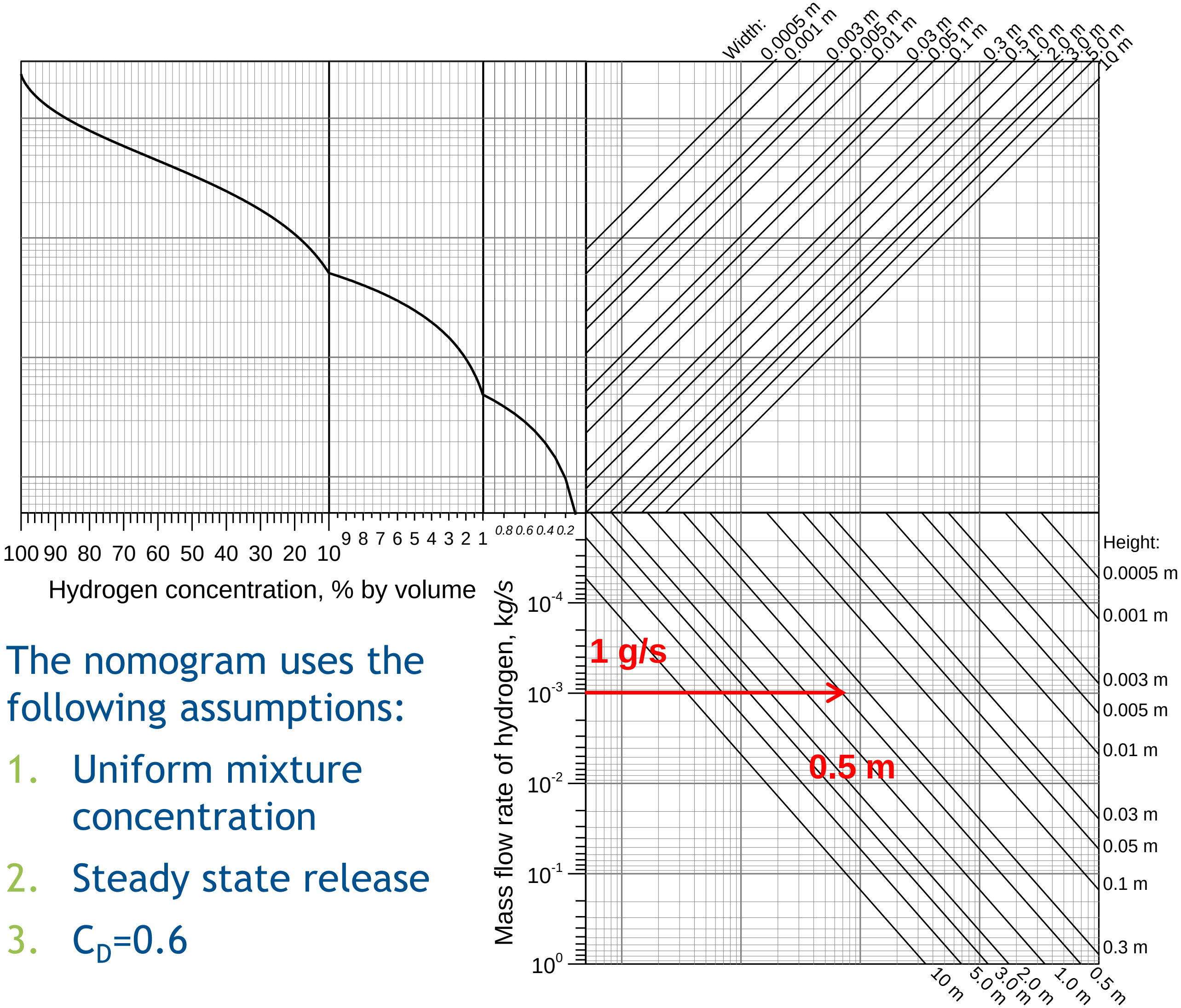

Calculation example 1:

1. Release rate (1 g/s)
2. Vent Height (0.5 m)

The nomogram uses the following assumptions:

1. Uniform mixture concentration
2. Steady state release
3. C_D=0.6

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Maximum concentration nomogram

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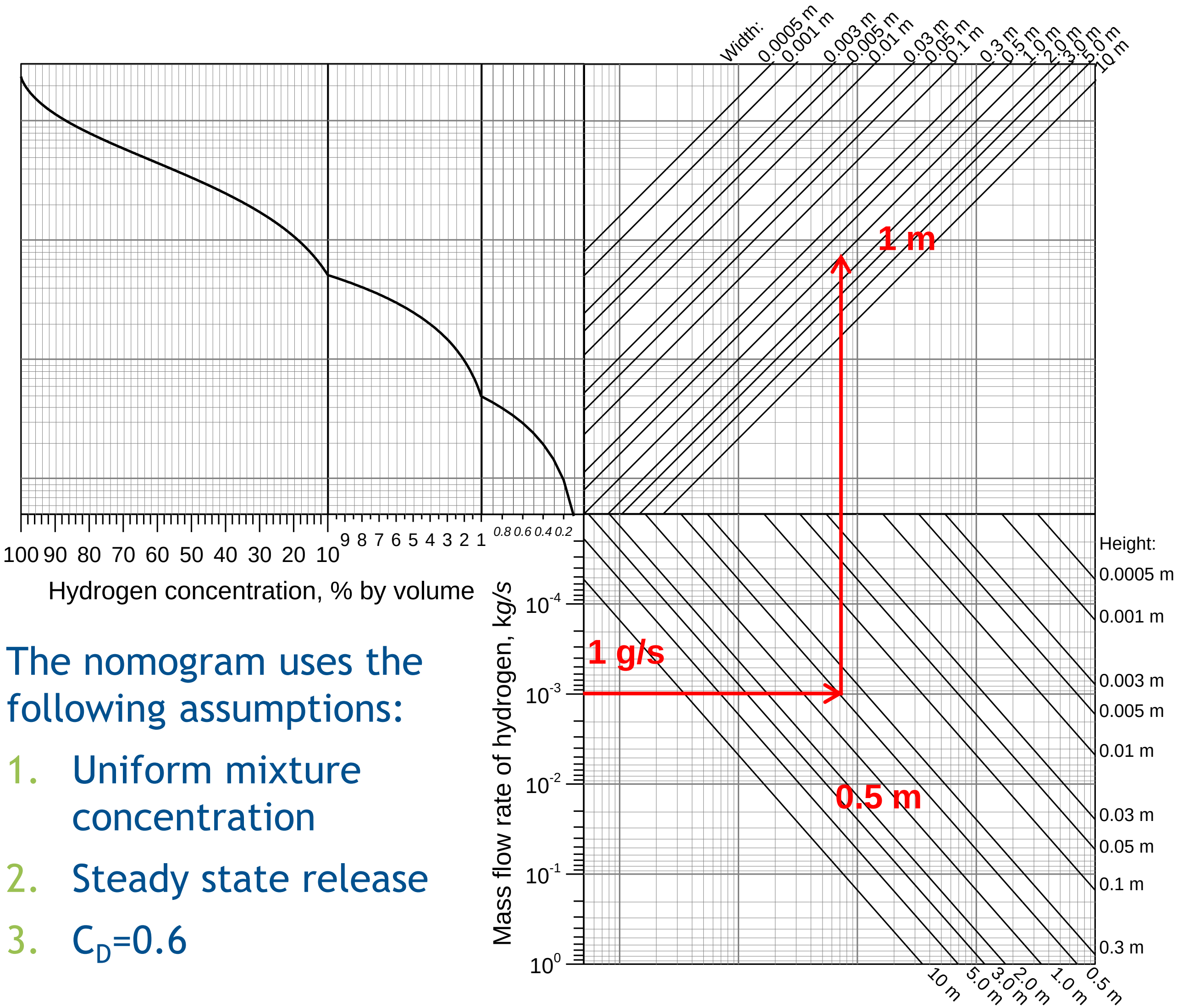

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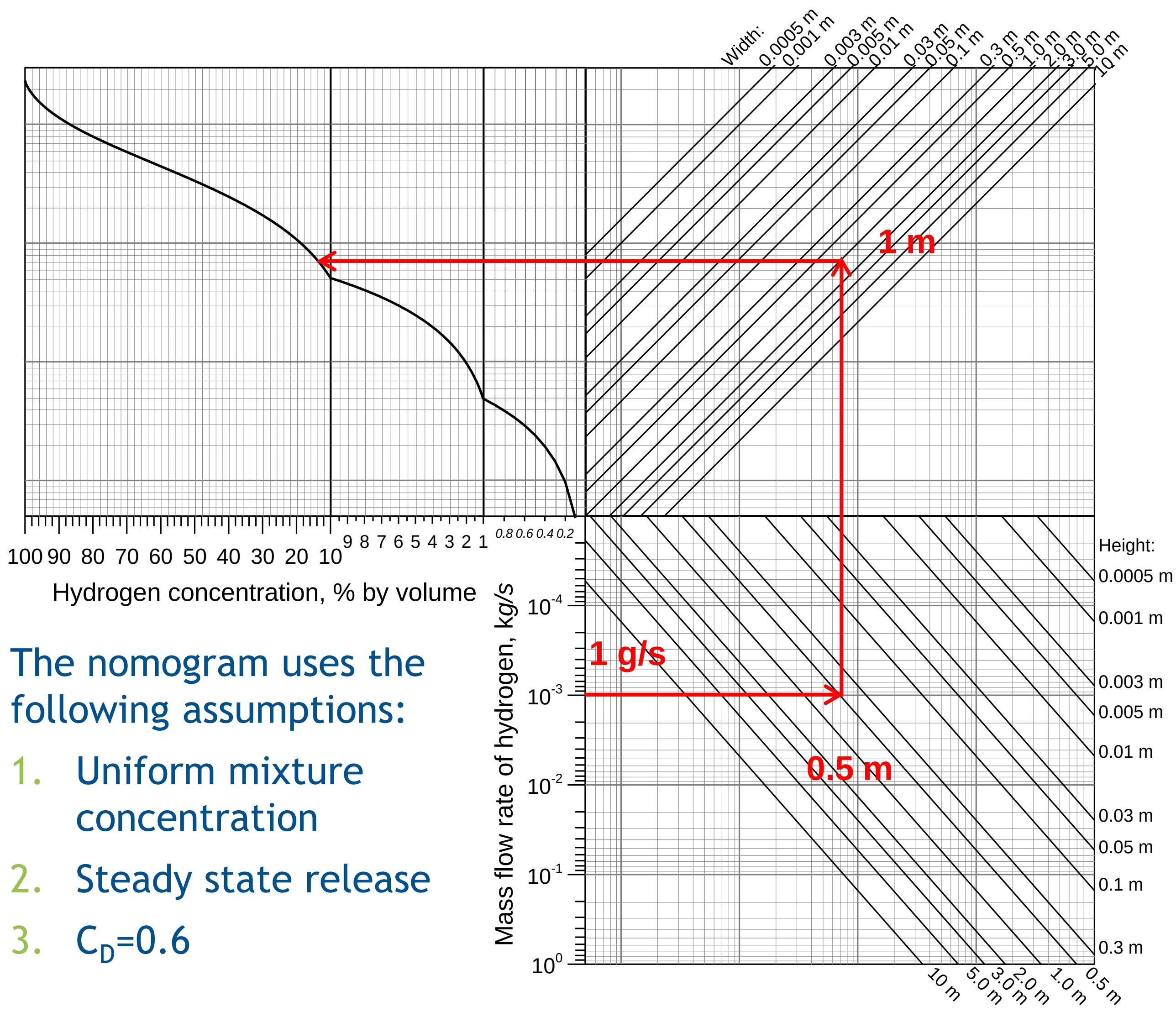
Maximum concentration nomogram



Calculation example 1:

1. Release rate (1 g/s)
2. Vent Height (0.5 m)
3. Vent width (1 m)
4. Function curve

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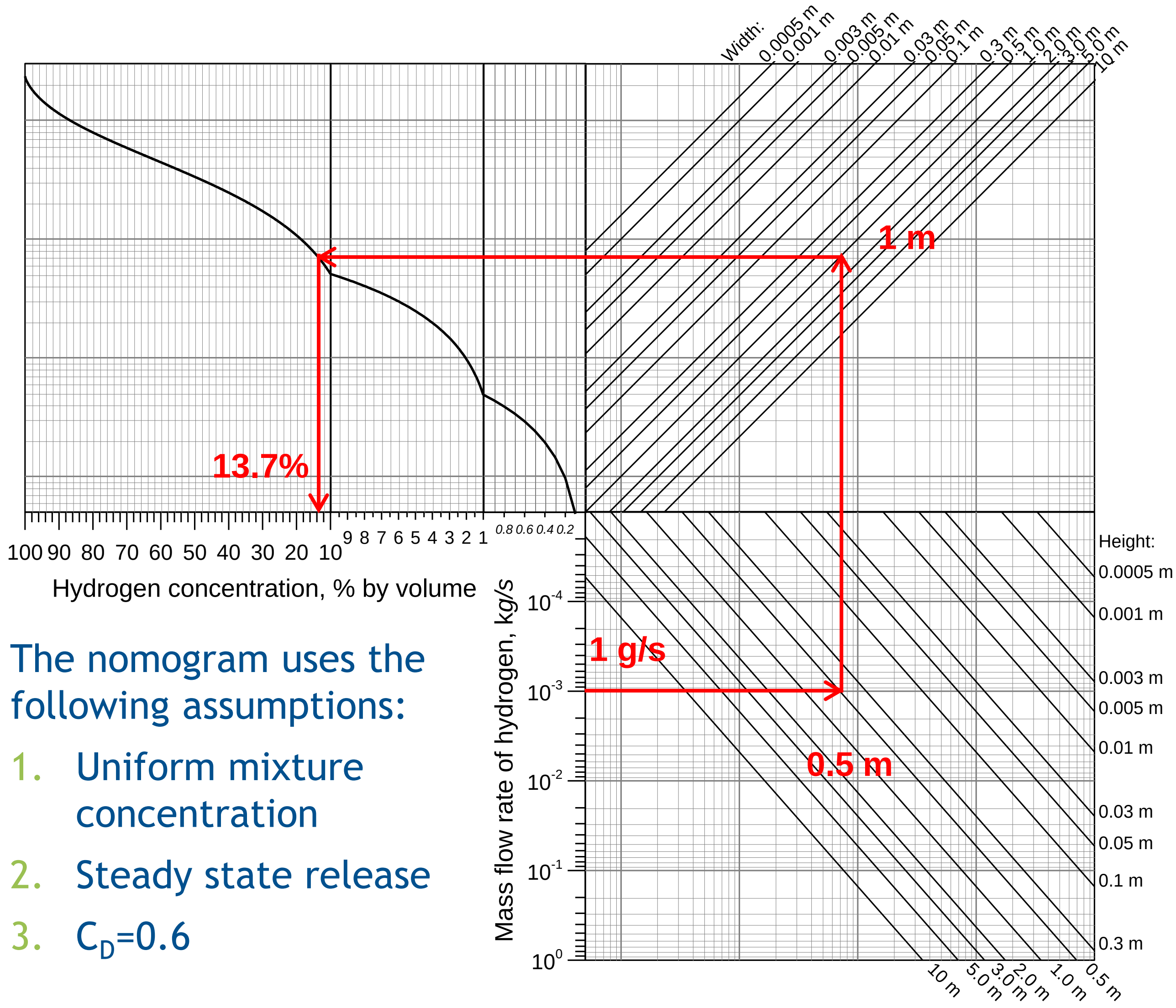
Maximum concentration nomogram



Calculation example 1:

1. Release rate (1 g/s)
2. Vent Height (0.5 m)
3. Vent width (1 m)
4. Function curve
5. Concentration (13.7%)

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Maximum concentration nomogram

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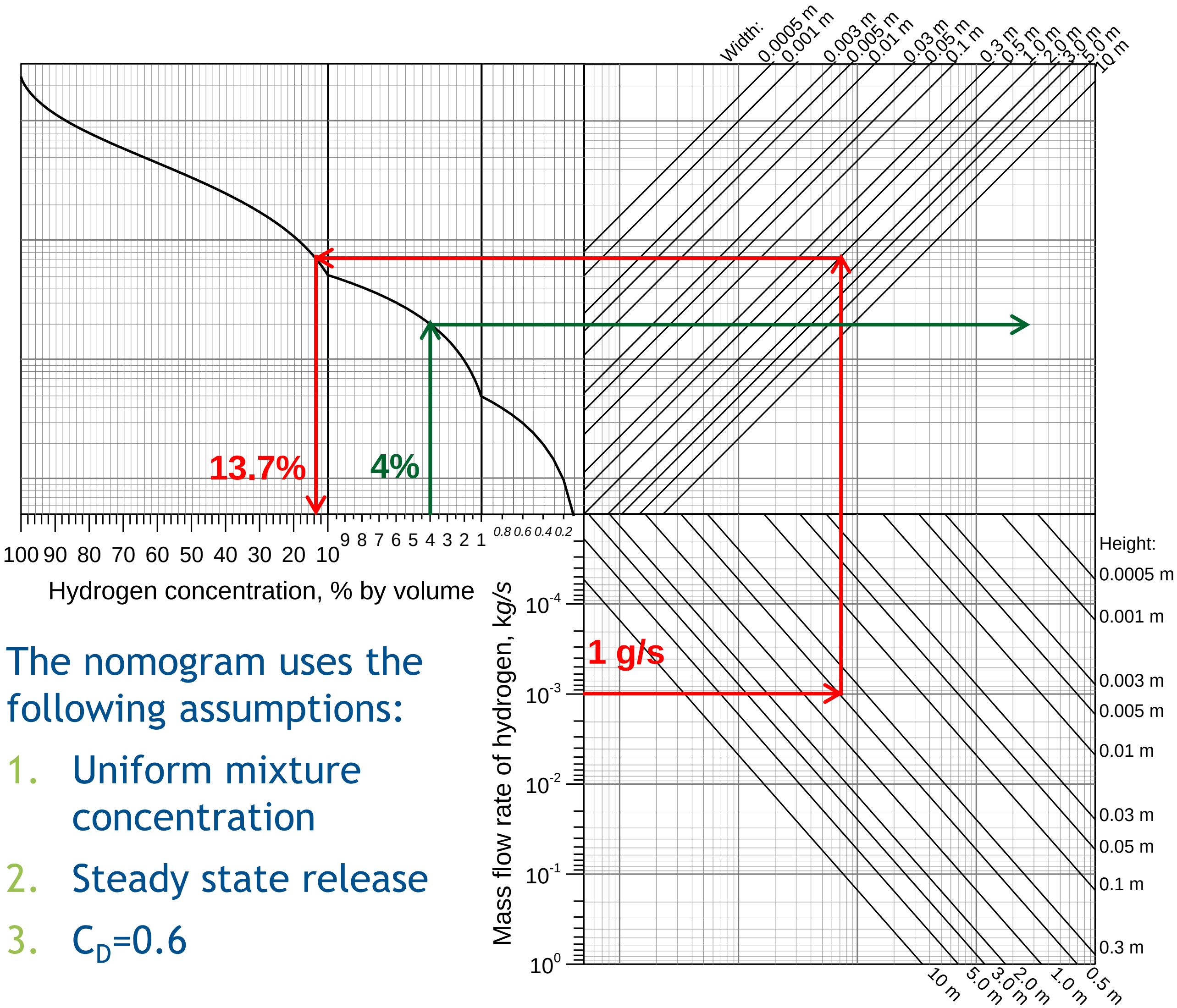

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3. Vent width (1 m)
4. Function curve
5. Concentration (13.7%)

Calculation example 2:

1. Maximum allowable concentration (~4%)
2. Function curve

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Maximum concentration nomogram

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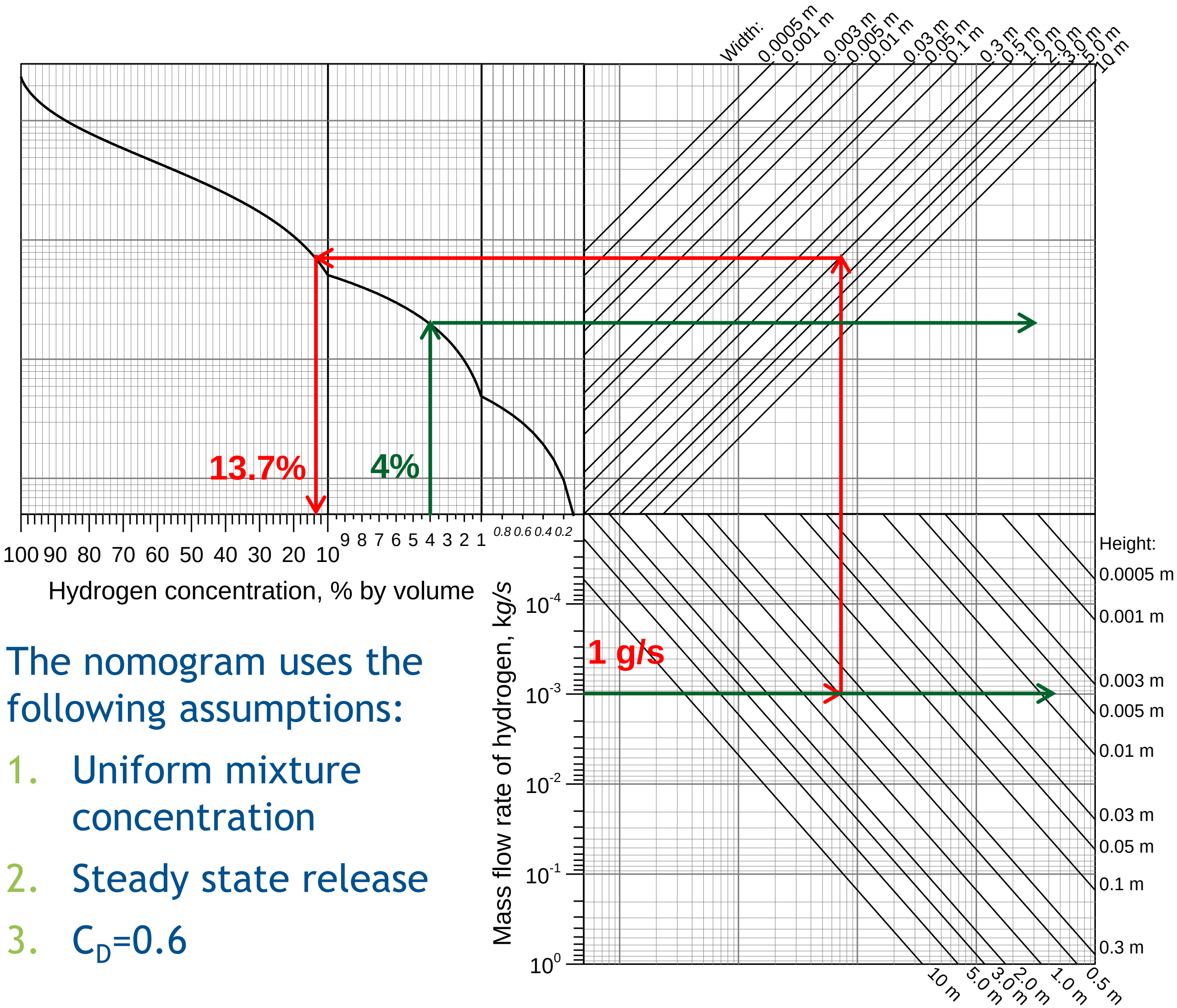

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Maximum concentration nomogram

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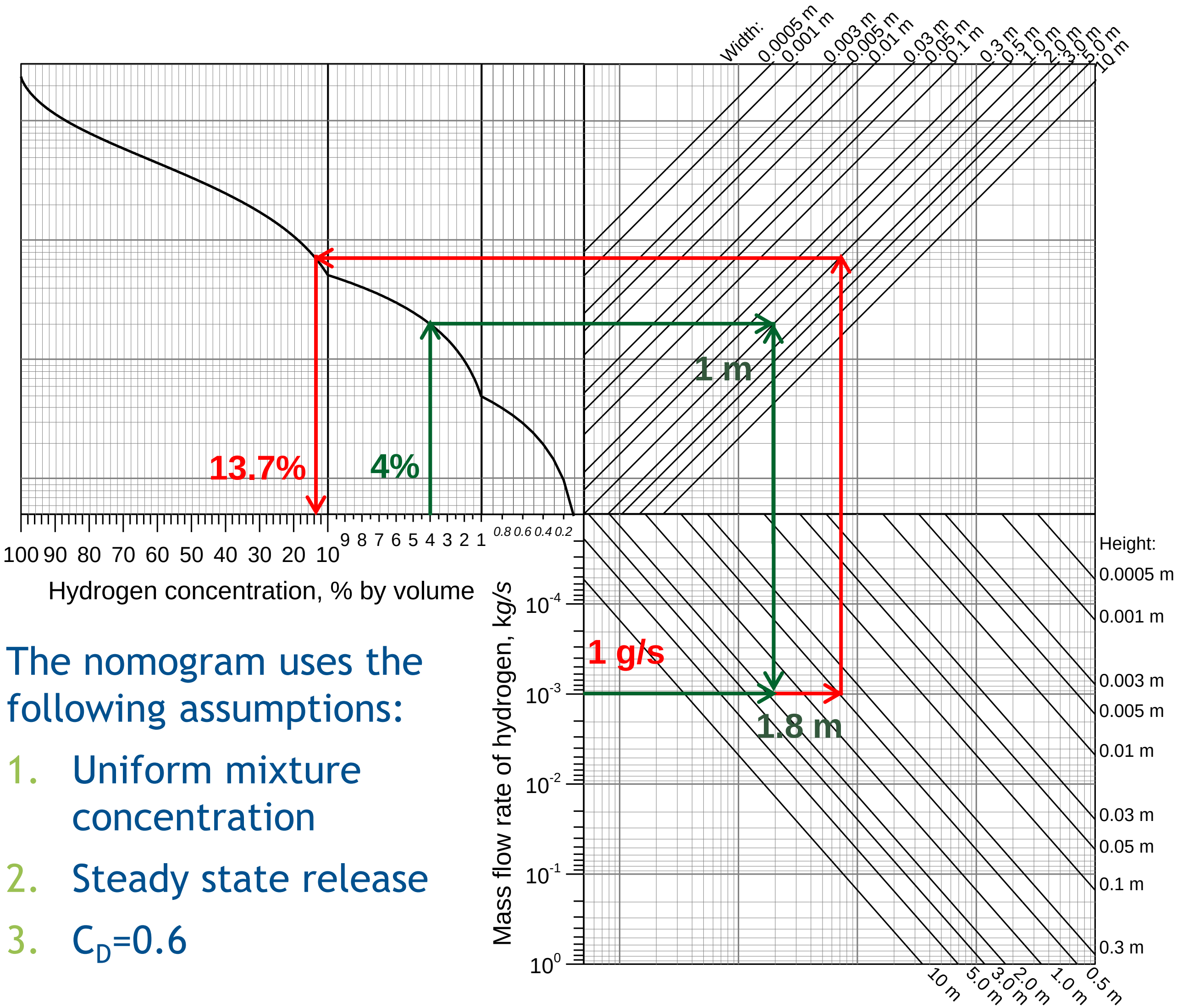

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Calculation example 2:

1. Maximum allowable concentration (~4%)
2. Function curve
3. Release rate (1 g/s)
4. Vent height and width (1.8 x 1 m)

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Maximum concentration nomogram

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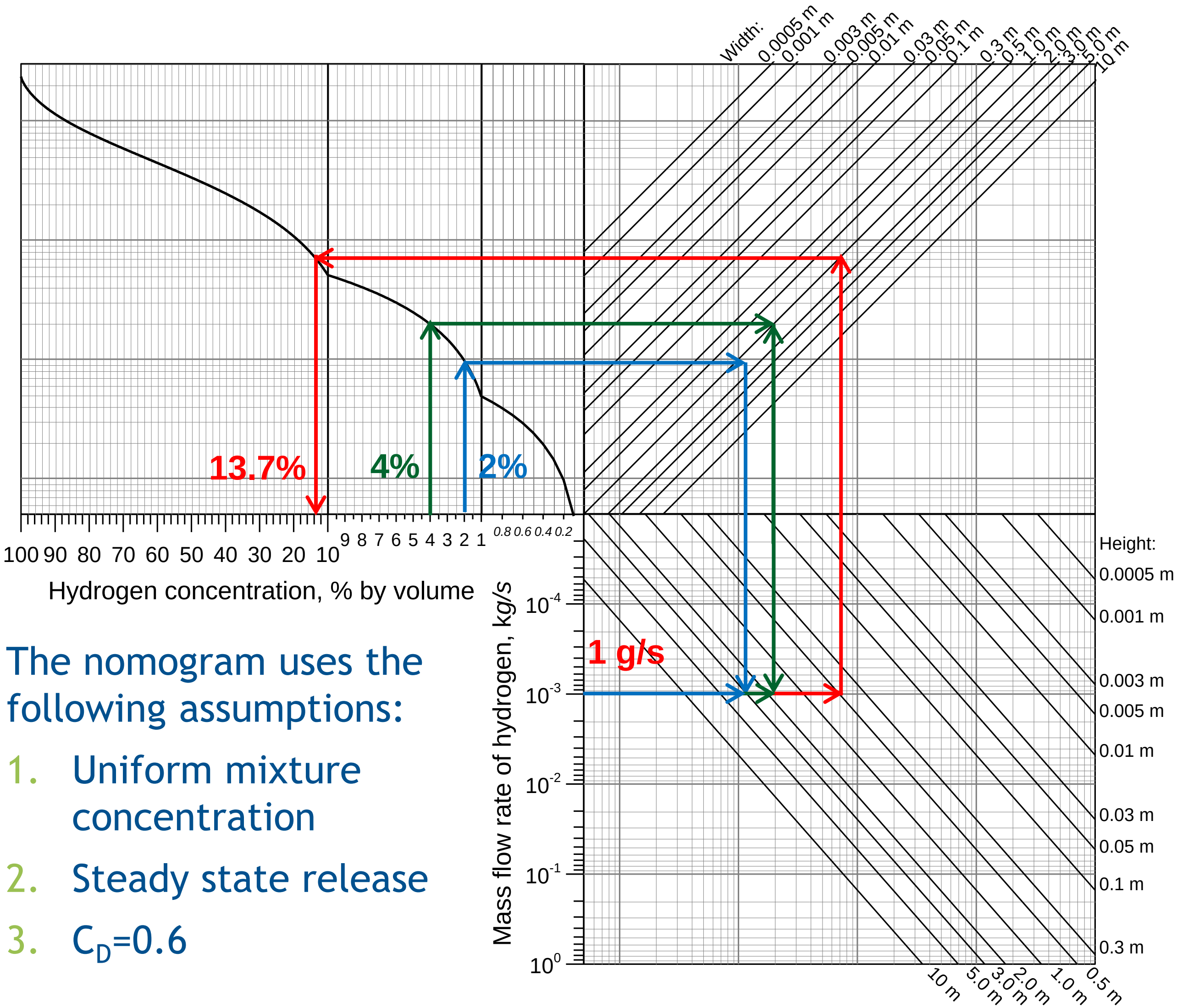

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Vent orientation effect 1/2

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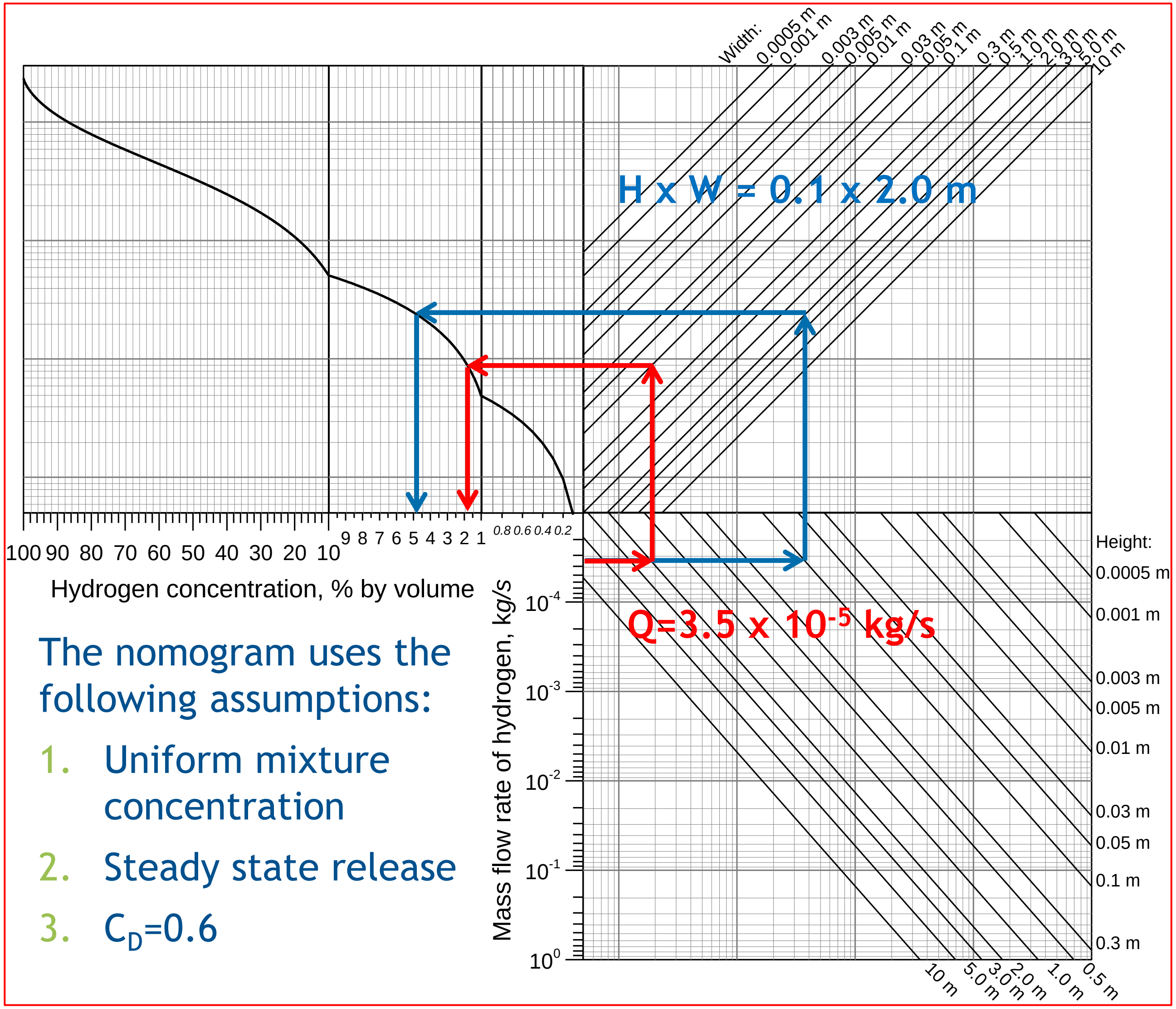

The nomogram uses the following assumptions:

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Comparison of 0.2 m² vents:

1. Horizontal orientation (H x W = 0.1 x 2.0 m): X ~ 4.7% by volume
2. Vertical orientation (H x W = 2.0 x 0.1 m): X ~ 1.7 % by volume

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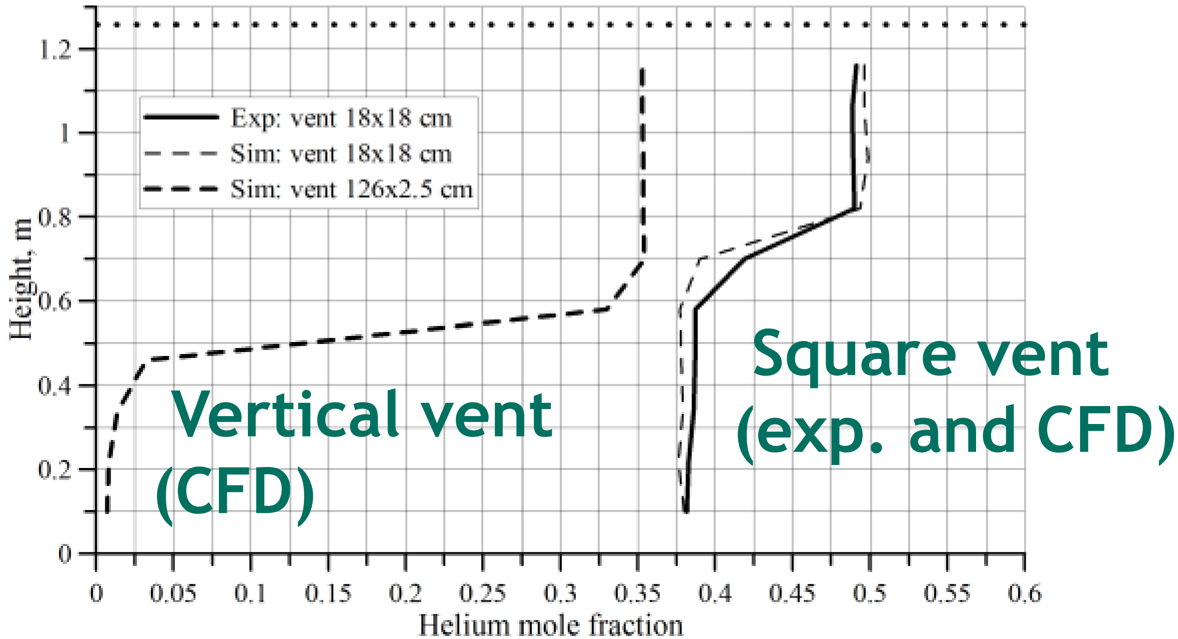
Vent orientation effect 2/2

Passive ventilation model predicts that for the given vent area vertically oriented vent would be more efficient compared to horizontally oriented (with steady state concentration inversely proportional to $A\sqrt{H}$ where A is vent area and H is vent height).

Comparison was performed for the 300 Nl/min flow rate release from 20 mm diameter pipe. Gamelan experimental data for square vent B (H x W=18 x 18 cm = 0.0324 m^2) were compared with numerical experiment for the narrow vertical vent B' (H x W = 126 x 2.57 cm) of the same area of 0.0324 m^2.



Forced ventilation methodology

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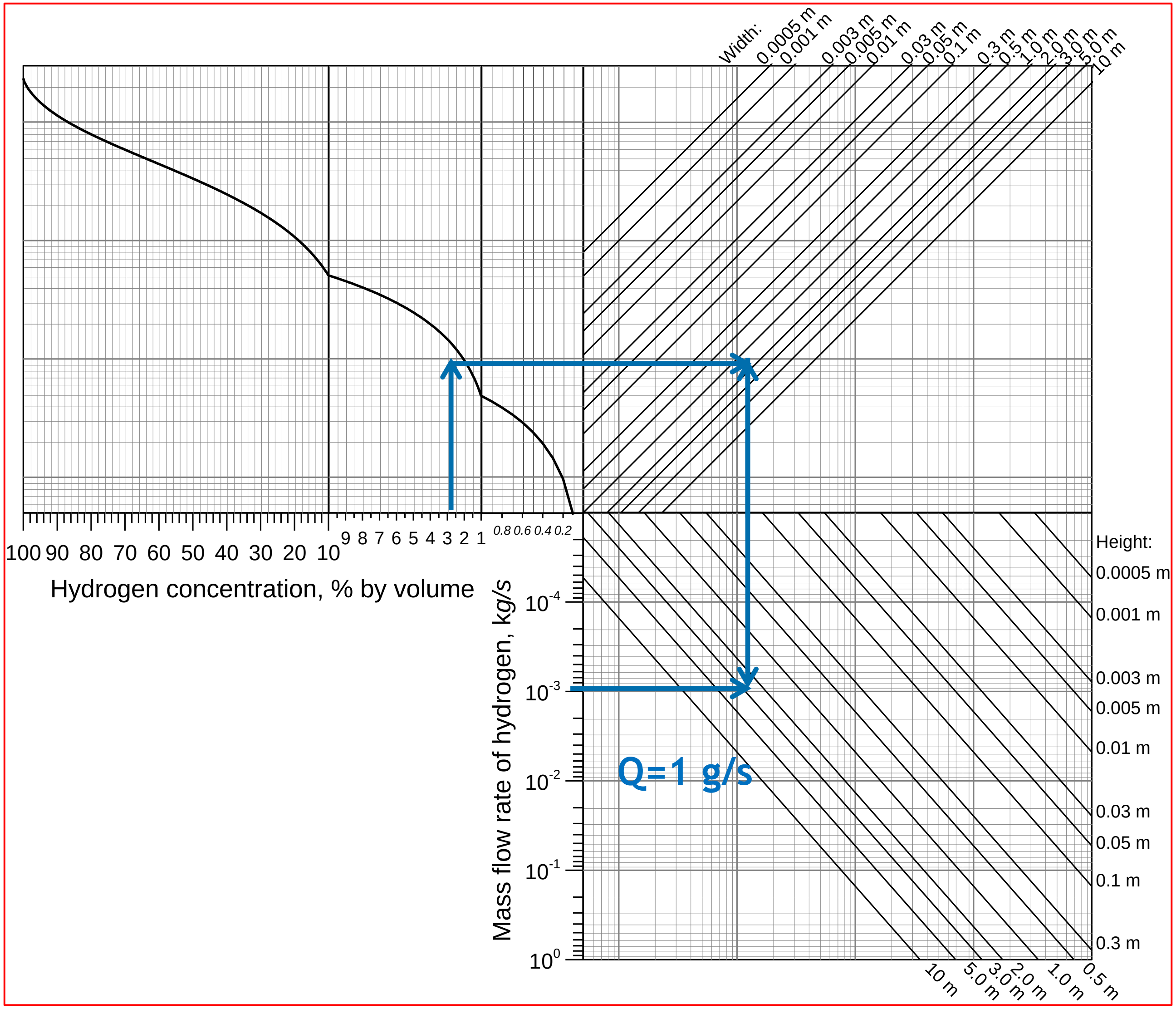

Calculation example:

1. Passive ventilation:

2% concentration by volume for 1 g/s release requires unacceptably large 2 x 2 m vent

2. Forced ventilation:

Same steady state concentration can be achieved by replacing single vent with an outlet connected to the forced ventilation, evacuating hydrogen-air mixture at the same flow rate as large passive vent would, and smaller vent connected to atmosphere to allow fresh air. Forced ventilation flow rate can be calculated as $Q_F=Q_{H2}/X$ where Q_{H2} is hydrogen release rate and X is hydrogen volume fraction.

For an illustrated example Q_F~0.56 m^3/s

Alternatively, forced ventilation can be used to blow fresh air into the enclosure with the rate $Q_{FA}=Q_{H2}(1-X)/X$. For an illustrated example Q_{FA}~0.55 m^3/s

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