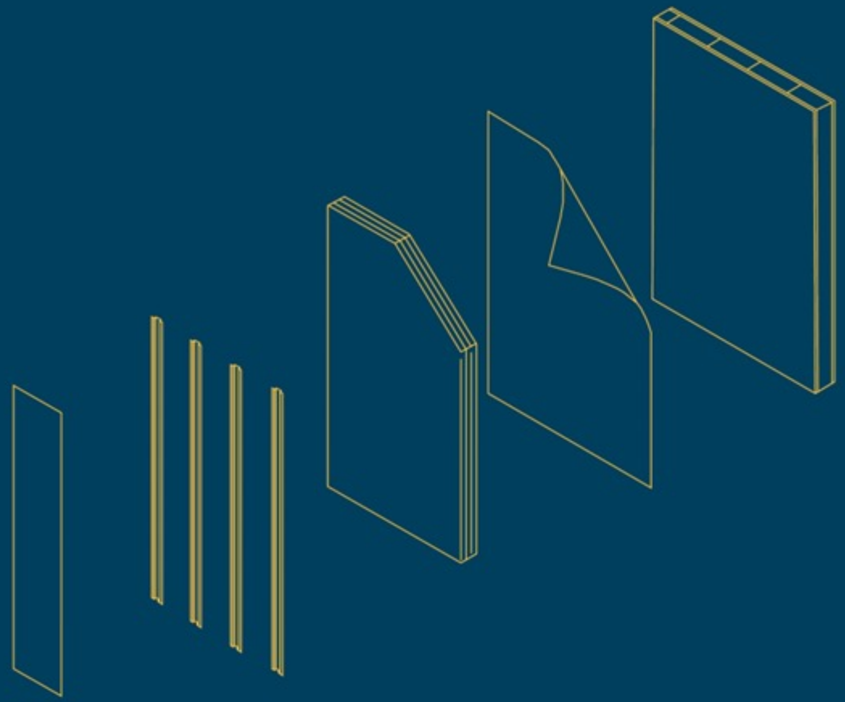
Design and Analysis of Ventilation Behind Rainscreen Cladding

Dr John Straube Ph.D., P.Eng.
Principal, RDH Building Science
Associate Professor, University of Waterloo



UNIVERSITY OF WATERLOO
Department of Civil and Environmental Engineering
Architectural Engineering

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Presentation Outline

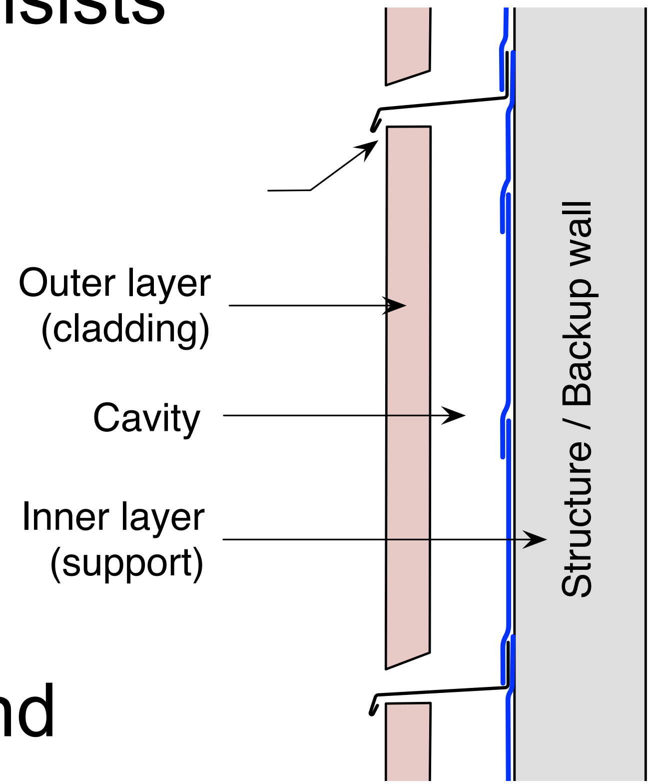
- Background definitions
- Airflow physics fundamentals
- Predicting airflow resistance
- Predicting driving air pressures
- Conclusions

Rainscreen Definition (RAiNA)

"An assembly applied to an exterior wall which consists of, at minimum

- an outer layer,
- an inner layer, and
- a cavity between them

sufficient for the passive removal of liquid water and water vapor"



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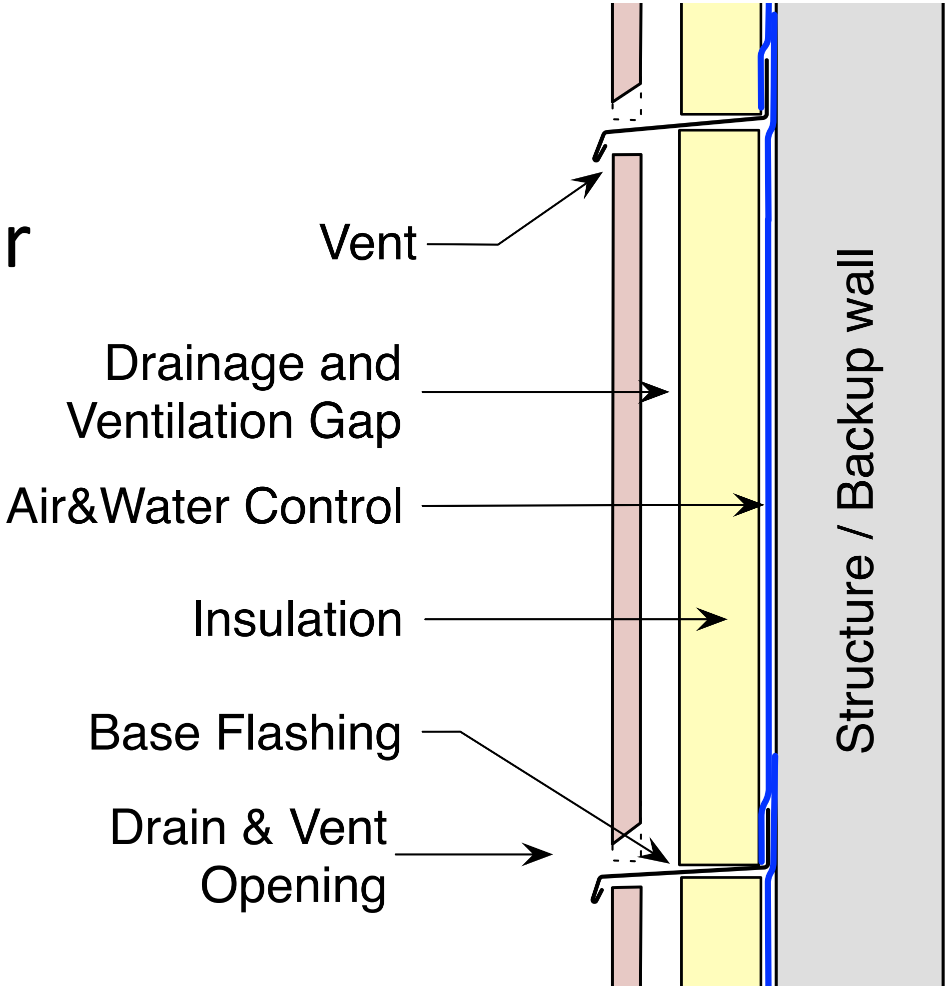
Ventilation!

Practical Conceptual Rainscreen

Core Requirements

- Cladding = outer layer
- Air & Water control = inner layer
- Gap = cavity

- Often we add insulation (ci)
- Air Barrier & Water Resistive Barrier is a code / practical requirement



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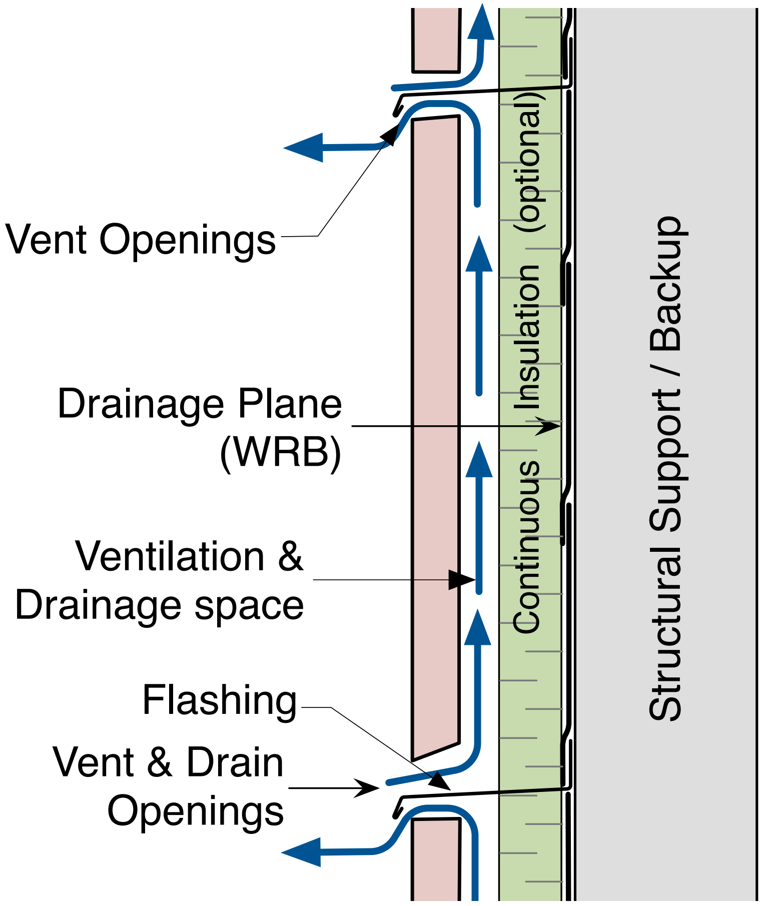
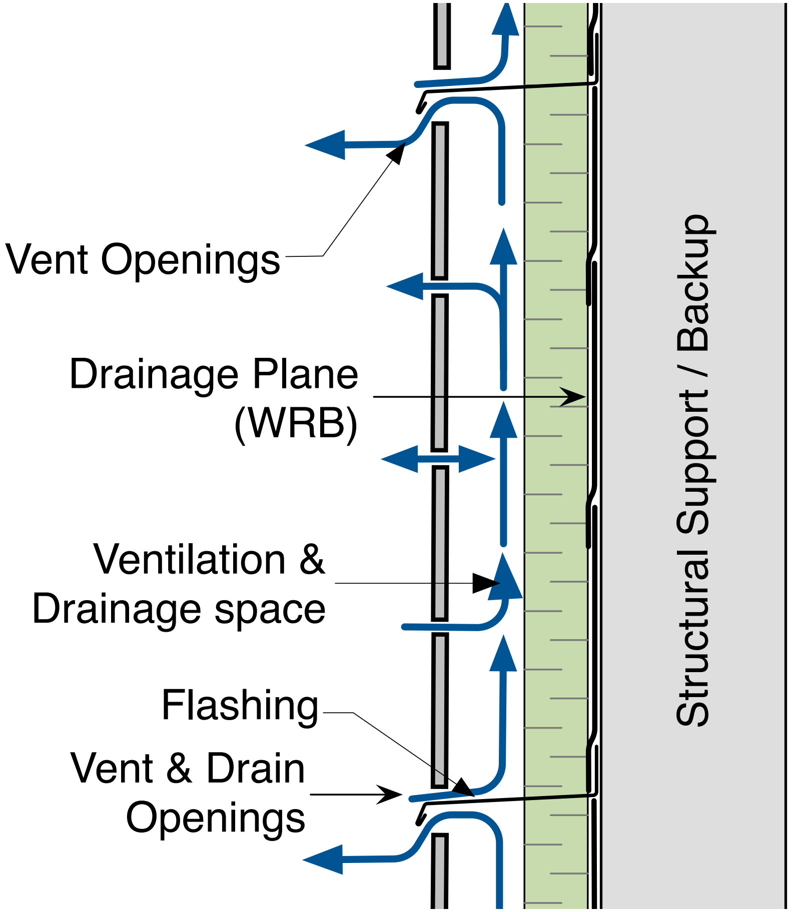
Two Ventilated System Types

Type 1: vents top and bottom



Type 2: distributed vents



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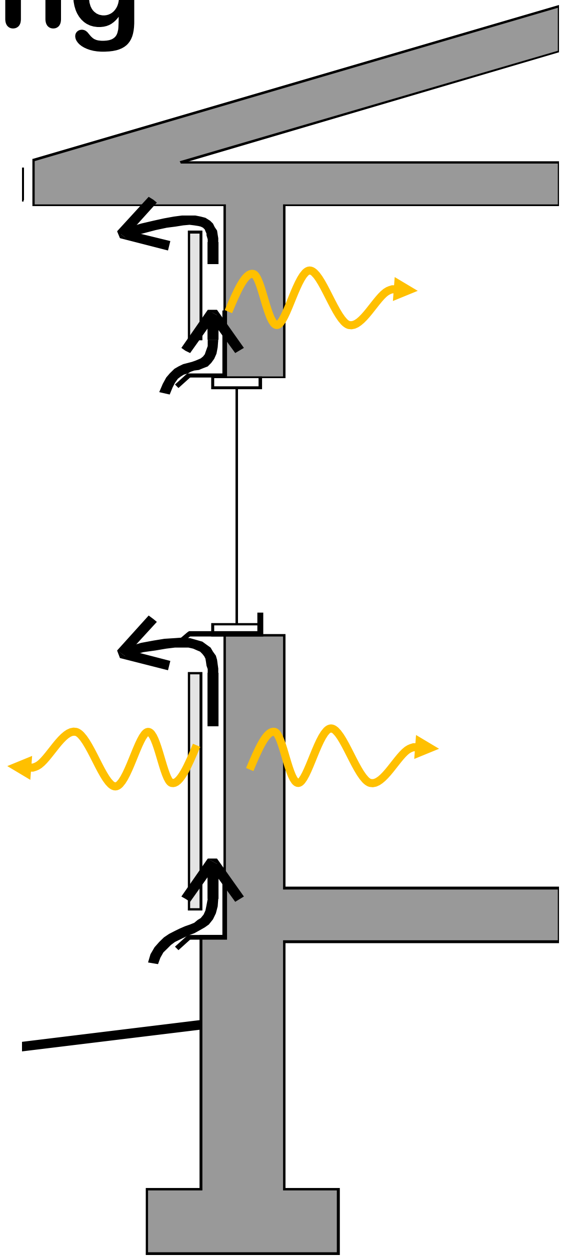
What / Why Ventilation Drying

Defined: “intentional airflow between exterior and cavity”

- 1. Important for some systems that
  - retain drain water, and/or
  - have claddings that absorb water
- 2. Bypasses cladding vapor resistance
  - Low permeance metal, HPL, even fiber cement

- **Diffusion**
  - **Drying through materials**



Air Flow Physics

Previous Research

ASHRAE RP-1091 -- Development of Design Strategies for Rainscreen and Sheathing Membrane Performance in Wood Frame Walls

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Research

11th Canadian Conference on Building Science and Technology
Banff, Alberta, 2007

The Role of Small Gaps Behind Wall Claddings on Drainage and Drying

John Straube, Ph.D.
Civil Engineering Dept & School of Architecture, University of Waterloo
Jonathan Smegal, M.A.Sc.
Building Science Consulting, Waterloo, Ont.

Research in Building Physics and Building Engineering – Fazio, Ge, Rao & Desmar
© 2006 Taylor & Francis Group, London, ISBN 0-415-4

Measured ventilation rates in water managed wall cavities

M.R. Bassett & S. McNeil
Building Research Association of New Zealand Limited (BRANZ Ltd)

Ventilated Wall Claddings: Review, Field Performance, and Hygrothermal Modeling

Graham Finch
Student Member ASHRAE

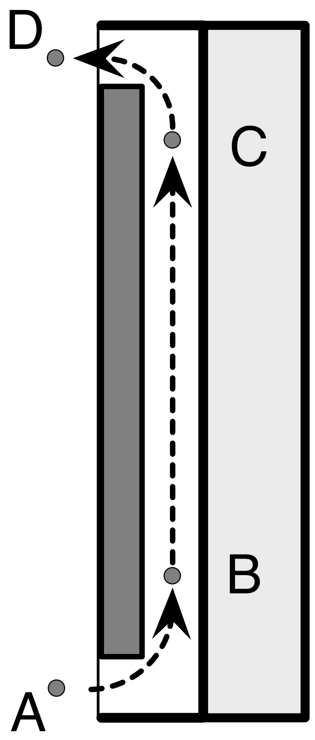
John Straube, PhD, PEng
Associate Member ASHRAE

CAVITY VENTILATION BEHIND BRICK VENEER CLADDING: EXPERIMENTAL AND NUMERICAL INVESTIGATION

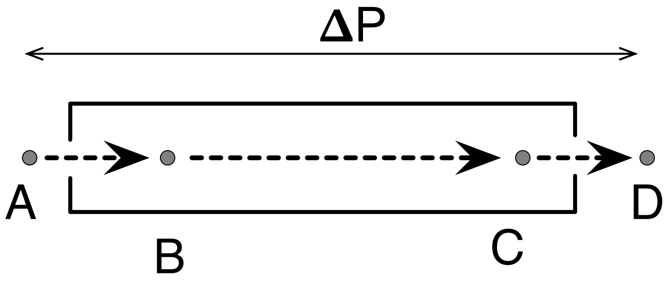
M. Vanpachtenbeke[1,2], J. Langmans[1], S. Roels[1], J. Van den Bulcke[2], and J. Van Acker[2]
[1]KU Leuven Department of Civil Engineering, Building Physics Section, Kasteelpark Arenberg 40 – bus 02447, BE-3001 Heverlee (Leuven), Belgium
[2]UGent Department of Forest and Water Management, Laboratory of Wood Technology – Woodlab, Coupure Links 653, BE-9000 Ghent, Belgium
michiel.vanpachtenbeke@kuleuven.be, michiel.vanpachtenbeke@ugent.be

Ventilation System Decomposition

- A ➔ B and C ➔ D are vents
- B ➔ C is the cavity
- Flow is constant along the path
- Hence find pressure loss for each of the three steps at a given flow



$$\Delta P_{total} = \Delta P_{vent,\ entry} + \Delta P_{cavity} + \Delta P_{vent,\ exit}$$



Flow through Slots / Vents

- Pressure drop varies with dynamic pressure (v^2)

$$\Delta P_{vent} = C \cdot \tfrac{1}{2} \cdot \rho \cdot v^2 \qquad \text{(velocity = flow / area)}$$

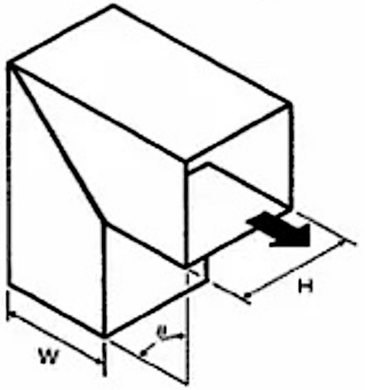
- Coefficients from testing / SMACNA / ASHRAE

SMACNA

DUCT DESIGN TABLES AND CHARTS

Table 14-10 LOSS COEFFICIENTS, ELBOWS (Cont.)
Use the velocity pressure (V_p) of the upstream section. Fitting loss (TP) = C × V_p

D. Elbow, Rectangular, Mitered (15)



Coefficient C (See Note 2—Page 14.19)

θ	H/W 0.25	0.5	0.75	1.0	1.5	2.0	3.0	4.0	5.0	6.0	8.0
20°	0.08	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.05
30°	0.18	0.17	0.17	0.16	0.15	0.15	0.13	0.13	0.12	0.12	0.11
45°	0.38	0.37	0.36	0.34	0.33	0.31	0.28	0.27	0.26	0.25	0.24
60°	0.60	0.59	0.57	0.55	0.52	0.49	0.46	0.43	0.41	0.39	0.38
75°	0.89	0.87	0.84	0.81	0.77	0.73	0.67	0.63	0.61	0.58	0.57
90°	1.3	1.3	1.2	1.2	1.1	1.1	0.98	0.92	0.89	0.85	0.83

Experiments (Pinon et al 2004)

	[mm]	[mm]	C	C	C
Vent type	Vent size	Cavity Depth	Inlet	Outlet	Inlet+Outlet
Circular	**27ϕ**	19 (3/4”)	2.13	2.01	4.14
Rectangular	**9.5 x 57**	19	2.25	2.02	4.27
	(3/8 x 2-1/4)	50 (2”)	2.19	1.38	3.57
		100 (4”)	2.29	1.19	3.48
Slot	**10**	19	1.81	1.93	3.74
	(3/8”)	50	2.24	1.71	3.95
Slot	**19**	19	1.84	3.02	4.86
	(3/4”)	50	1.67	2.06	3.73
		100	2.21	2.61	4.82

Source: ASHRAE RP1091

$$\Delta P_{vent} = C \cdot \tfrac{1}{2} \cdot \rho \cdot v^2$$

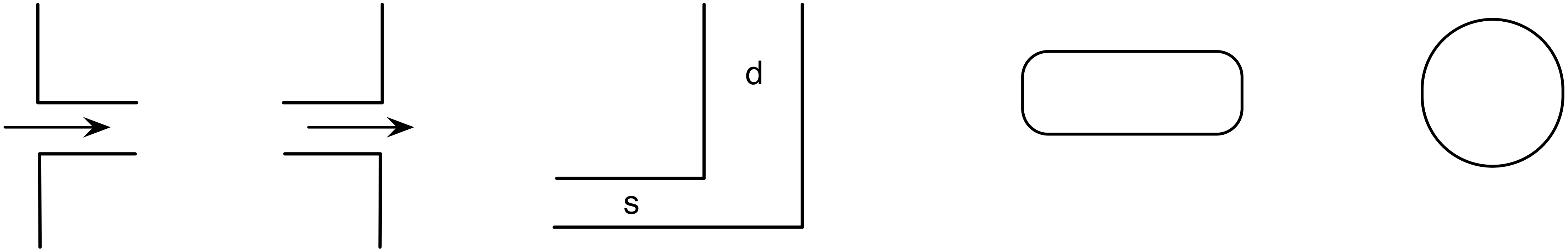
- Most vents have a C of around 2.0 . . .
- But, a ½” diameter hole every 24” o.c. has an area over 60 times less than a ½” slot
- For the same flow rate this is a difference in pressure loss of over 3700!

Recommended

- Relevant coefficients from research

$\Delta P_{vent} = C \cdot \frac{1}{2} \cdot \rho \cdot v^2$ remember v changes with Flow and Area

Slot vents | **Orifice vents**



Entrance:
$C = 0.5$

Exit:
$C = 0.88$

Rectangular Elbow:
$C = 1.0 - 1.50$

Rectangular:
$C = 0.6\text{-}0.8$

Circular:
$C = 0.6\text{-}0.8$

Flow Through Cavity

- Assume laminar flow (most common)
  - $\Delta P_{cavity} = \dfrac{v\,h}{4610\,\gamma\,d^2} = \dfrac{Q\,h}{4610\,\gamma\,b\,d^3}$

    d is the cavity depth [m],

    v is the cavity flow velocity [m/s]

    h is the cavity height [m],

    b is the cavity width [m],

    γ is a blockage factor, and

    Q is the flow volume [m^3/s]
- Therefore, for cavity double the flow, double the pressure drop

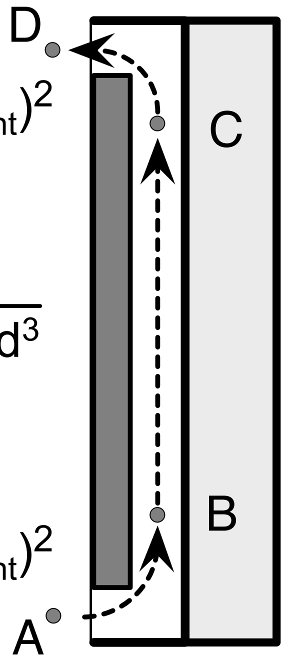
System Flow

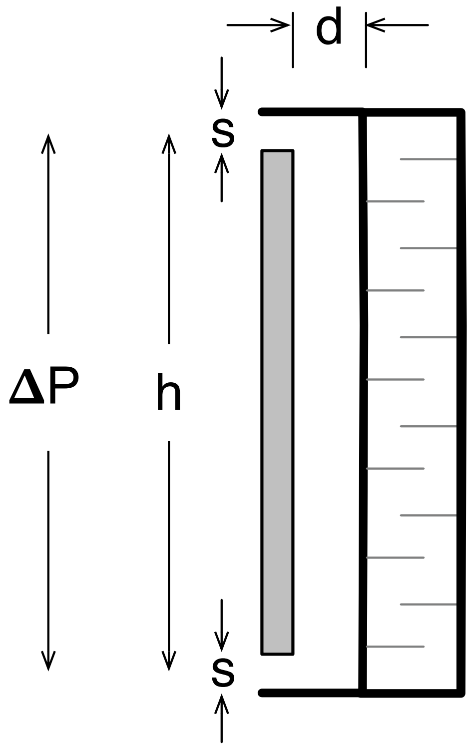
- Analysis can now match applied pressure loss to air pressure differences driving ventilation

$$\Delta P_{vent} = C \cdot \tfrac{1}{2} \cdot \rho \cdot (Q/A_{vent})^2$$

$$\Delta P_{cavity} = \frac{Q \cdot h}{4610 \cdot \gamma \cdot b \cdot d^3}$$

$$\Delta P_{vent} = C \cdot \tfrac{1}{2} \cdot \rho \cdot (Q/A_{vent})^2$$





h = cavity height or distance, vent-to-vent

d = depth of free air space

s = vertical dimension of a vent slot

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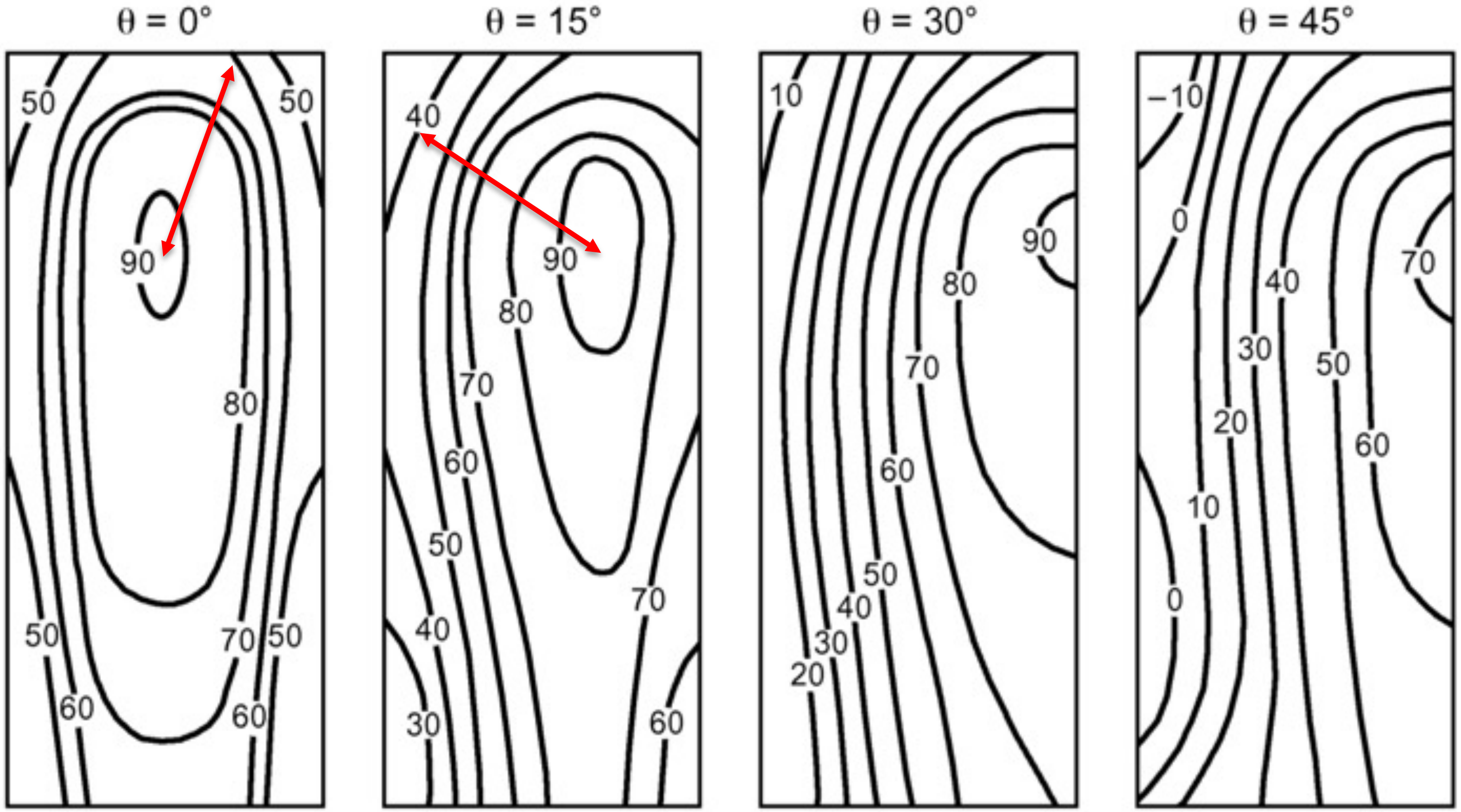
Air pressures driving ventilation

What drives ventilation flow

- Wind pressure variations
  - Highly variable can be large, often small
- Thermal buoyancy
  - Reliable, predictable, upward
- Moisture buoyancy
  - Small, upward

Wind pressure variations

- Highly dynamic
- Direction up/down
- Ventilation can be driven by spatially variable pressures
- Varies as fraction of
  ½ · ρ · v²
- Perhaps a few % to 50%
- Commonly a few Pa to short bursts of 20-50 Pa



Example pressure contours from *ASHRAE Handbook of Fundamentals*

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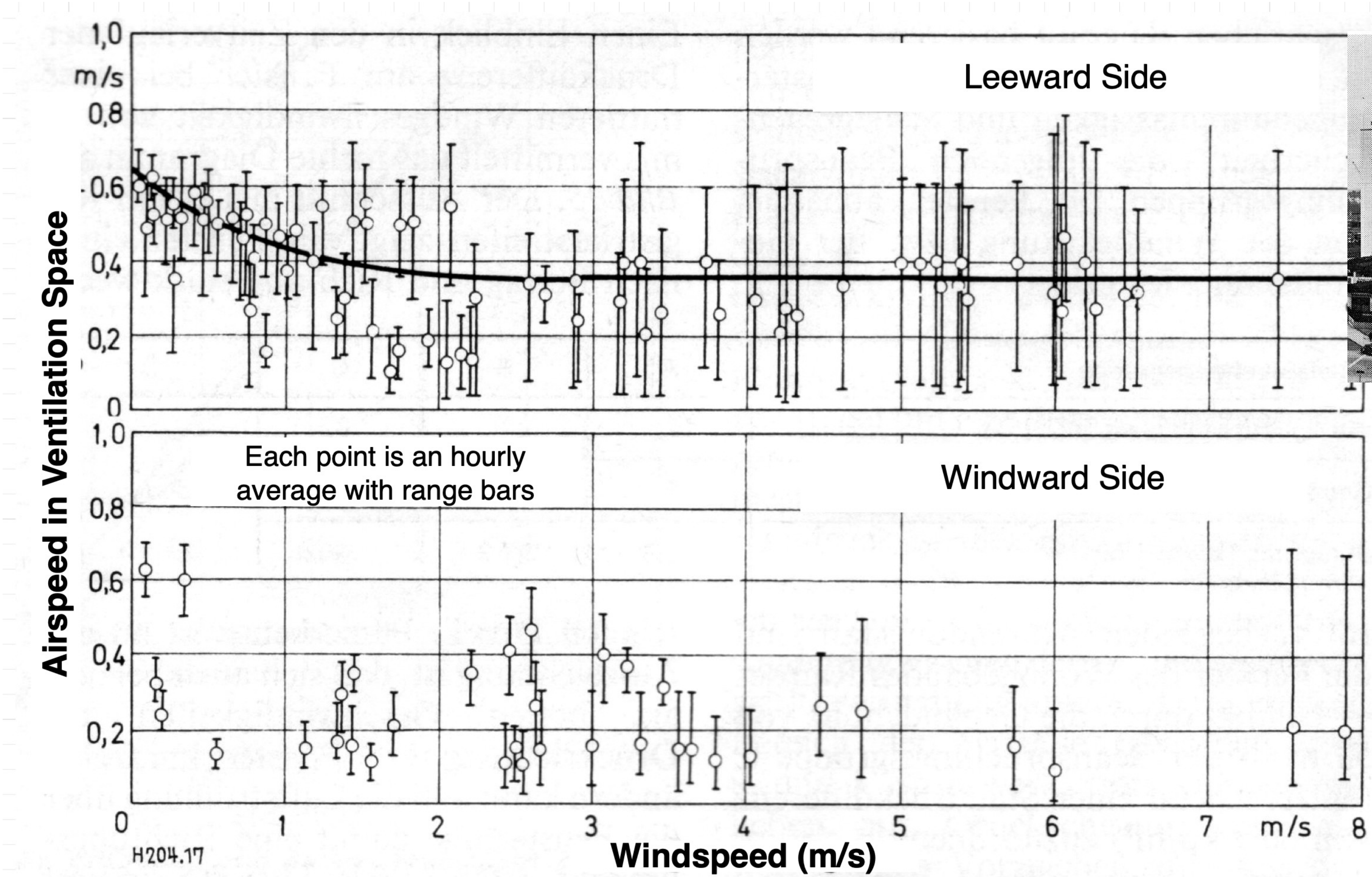
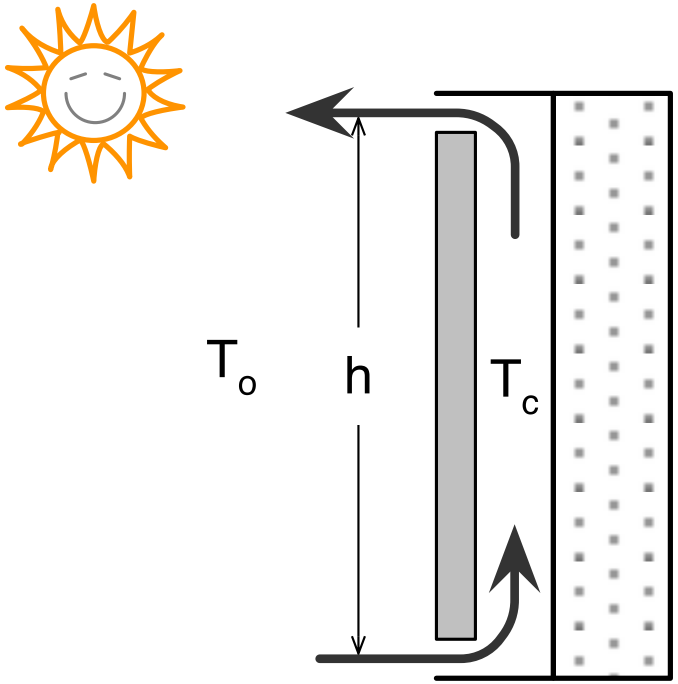
Wind Pressures Can Drive Ventilation

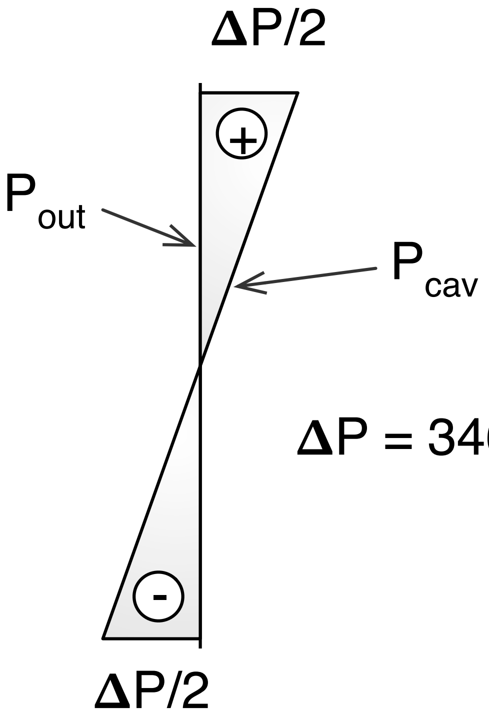


Schwarz, B., "Witterungsbeansphruchung von Hochhausfassaden," *HLH* Bd. 24, Nr. 12, pp. 376-384, 1973.

Thermal buoyancy

- Predictable, well-studied, operates for hours
- Ranges from around 1 to as much 10 Pa for most systems





Example: 2.4 m (8 ft) tall,
20C 68F in cavity
0C 32F outdoor air
Pressure difference is 2.1 Pa

$$\Delta P = 3465\, h\, (1/T_o - 1/T_{cav})$$

Solar Buoyancy: acts when solar heat is available to evaporate water

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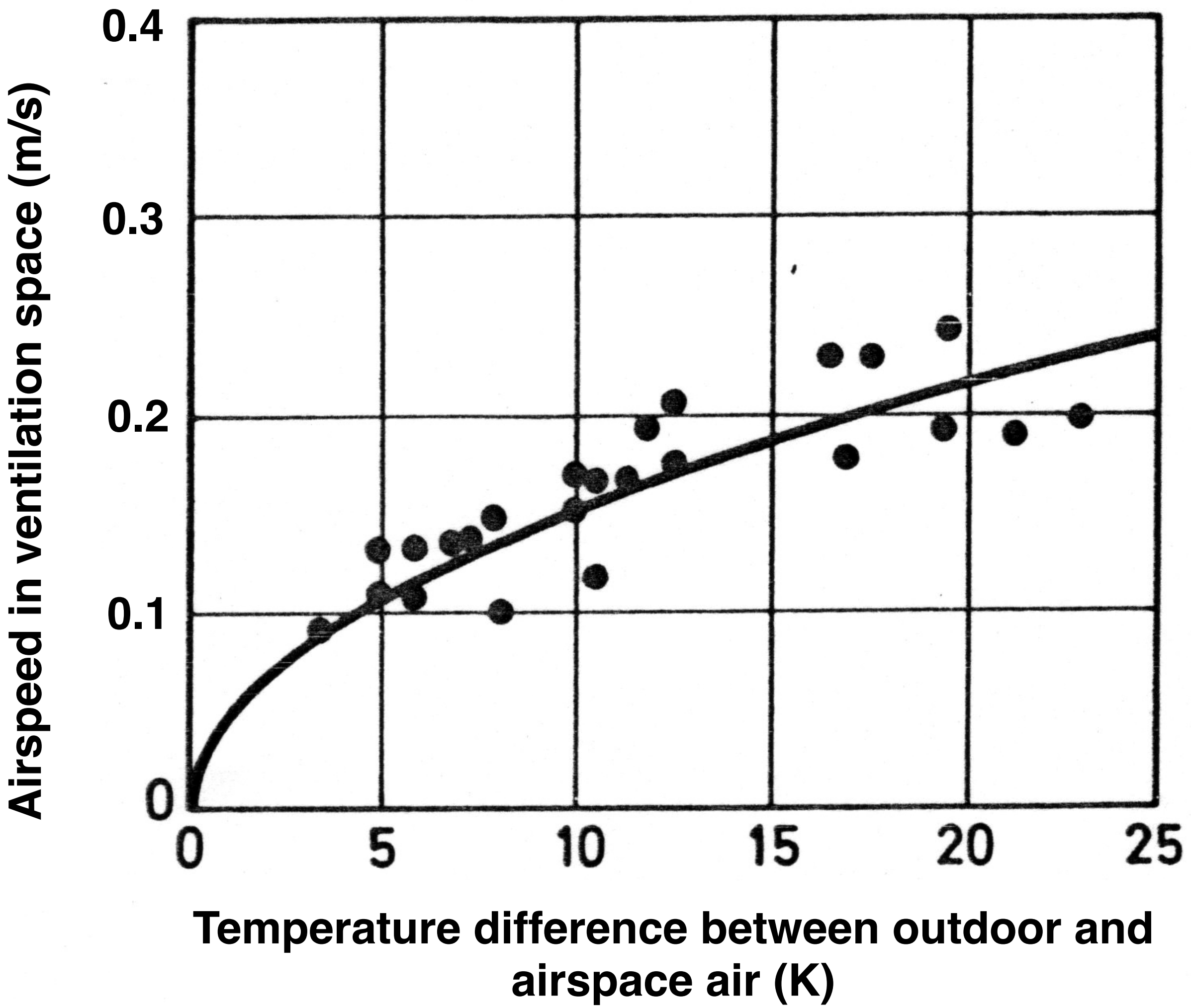
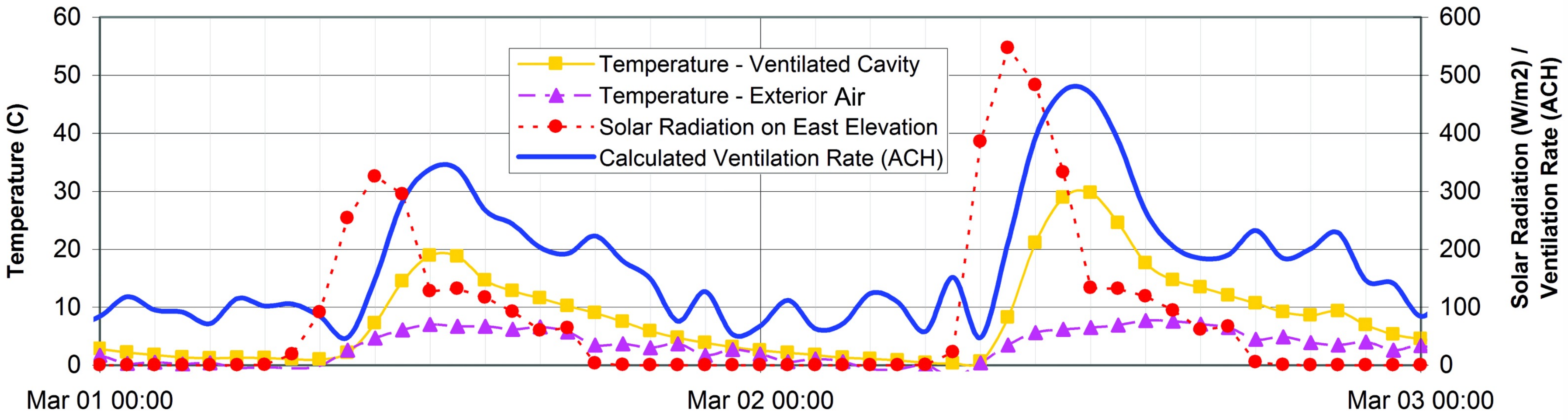
Measured Thermal Buoyancy Flow

- Measured cavity air velocity
- A clear 1-1/4” air space under low wind speed conditions



Popp, W., Mayer, E., Künzel, H., "Untersuchungen über die Belüftung des Luftraumes hinter vorgesetzten Fassadenbekleidung aus kleinformatigen Elementen", Fraunhofer Institut für Bauphysik, Forschungsbericht B Ho 22/80, April, 1980.

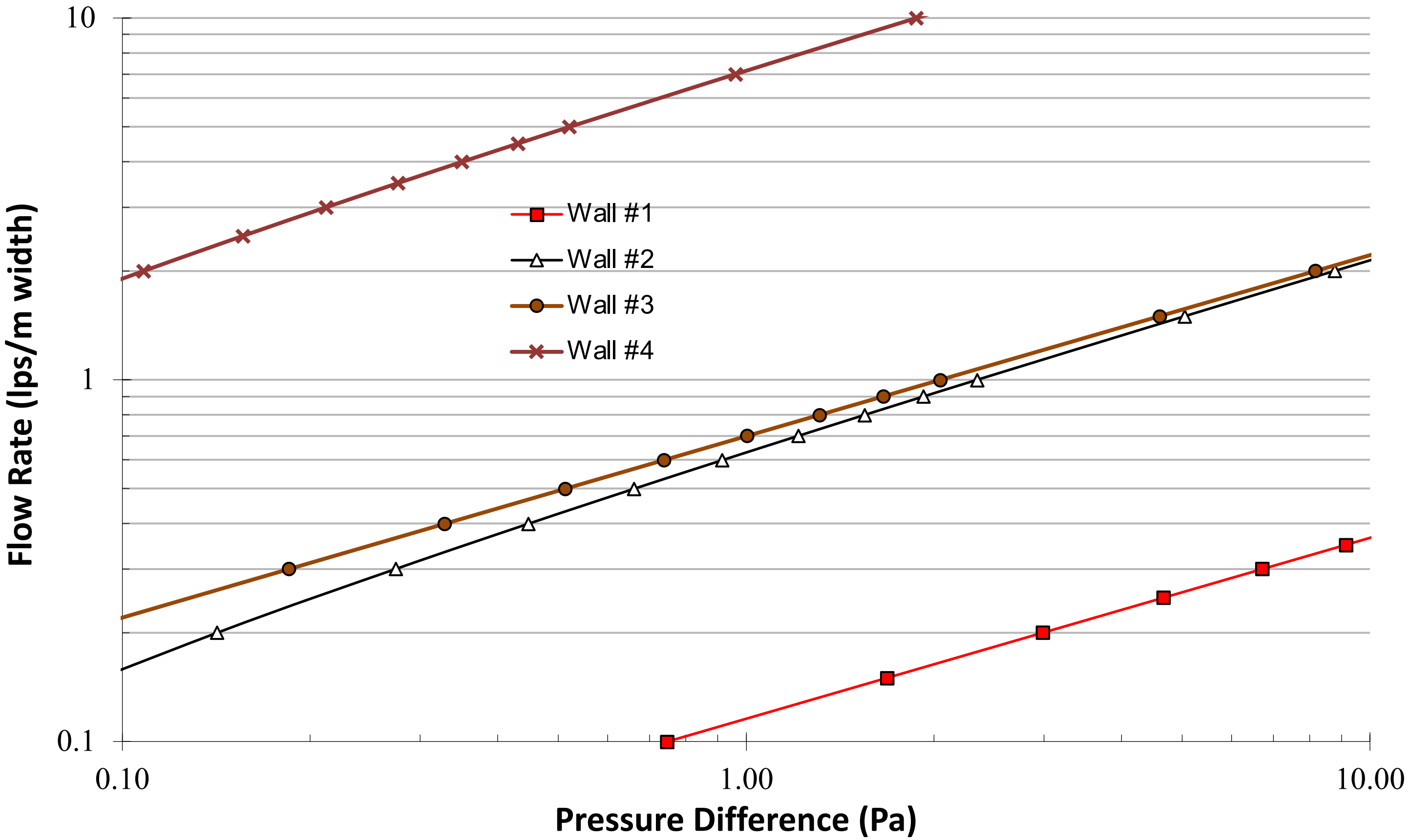
Field measurements (Finch et al)



Finch, G., Straube, J. "Ventilated Wall Claddings: Review, Field Performance, and Hygrothermal Modeling". *ASHRAE Thermal Performance of the Exterior Envelopes of Whole Buildings X International Conference*, Clearwater Beach, FL December 2007.

Ventilation airflows

Calculated Air Flow Rates



Wall #1: 10 ft high, 2" deep air space, 1/2" diameter vent @24" o.c. top and bottom

Wall #2: 8ft high veneer, 1/2" deep air space, 3/8"x2.5" @ 24" o.c., top and bottom

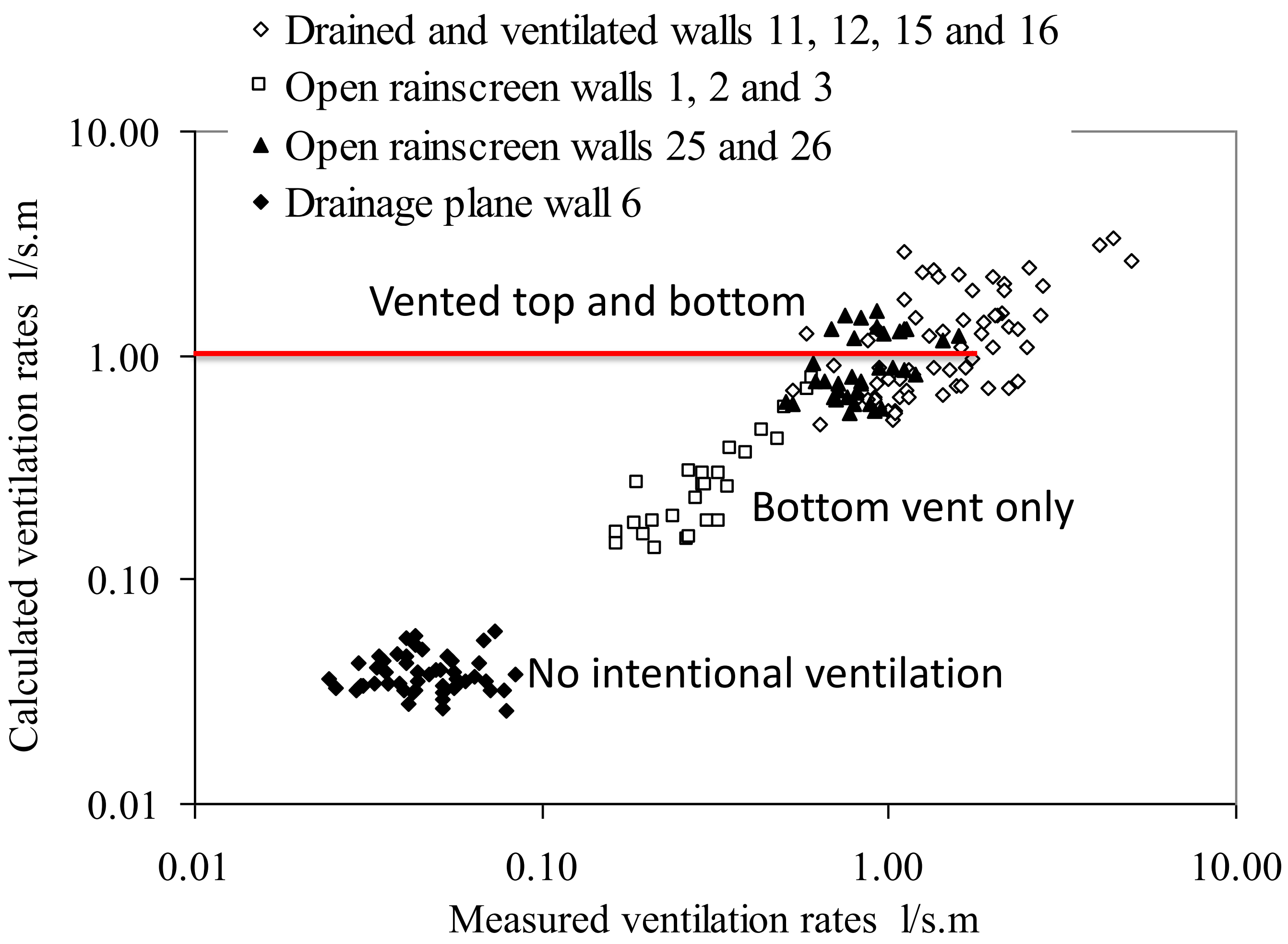
Wall #3: 8ft high veneer, 2" deep air space, 3/8"x2.5" @ 24" o.c., top and bottom

Wall #4: 40 ft (5 storeys) high, 2" deep air space, full-width 1/2" slot top and bottom

- Vast range of performance between common systems
- Well vented systems show 100x more flow than poorly-vented
- Vent area is the dominant factor
- Cavity depth is not a big factor

Measured Ventilation Rates

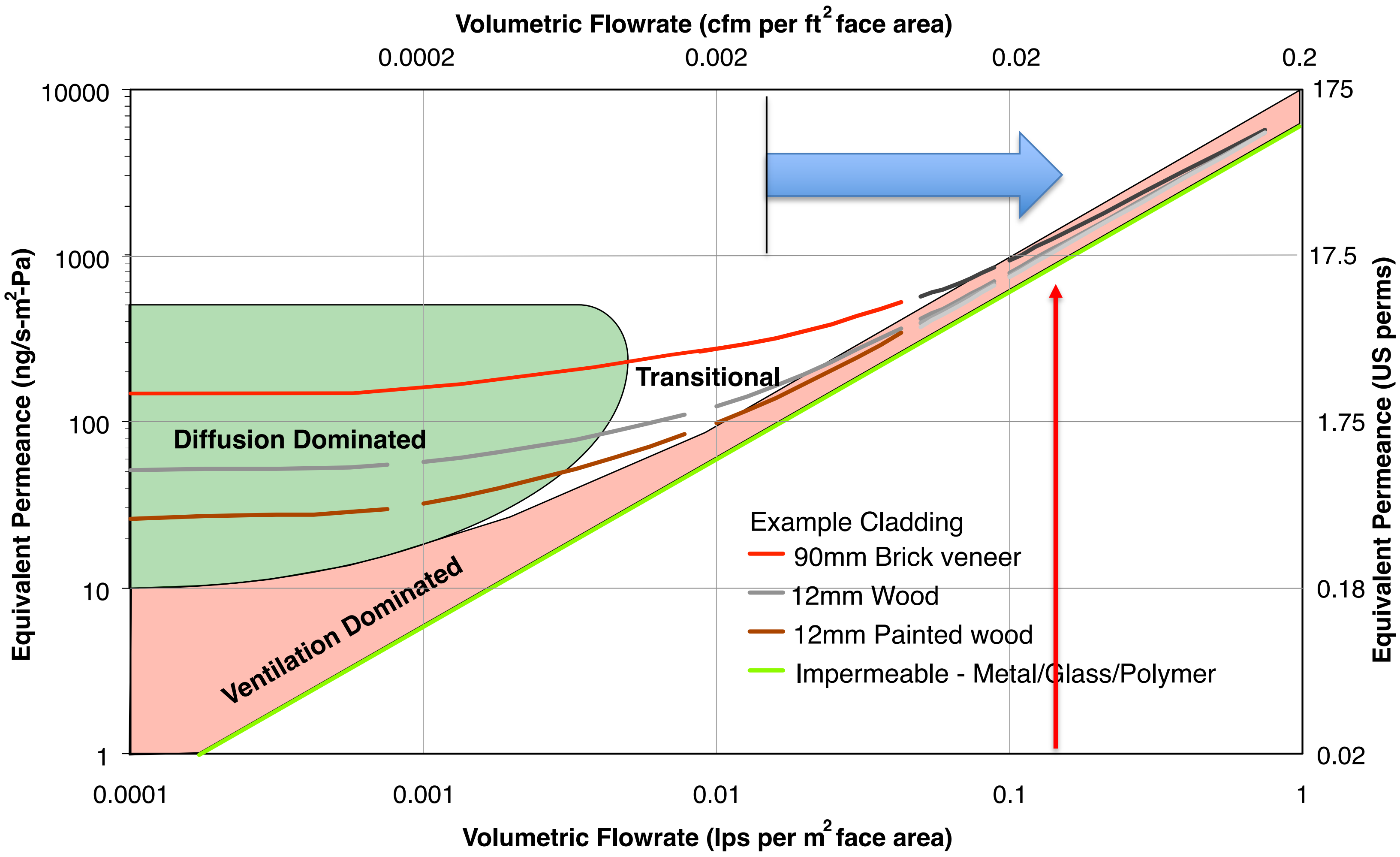
- Field measured with tracer gas
- Slot vents, ¾" cavities
- Intentional ventilation results in around 1



Bassett, M.R. and McNeil, S., 2006. Measured ventilation rates in water managed wall cavities. In *Research in Building Physics and Building Engineering* (pp. 403-410). CRC Press.

Ventilation to bypass Cladding

- Many modern panel claddings are vapor impermeable
  - Steel, alu, HDL
- Ventilation allows vapor to bypass vapor resistant cladding
- Very little ventilation is required to do this



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Building ventilated systems

Ventilation Gaps

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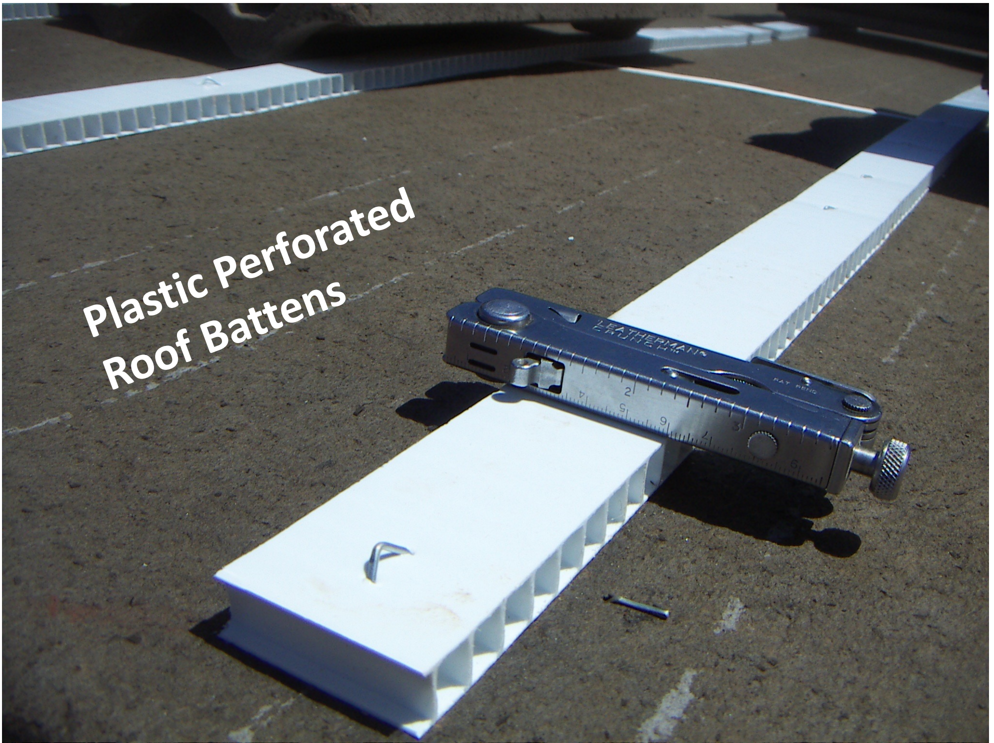
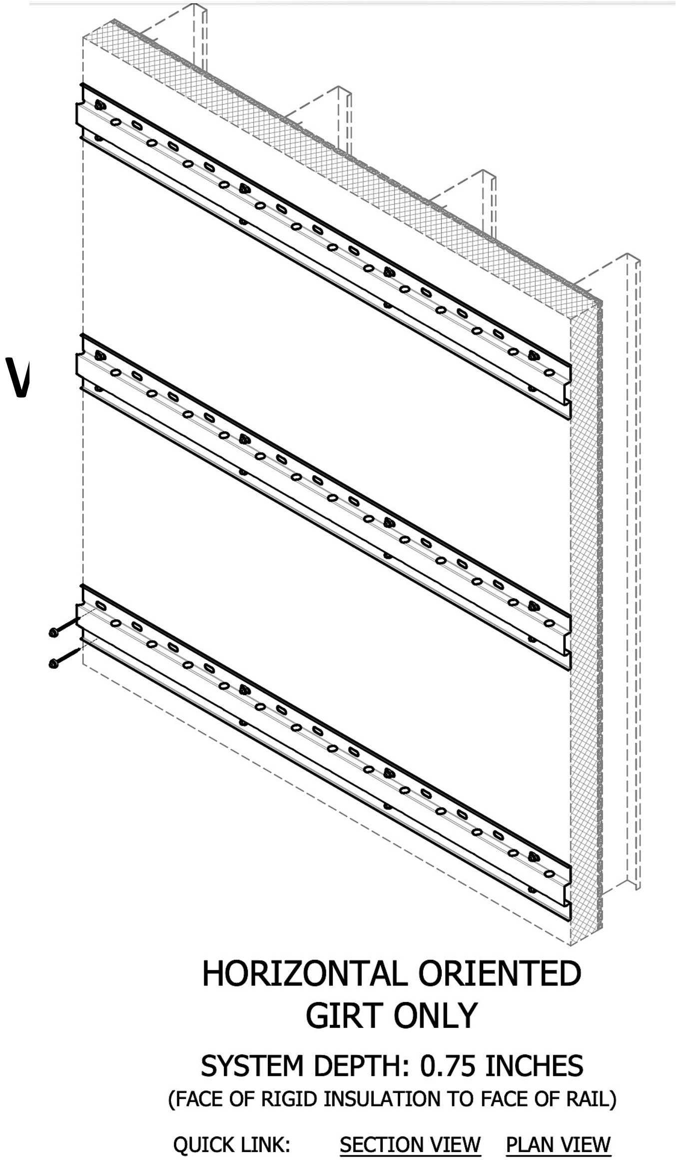
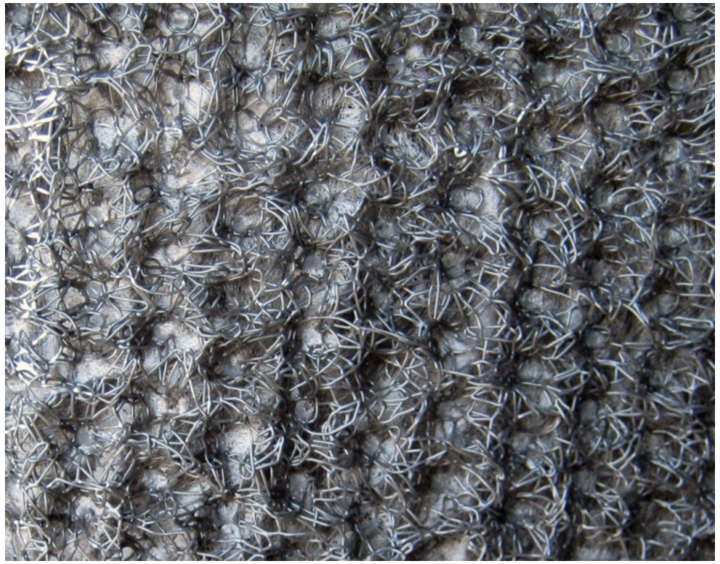
Ventilation Gaps

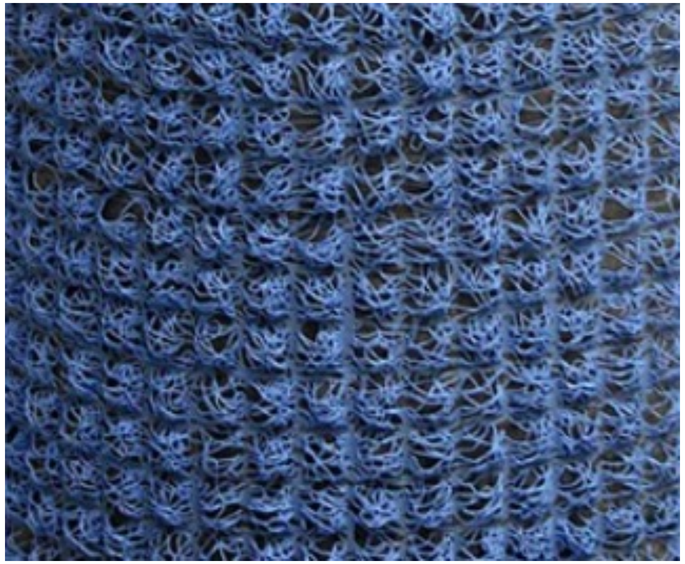
- Holes in horizontal girts are flow restrictions
- May allow enough airflow



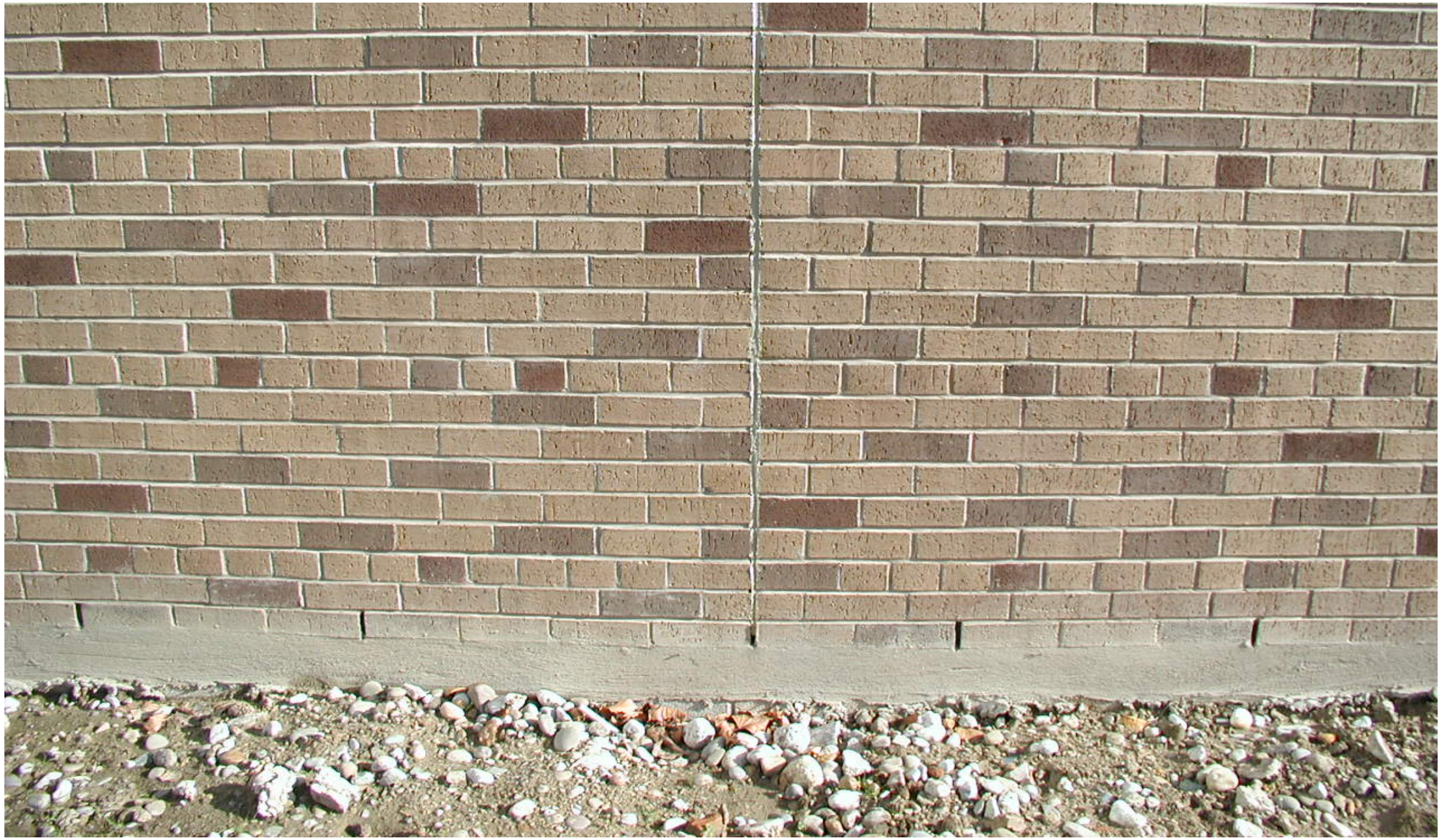


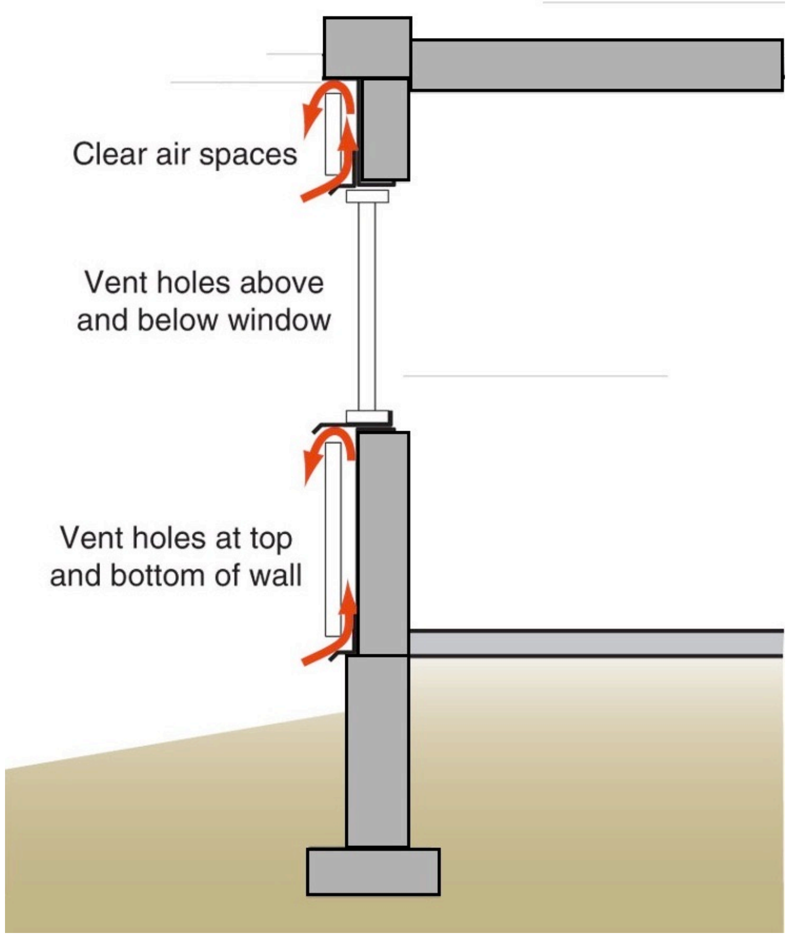
Air gap / cavity examples





Vent openings





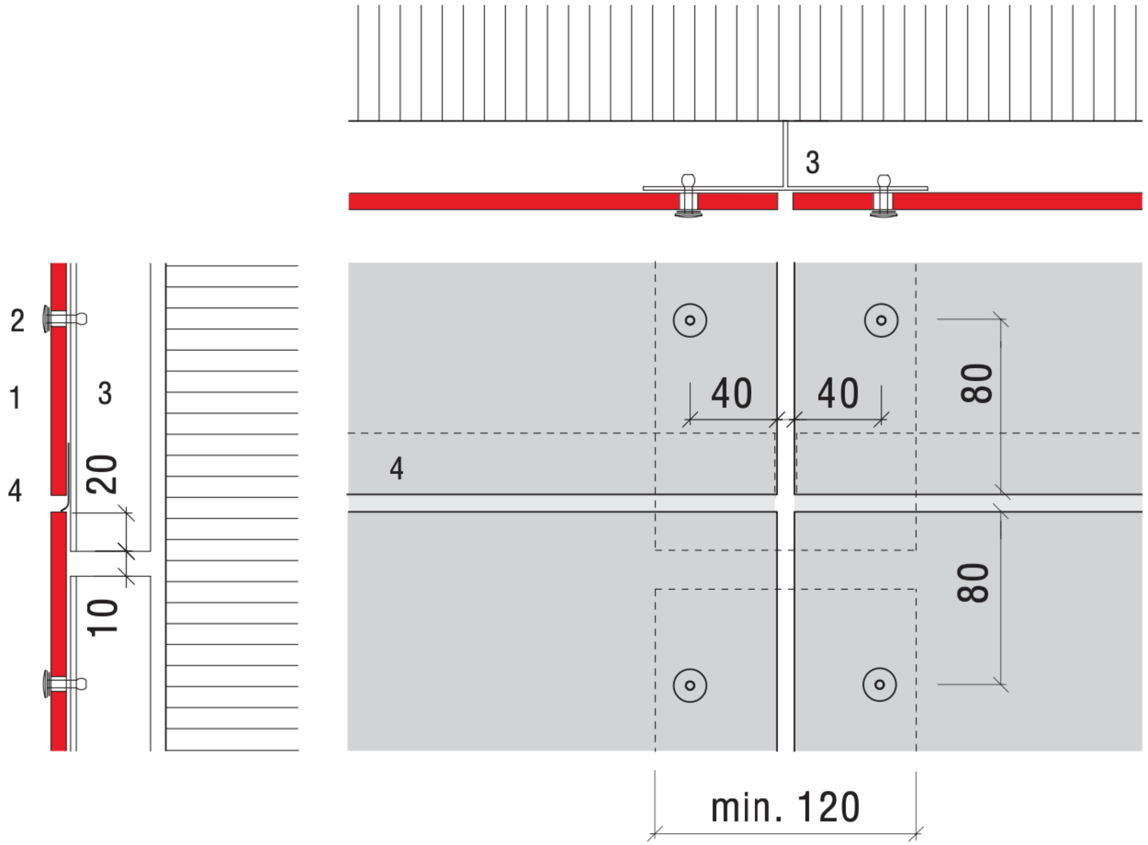
Small vents, but can be somewhat meaningful

Open Joints = Large Vent Openings

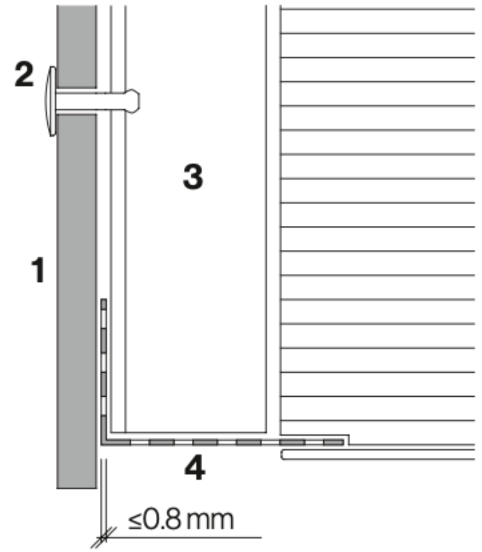
- Highly Ventilated!
- Hardly worth calculating

Ventilation Openings are Often Blocked

- Investigate specific systems, many have poor vents

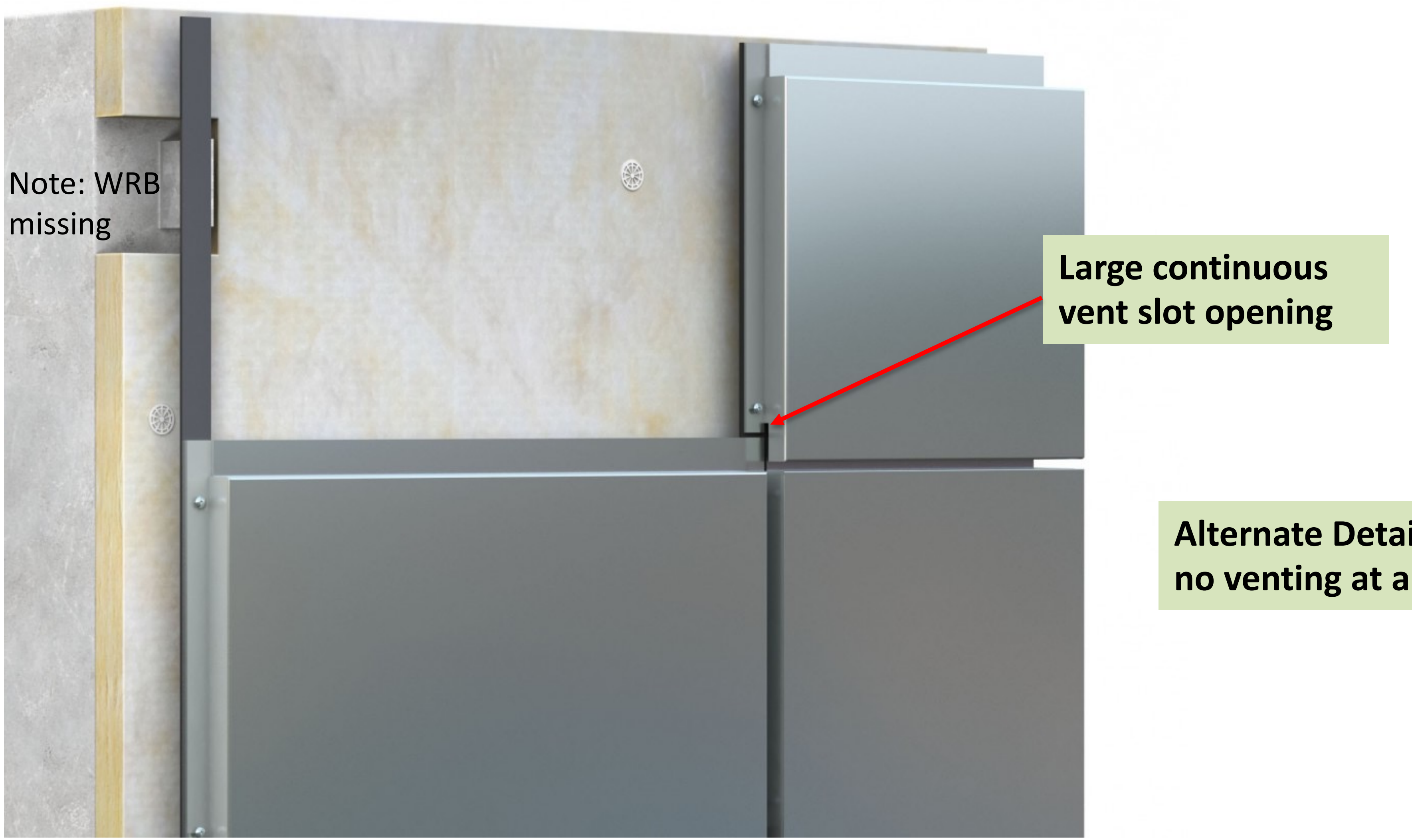


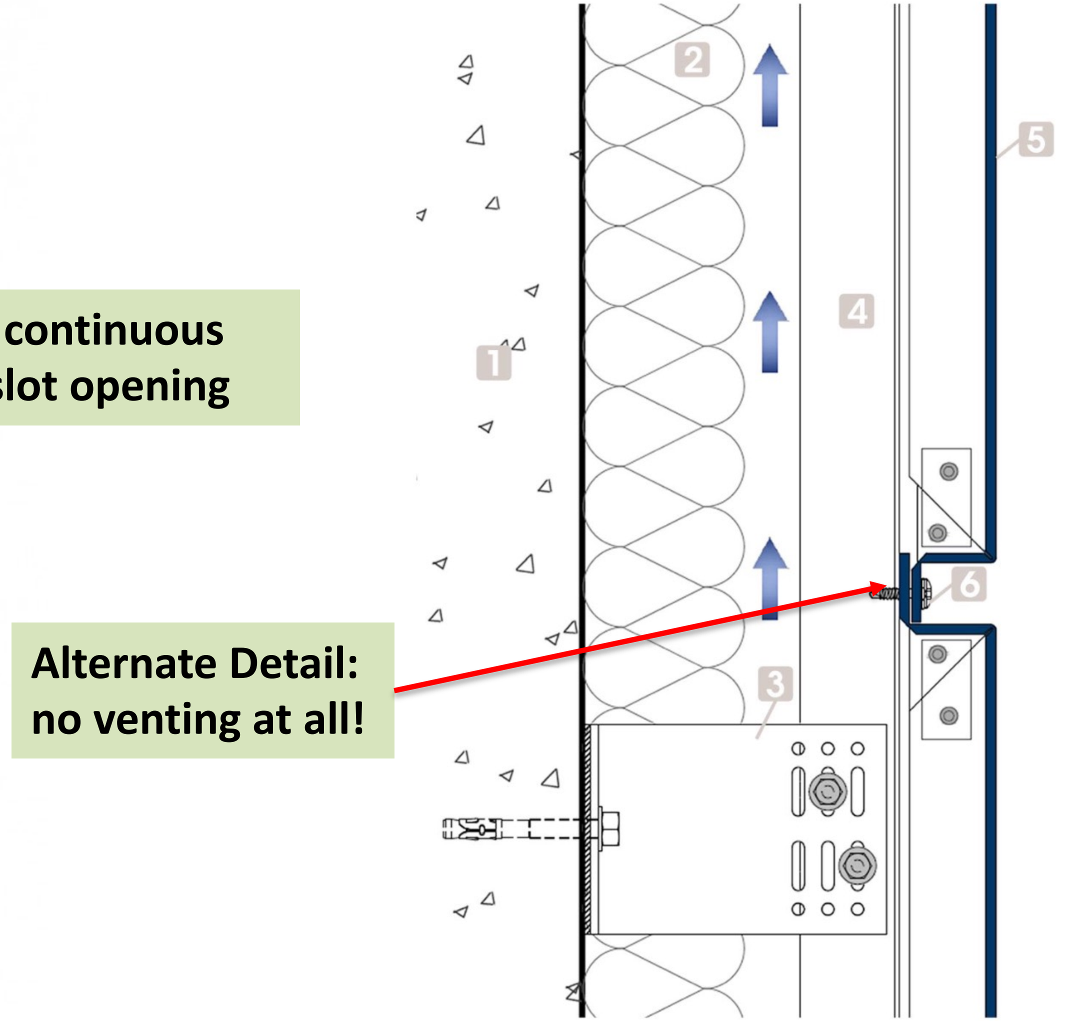
This system closes joints on the face …
and opens them top and bottom



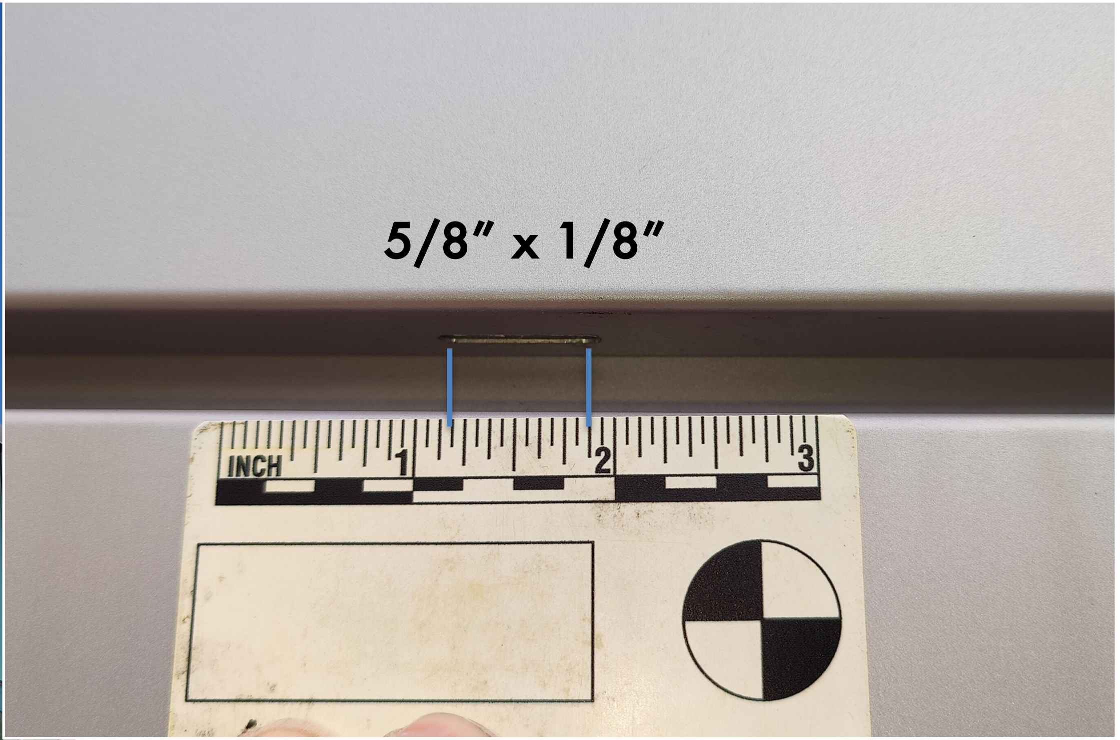
4. Perforated Angle
How perforated?
25%? 50%

Joints are not always vent openings





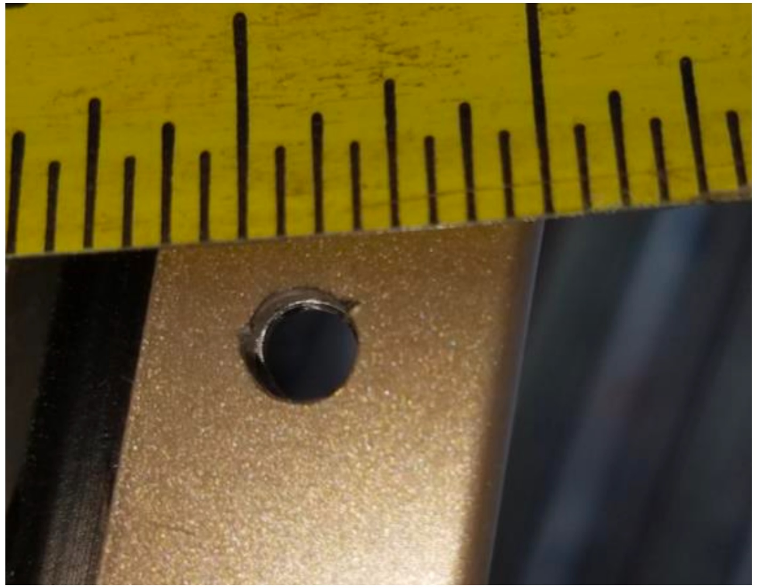
Joints are not always vent openings



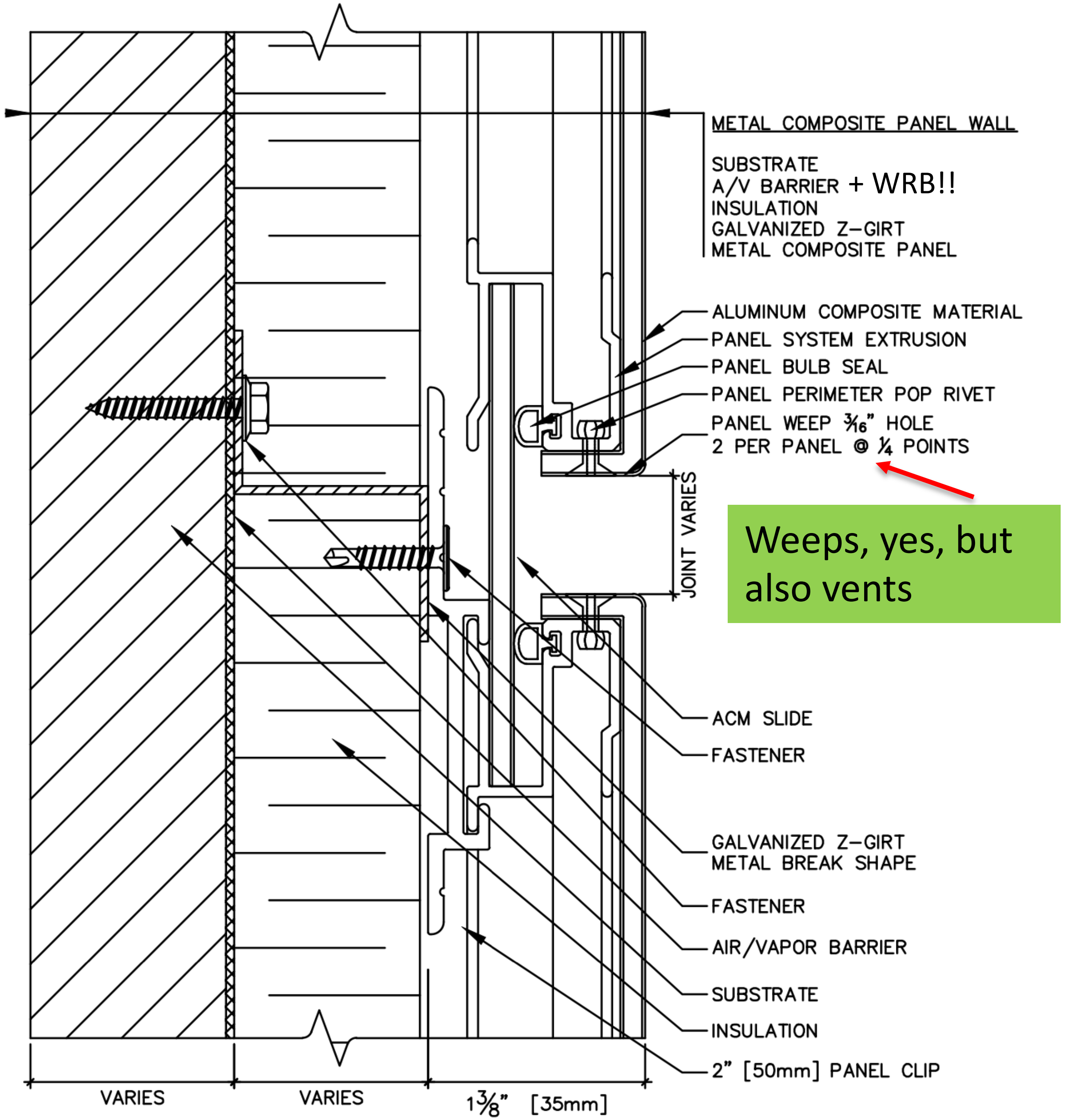
Just two small weep (vent) holes at each panel base.

Vent holes

- If used, usually biggest resistance to air flow
- Vents control ventilation and pressure equalization performance



Weep Hole in Bottom of ACM Panel



Unvented Metal Cladding

- Metal is a perfect vapor barrier
- Often not intentional ventilated
- During cold weather
  - condensation occurs on back of cold impermeable metal
  - When warmed above freezing, condensate runs down by drainage
  - “weeps” out at bottom
- Ventilation would be better, but…

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Summary

Some conclusions

- We can calculate and roughly predict ventilation flow
- Ventilation flow is resisted by both vents and gaps
- Vents seems to be much more important and significant
- Larger gaps are more important for Dimensional Tolerances
- We don't have very much detailed information about common vents, drainage mats, etc.

Practical Implications

- Not all systems need ventilation

… but it is almost always helpful for rainscreen walls

- Required amount of ventilation for benefit varies
  - Moisture sensitive claddings benefit the most
- Both vent openings and gap must be considered
- Many current systems have very small vent openings

Questions?

Vented vs Ventilated

- Both have air gaps, both are drained