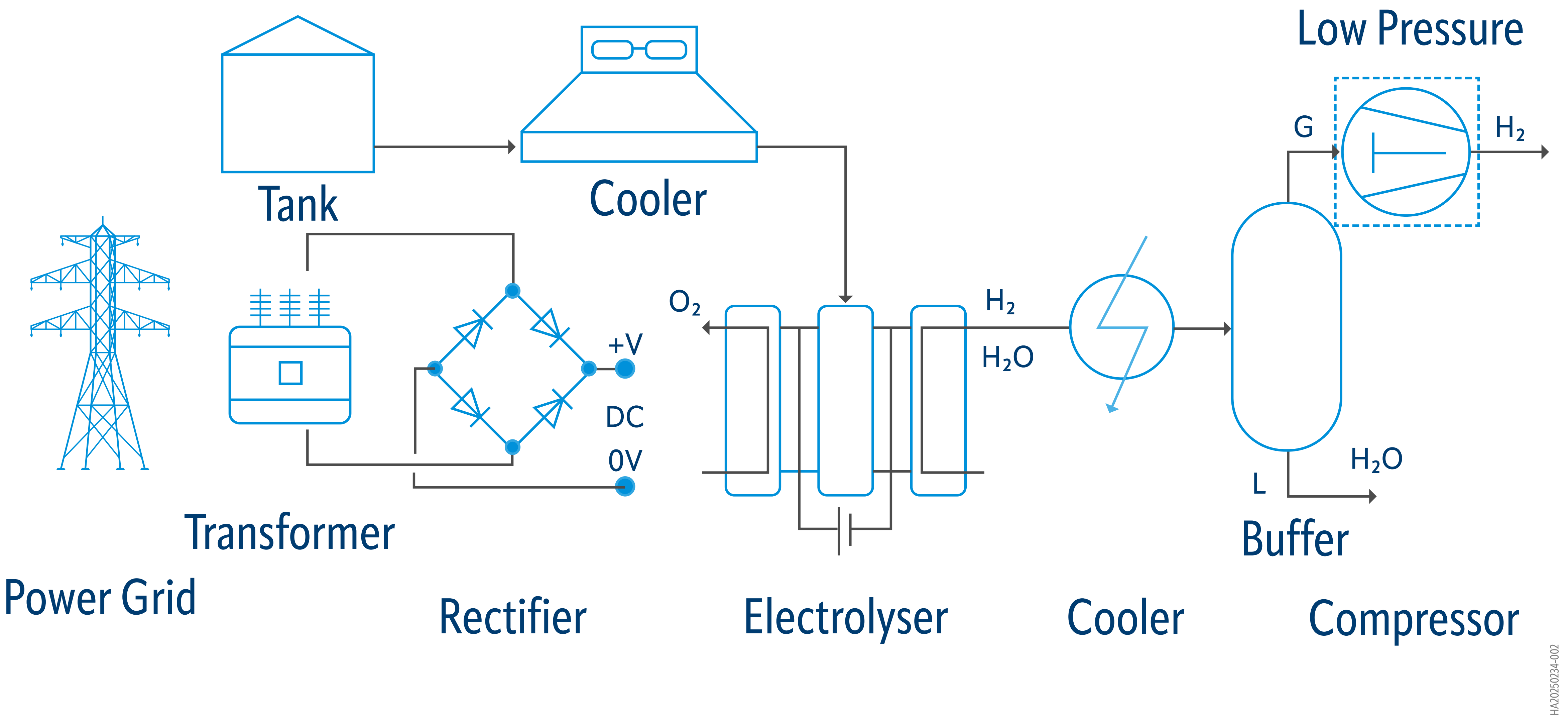
NATURAL VENTILATION OF ELECTROLYSER BUILDINGS

6TH & 7TH May 2025

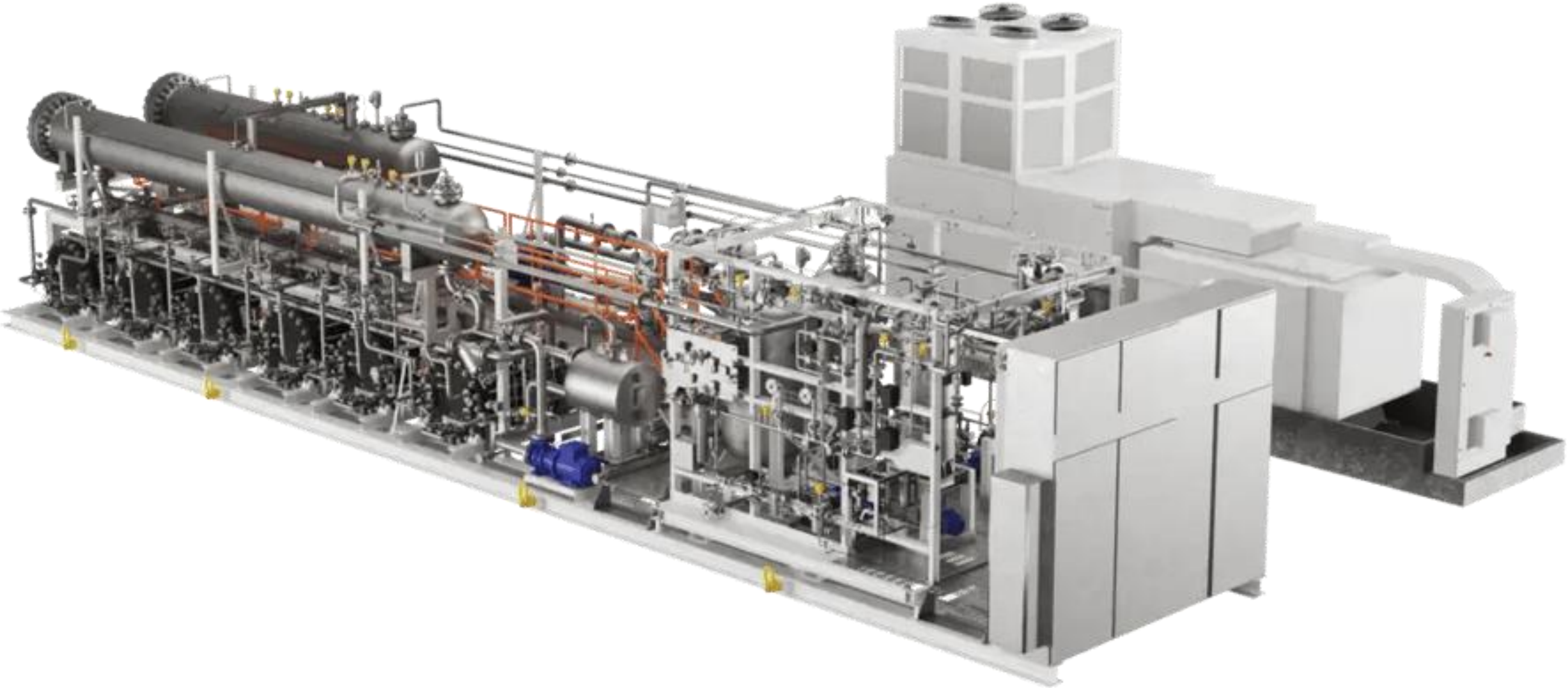
ELECTROLYSER TYPES

- Alkaline Water Electrolysis
- Anion Exchange Membrane (AEM) Water Electrolysis
- **Proton Exchange Membrane** (PEM) Water Electrolysis
- Solid Oxide Water Electrolysis

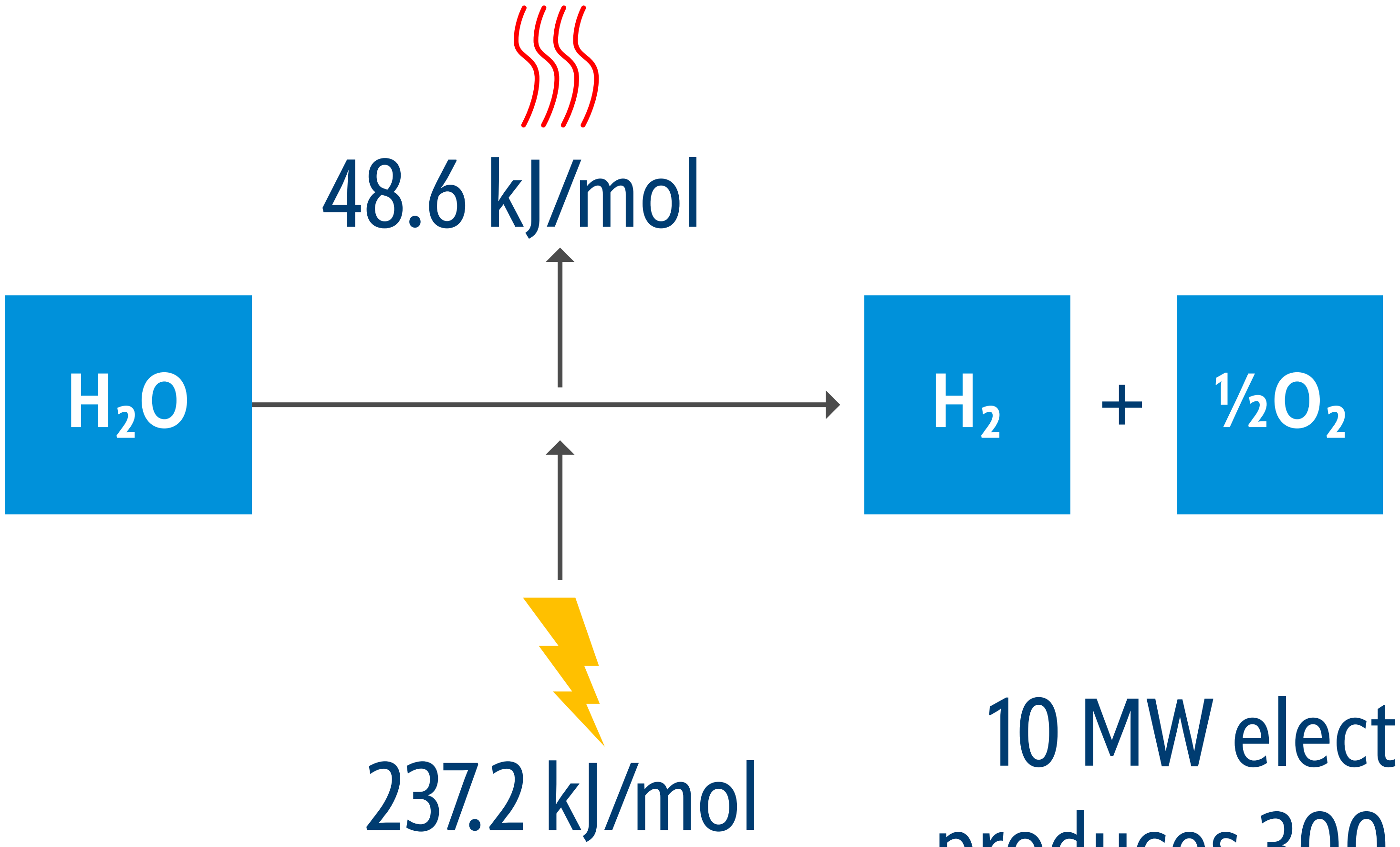
HYDROGEN PRODUCTION (PEM)



10MW PEM ELECTROLYSER



HEAT GAIN ELECTROLYSERS



10 MW electrolyser produces 300 kW heat

HA20250234-002

SOME PROCESS CONDITIONS (EXAMPLE)

Parameter		Unit	PEM (10 MW)	
			Low Pressure	High Pressure
Temperature	T_p	°C (K)	48 (321)	75 (348)
Pressure	p_p	bar	0.09	39.5
Flow Rate Hydrogen	Q_{p,H_2}	kg/hr	330	230
Saturated Vapor Pressure	p_{H_2O}	Pa	7222	23141

TYPICAL DIMENSIONS PEM ELECTROLYSER (SEGMENT)

Parameter	Symbol	Unit	Segment
Length	L	m	25
Width	W	m	12
Height	H	m	10
Surface Area Floor	A_F	m^2	300
Surface Area Wall	A_W	m^2	2 x 120
Gross Volume	V	m^3	3000
Equipment		%	20
Net Volume	V_0	m^3	2400

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HEAT GAIN

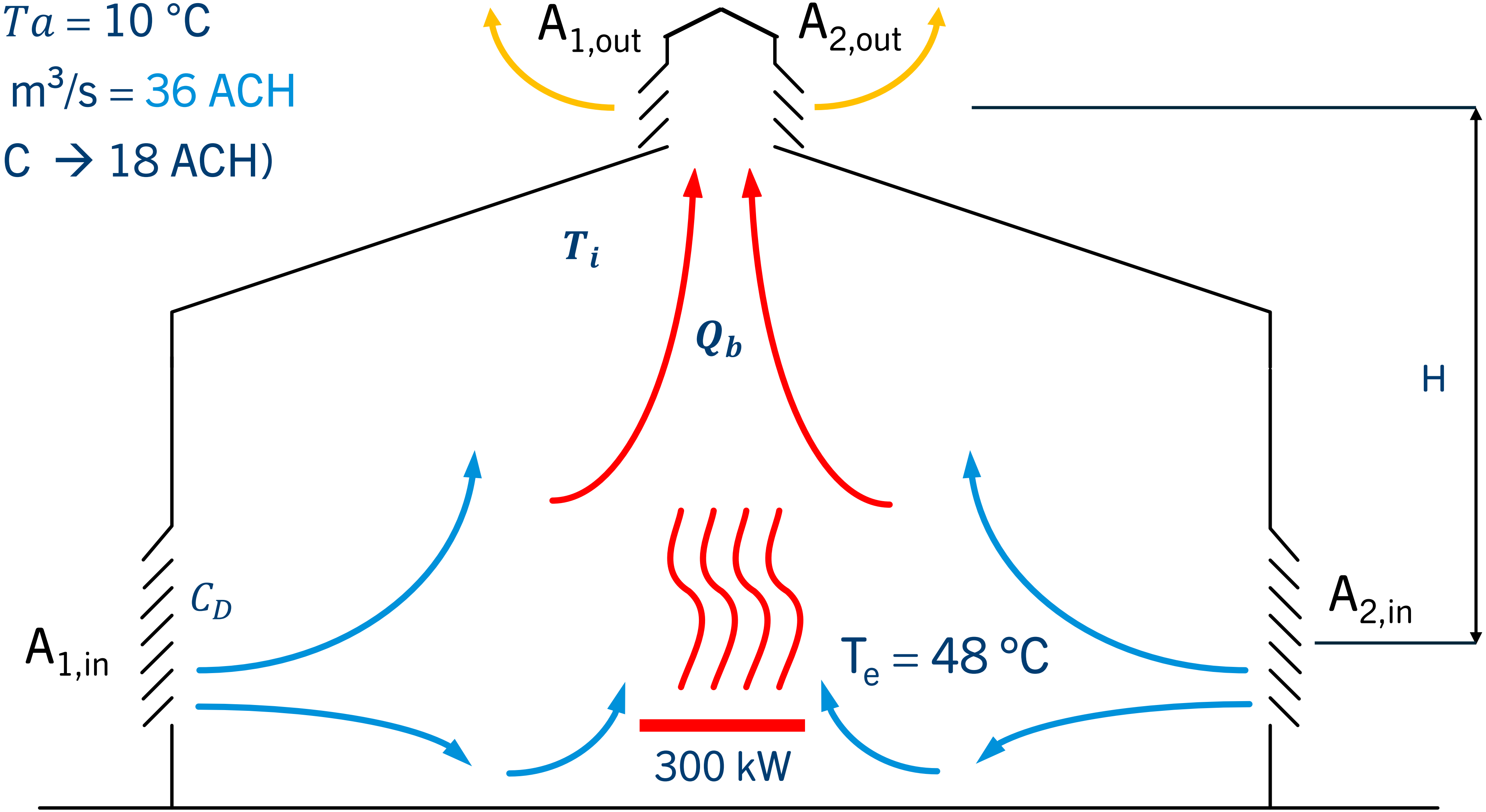
Parameter		Unit	PEM (10 MW)	
			Low Pressure	High Pressure
Temperature Electrolyser	T_p	°C (K)	48 (321)	75 (348)
Heat Gain	Q	kW	300	300
Ambient Temperature	T_a	°C (K)	10 (283)	10 (283)
Relative Humidity	RH	%	60	60
Designed Temperature Rise	ΔT	°C (K)	10	10
Required Air Flow	Q_a	m^3/s	23.9	31.0
Required Ventilation Rate		ACH	36	46

NATURAL BUOYANCY VENTILATION BASICS

$\Delta T = Ti - Ta = 10\ °C$

$Qa = 23.9\ m^3/s = 36\ ACH$

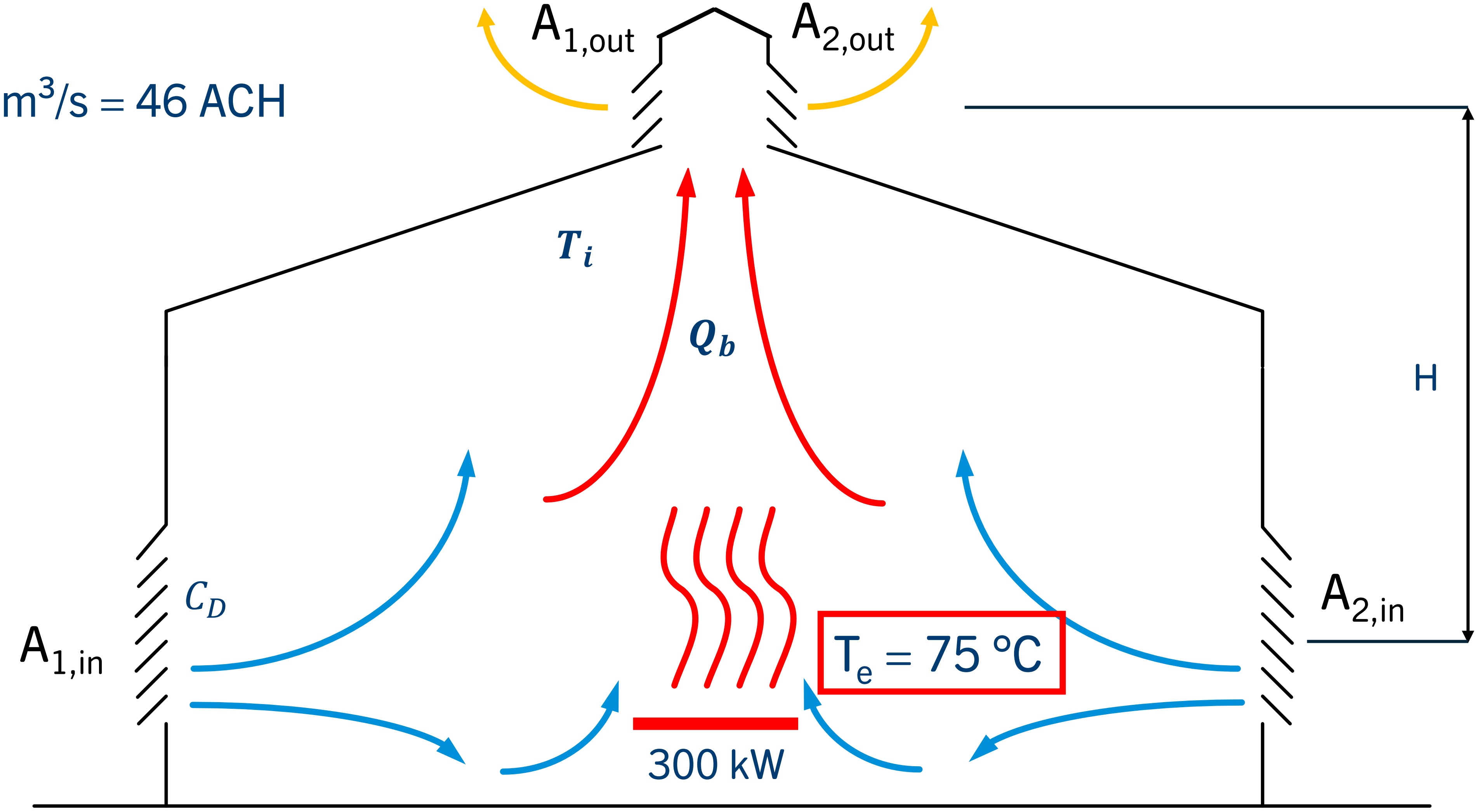
$(\Delta T = 20\ °C \rightarrow 18\ ACH)$



NATURAL BUOYANCY VENTILATION BASICS

High Pressure

$Q_a = 31.0\ m^3/s = 46\ ACH$



GRILL AREA

$$Q_a = C_D A_e \sqrt{\frac{4\Delta T}{(T_a + T_p)} gH} \ [\mathrm{m^3/s}] \qquad A_e = \sqrt{\frac{A_{in}^2 A_{out}^2}{A_{in}^2 + A_{out}^2}} \ [\mathrm{m^2}]$$

Q_a = Volumetric flow rate of air [m^3/s]

A_{in} = Sum of the grill area in [m^2]

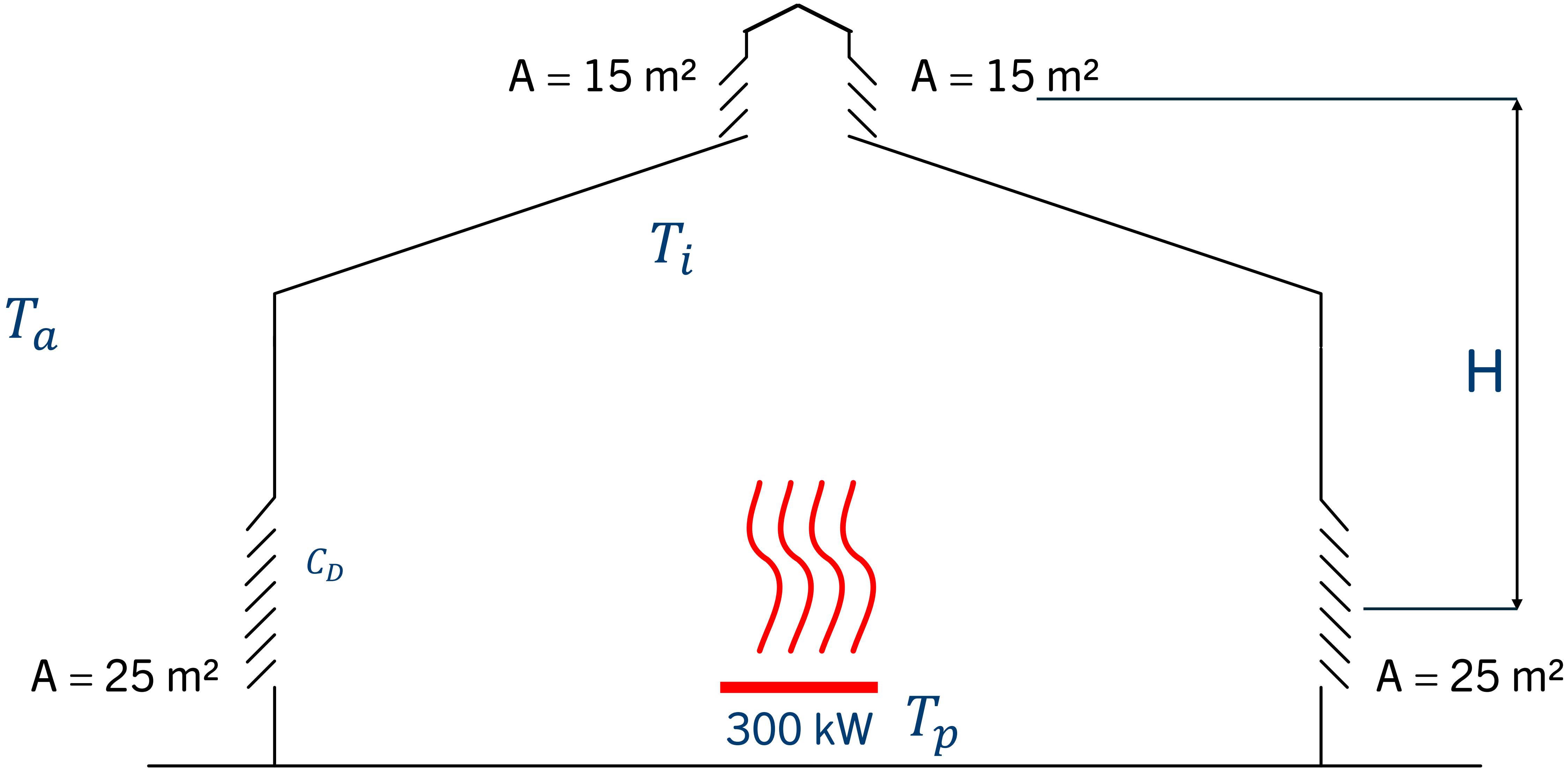
A_{out} = Sum of the grill area out [m^2]

A_e = Effective Area [m^2]

C_D = Discharge coefficient = 0.75 [-]

ΔT = Temperature difference between ambient temperature and electrolyser [K]

GRILL AREA



PRESSURE COEFFICIENT BUILDINGS

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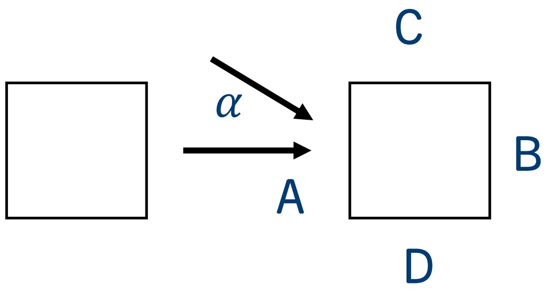
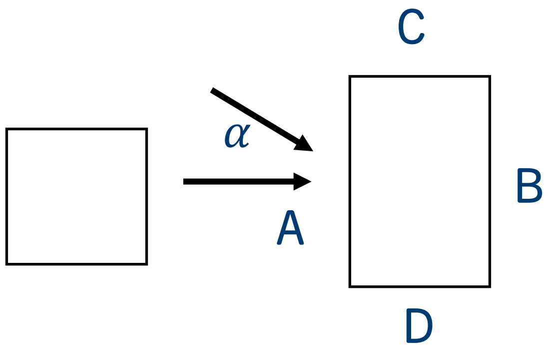
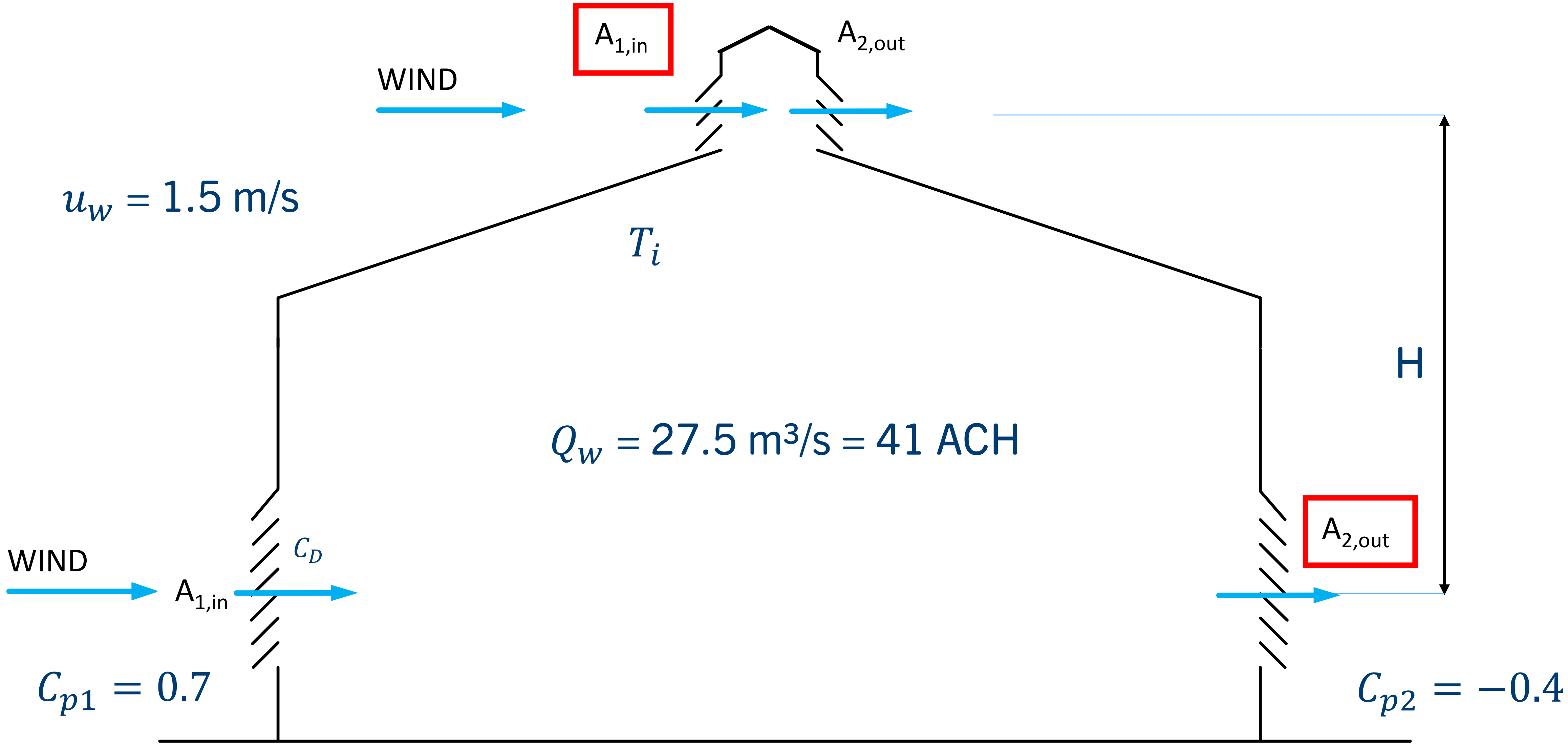
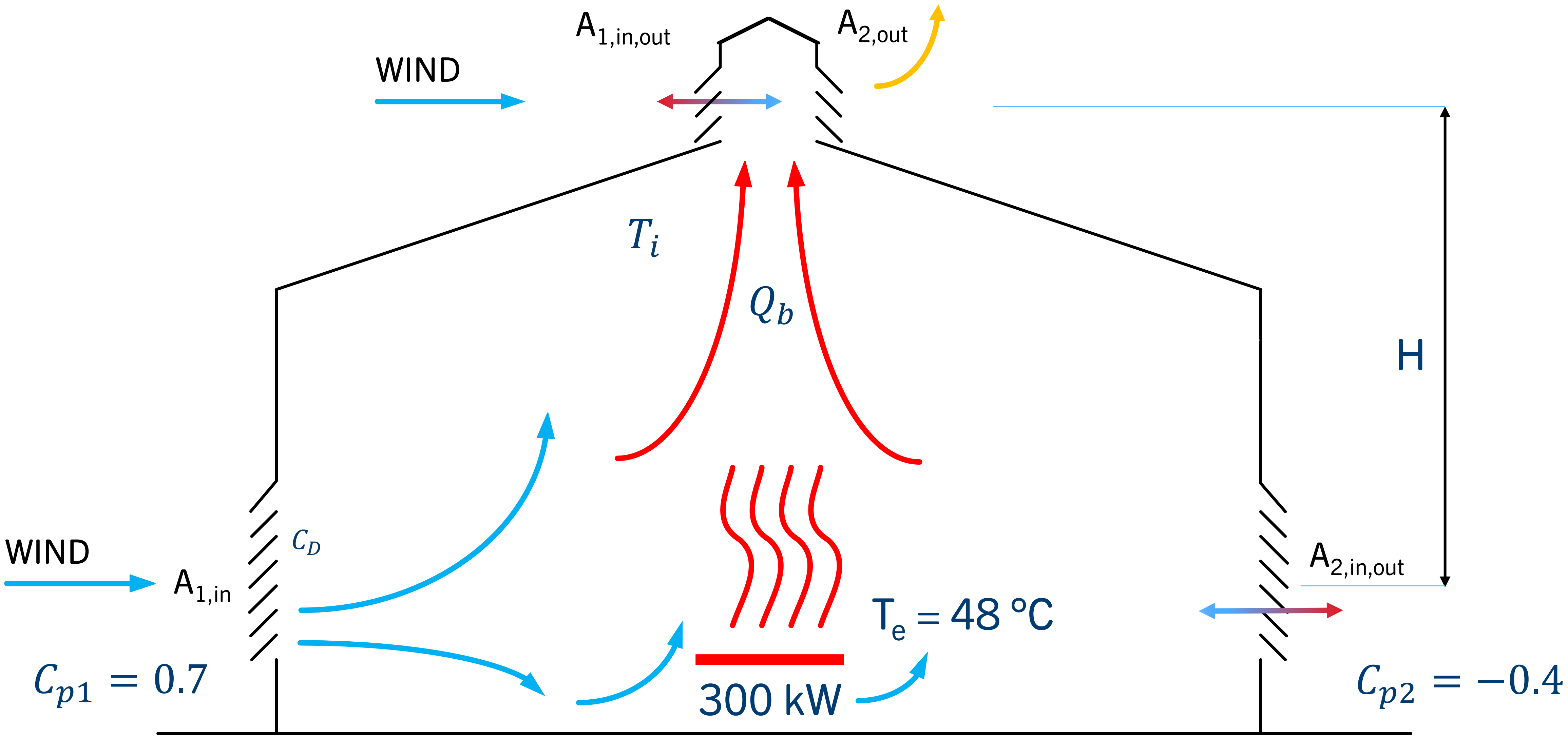
Building Height Ratio	Building Plan Ratio	Side Elevation/Plan	Wind Angle α	A	B	C	D
$\frac{3}{2} < \frac{h}{w} < 6$	$1 < \frac{l}{w} < \frac{3}{2}$		0	+0.8	-0.25	-0.8	-0.8
			90	-0.8	-0.8	+0.8	-0.25
	$\frac{3}{2} < \frac{l}{w} < 4$		0	+0.7	-0.4	-0.7	-0.7
			90	-0.5	-0.5	+0.8	-0.1

Source: BS 5925:1991 Table 13

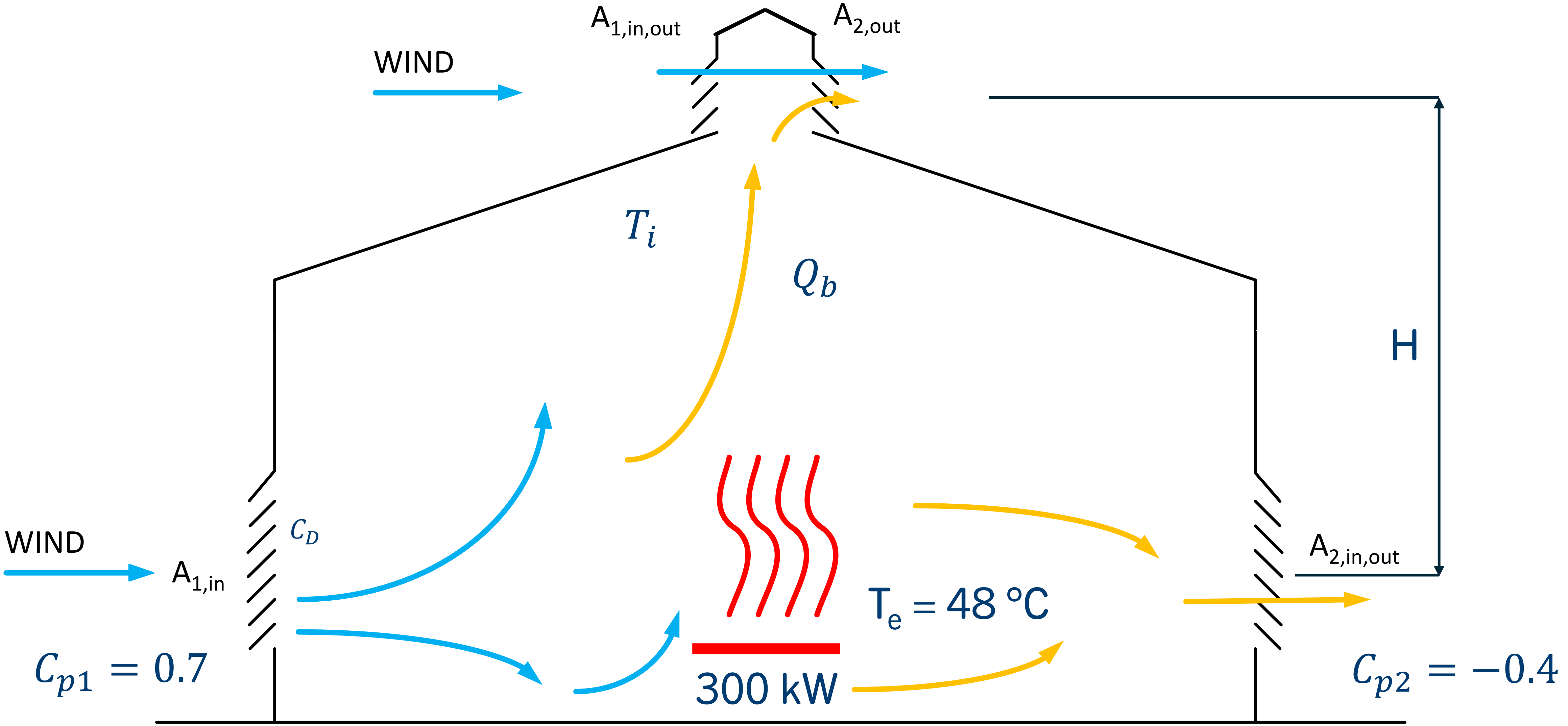
NATURAL VENTILATION WIND



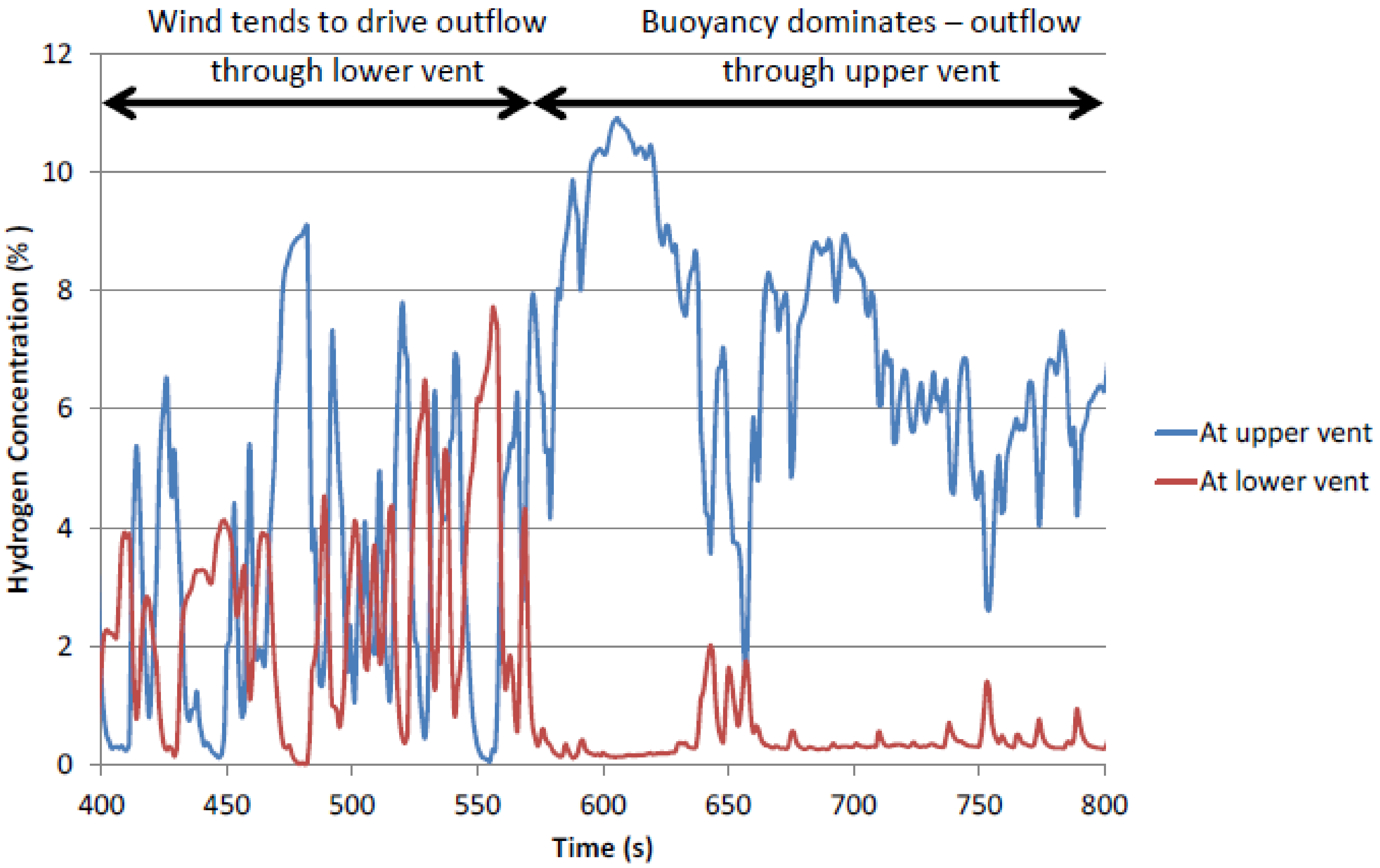
BUOYANCY AND WIND IN BALANCE



WIND DOMINATED VENTILATION

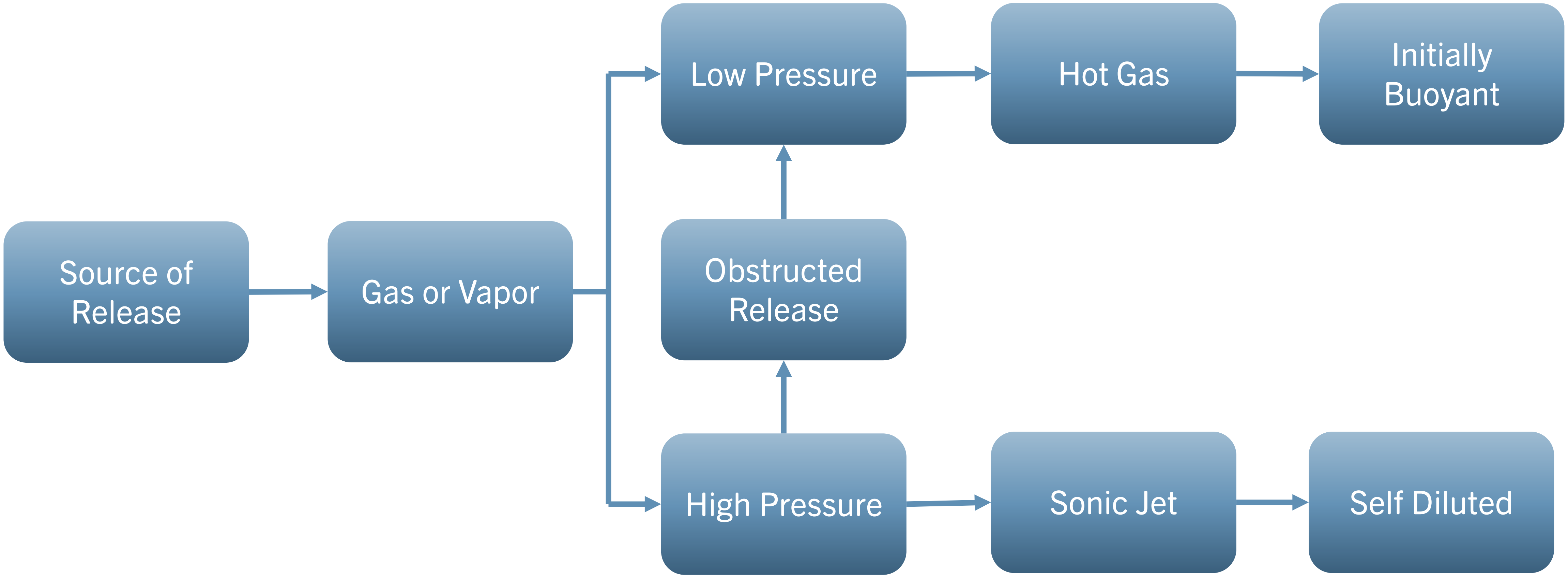


EMPIRICAL DATA



Source: Hooker, P., Hoyes, J.R., Hall, J. (2013)

BUOYANCY RELEASED HYDROGEN



Source: IEC-60079-10-1

CRITICAL PRESSURE CALCULATIONS

Parameter		Unit	Low Pressure	High Pressure
Temperature	$\mathbf{T}$	K (°C)	321 (48)	348 (75)
Partial Vapor Pressure Water	p_{H_2O}	Pa	7222	23141
Molecular Mass	$\mathbf{M}$	kg/kmol	3.16	5.67
Specific Heat at Constant p	c_p	J/kg K	13539	11734
Ratio	γ	-	1.24	1.14
Critical Pressure	p_c	kPa	182	176

HOLE SIZE AND ORIFICES

(Based on EN IEC 60079-10-1 Table B.1)

Type of Item	Item	Typical values for the conditions at which the release opening may expand due to erosion[1)]	
		S [mm²]	Ø [mm]
Sealing elements on fixed parts	Flanges with compressed gaskets	> 0.25 up to 2.5	> 0.56 up to 1.78
	Small bore connections up to 50 mm² (Ø = 8 mm)	> 0.1 up to 0.25	> 0.36 up to 0.56
Sealing elements on moving parts at low speed	Valve stem packing	**2.5**	**1.78**
	Pressure relief valves	NA	NA
Sealing elements on moving parts at high speed	Compressor	> 1 up to 5	> 1.13 up to 2.52

1) Hydrogen leaks can cause erosion of orifices, especially in high-pressure systems. Hydrogen is a small molecule that can penetrate materials more easily than larger molecules, potentially leading to material degradation over time. This can result in erosion, particularly if the orifice is made of a material that is susceptible to hydrogen embrittlement or corrosion.

LEAKAGE RATE

(2.5 mm hole size)

Parameter		Unit	Low Pressure	High Pressure
Pressure	$\mathbf{p}$	barg	0.09	39.5
Flow			Non-choked	Chocked
Leakage mass rate	W_g	g/s	0.078	6.5
Leakage volumetric rate	Q_g	m^3/s	$9x10^{-4}$	0.26
Fraction water vapor	x_{H_2O}	-	0.066	0.212
Leakage rate hydrogen	Q_{g,H_2}	m^3/s	$1.5x10^{-2}$	$5.8x10^{-2}$

DEGREE OF DILUTION

(Buoyancy only)

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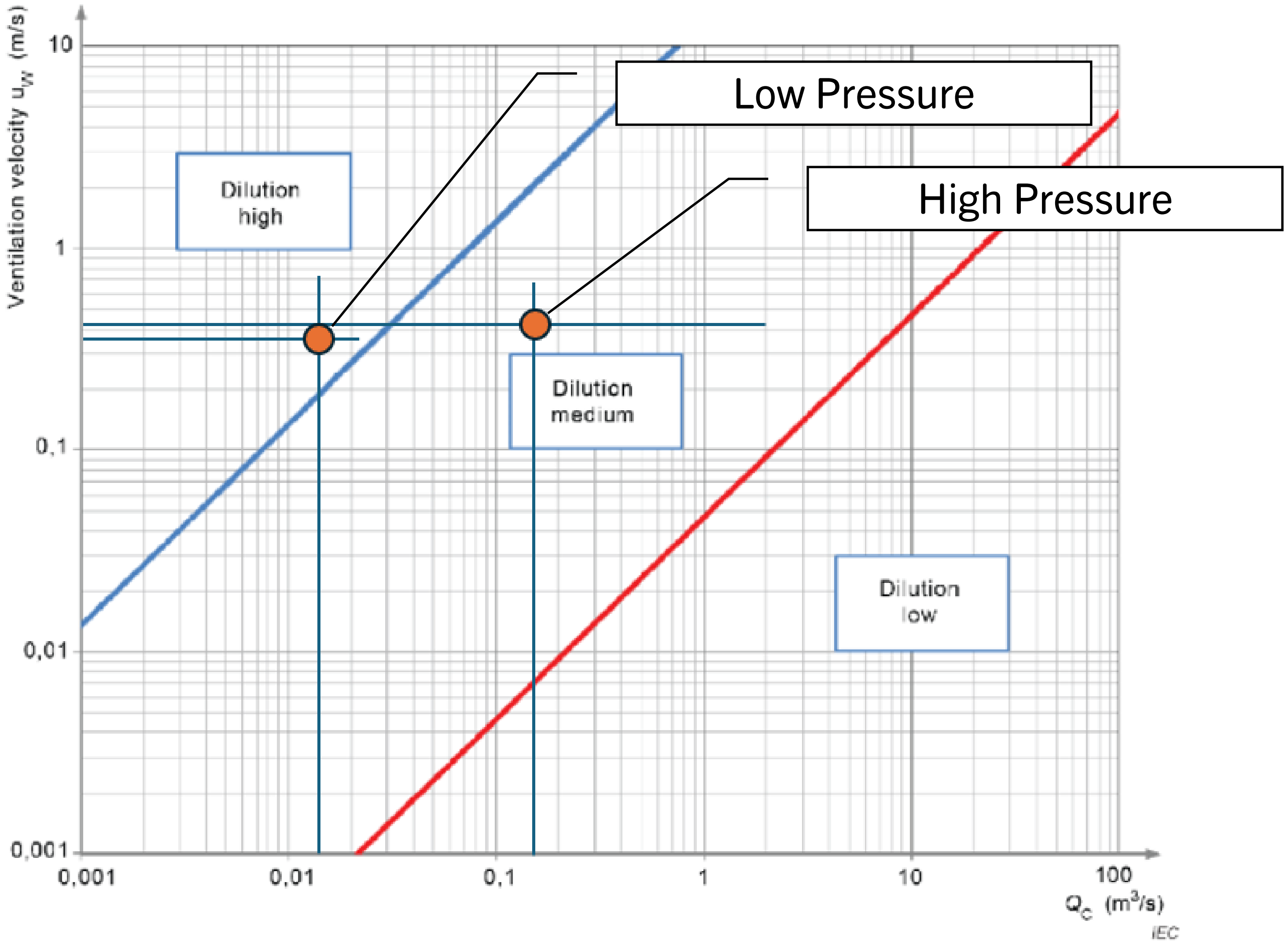
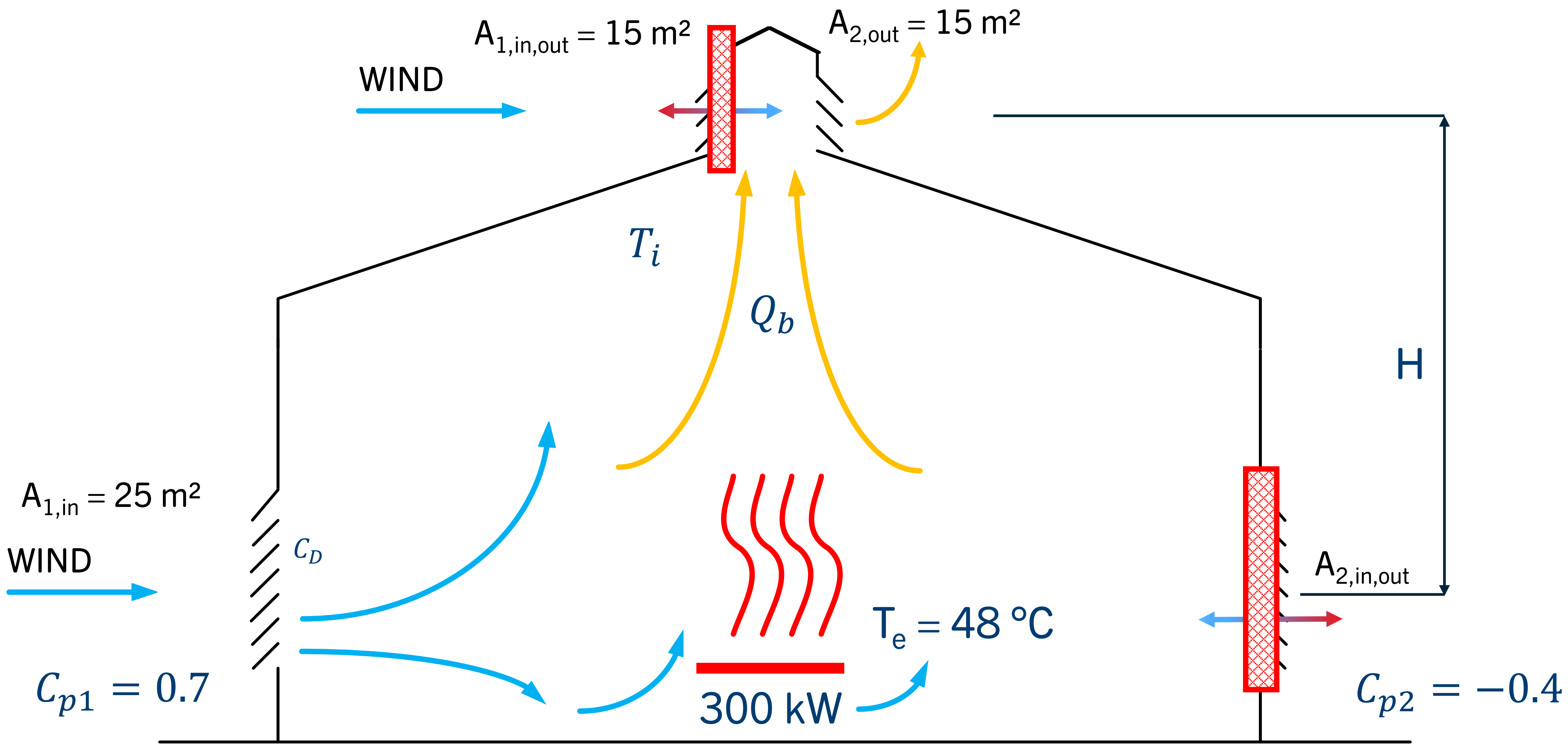
Parameter		Unit	Low Pressure	High Pressure
Flow rate hydrogen release	$Q_{g,H2}$	m^3/s	$1.5x10^{-2}$	$5.8x10^{-2}$
Flow rate buoyancy	Q_b	m^3/s	105.0	122.7
Ventilation velocity	u_w	m/s	0.35	0.41
Volumetric release characteristic	Q_c	m^3/s	0.013	0.158
Degree of dilution (Figure C1)			High	Medium
Type of HAC Zone			2NE	1

DEGREE OF DILUTION

(Buoyancy only)



NATURAL VENTILATION BASIC BUOYANCY AND WIND



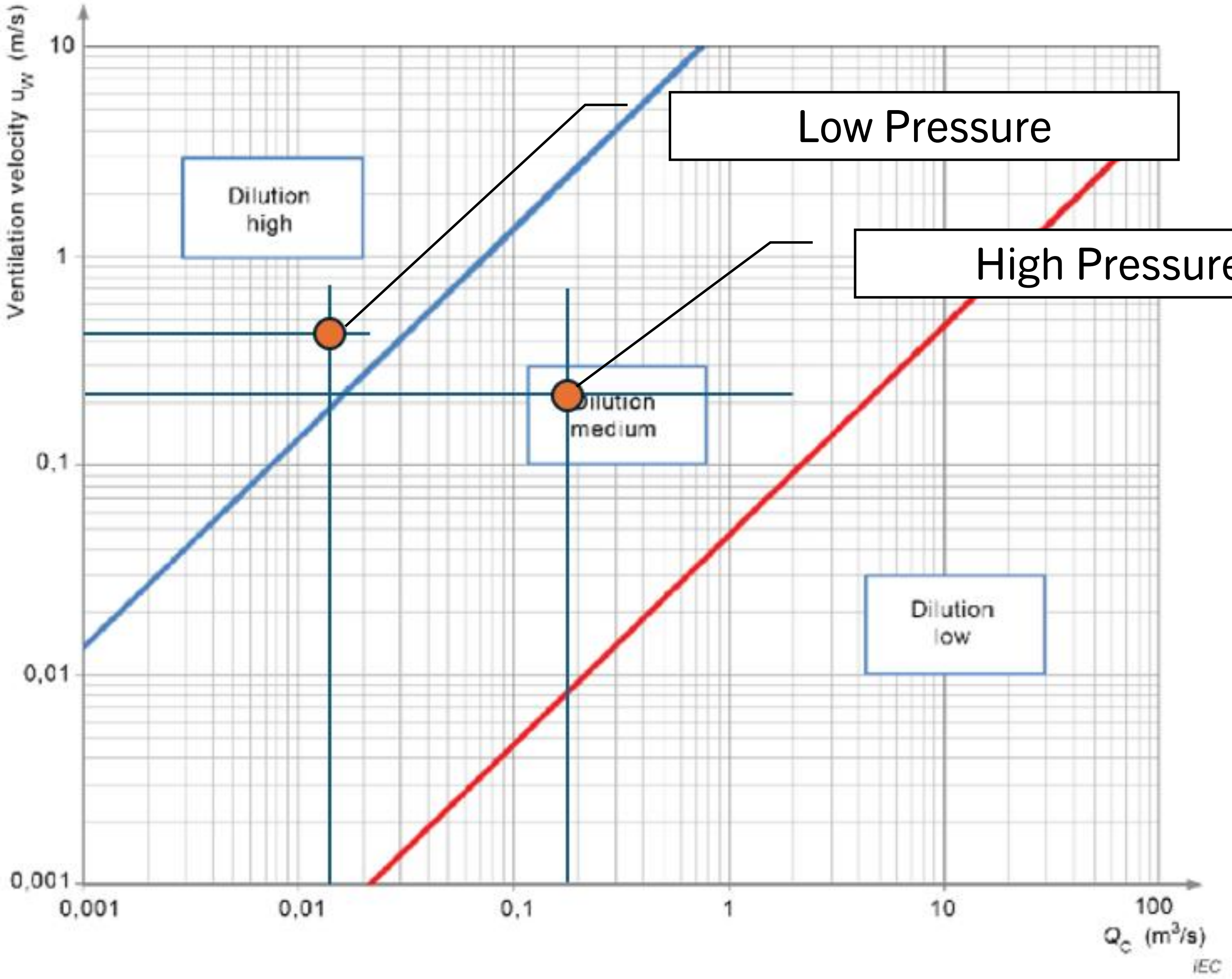
DEGREE OF DILUTION

(Buoyancy and Wind)

Parameter		Unit	Low Pressure	High Pressure
Flow rate hydrogen release	$Q_{g,H2}$	m^3/s	$1.5x10^{-2}$	$5.8x10^{-2}$
Flow rate buoyancy	Q_b	m^3/s	52.2	61.3
Ventilation velocity	u_w	m/s	0.34	0.204
Volumetric release characteristic	Q_c	m^3/s	0.013	0.185
Degree of dilution (Figure C1)			High	Medium
Type of HAC Zone			2NE	1

DEGREE OF DILUTION

(Buoyancy and Wind)

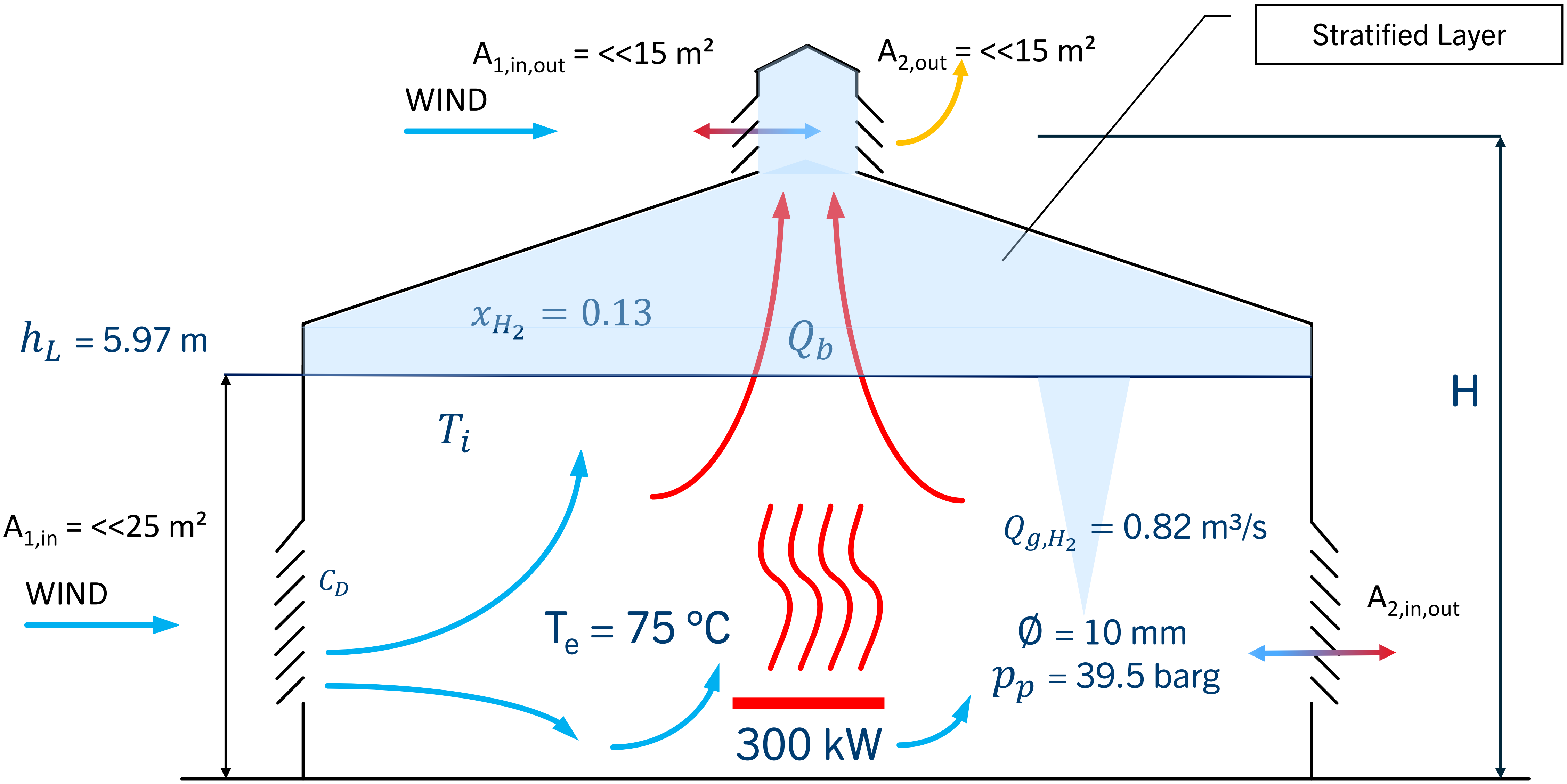


ENGINEERING CHALLENGES

(Ambient Conditions)

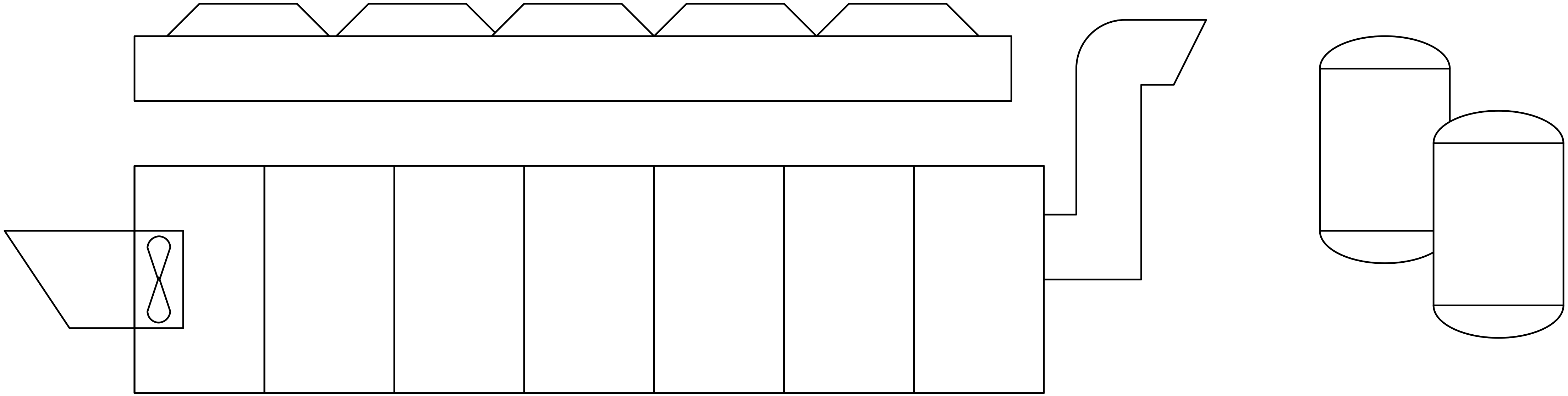
- Design temperature not below 5 °C
- Temperature needs to be controlled
- Colder climates initiate less air changes
- Reduction of area of the openings leading to less dilution
- Potentially leading to more stringent ATEX zones

NATURAL VENTILATION HIGH HYDROGEN LOAD



MITIGATION

- Shape of the building
- Hydrogen detectors at the outlets of the building
- Emergency shutdown and depressurization
- Sizing of the inlets and outlets of the building
- No building



CONCLUSION

- Natural ventilation of low-pressure electrolysers inside a building is feasible, when sufficient area of openings can be maintained
- Natural ventilation of high-pressure electrolysers inside building requires hazardous zoning according IEC 60079-10-1

REFERENCES

- ASHRAE. Handbook—Fundamentals, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., 2005, Atlanta, GA.
- G.R. Hunt, P.F. Linden, The fluid mechanics of natural ventilation-displacement ventilation by buoyancy-driven flows assisted by wind, Building and Environment 34 (1999) 707-710.
- Hooker, P., Hoyes, J.R., Hall, J., Accumulation of Hydrogen Released into an Enclosure Fitted With Passive Vents – Experimental Results and Simple Models, SYMPOSIUM SERIES NO 159, Health and Safety Laboratory, Buxton, UK, December 2013.
- Linden, P.F., Lane-Serff, G.F. and Smeed, D.A. (1990). Emptying filling boxes: the fluid mechanics of natural ventilation. J. Fluid Mech., 212, 309-335.
- BS 5925:1991 Code of Practice for Ventilation Principles and Designing for Natural Ventilation.
- EN IEC 60079-10-1 Explosive Atmospheres Part 10-1 Classification of Areas – Explosive Gas Atmospheres.

THANK YOU