Attic Ventilation

Affordable Comfort 2011

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BRC Attic Research Lab

What are the Reasons for Attic Ventilation?

- Prevent winter condensation problems
- Prevent ice damming problems
- Promote shingle life
- Reduce summer cooling energy costs

What is the attic ventilation standard?

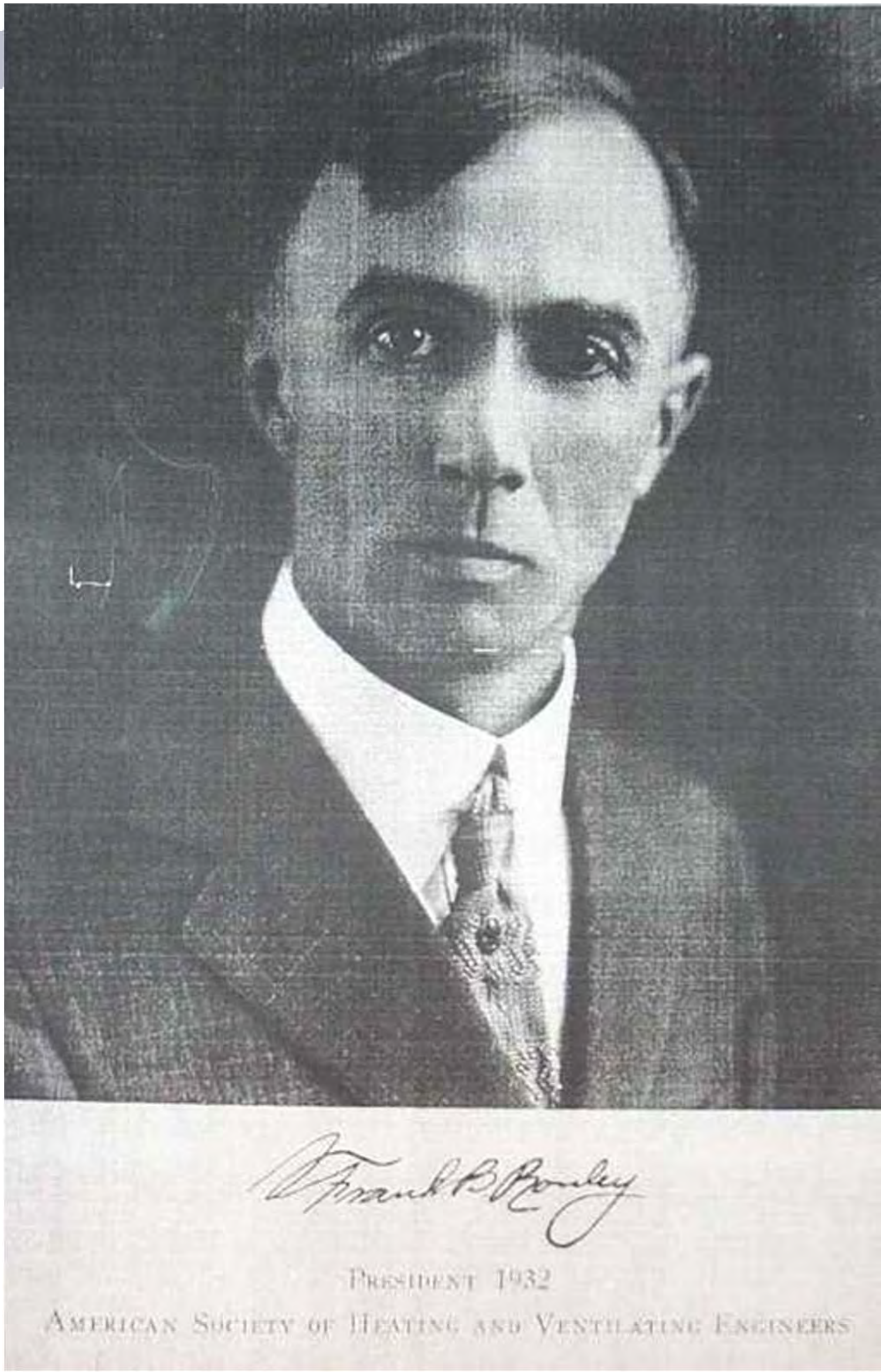
1:300 – vent area to reflected roof area

Where does this come from?

On what basis?

Frank Rowley

- Professor of Mechanical Engineering at the University of Minnesota
- Measured R-values of building materials
- Was President of ASHRAE in 1932
- Received research funding from National Mineral Wool Association.



Rowley 1938

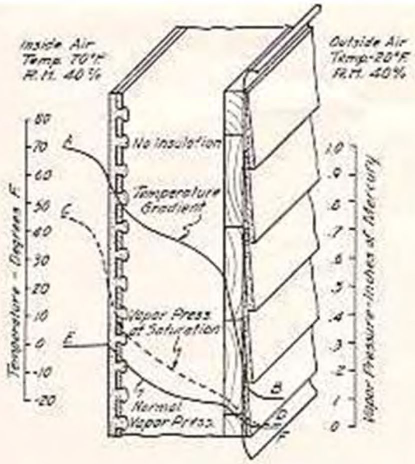


Fig. 7—Frame wall without insulation showing normal temperature and vapor pressure gradient through wall

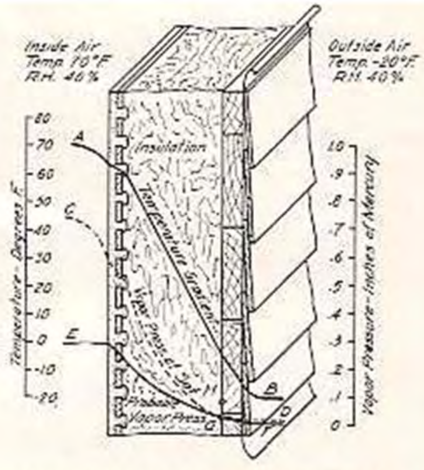
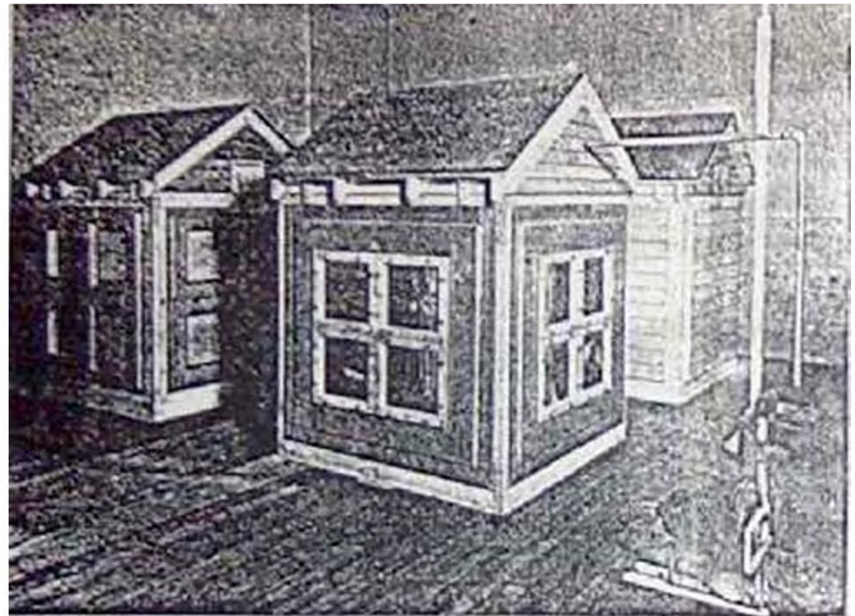


Fig. 8—Frame wall with insulation showing temperature and vapor pressure gradients as established through wall. H indicates vapor pressure required at inner surface of sheathing to prevent condensation. G indicates maximum vapor pressure allowed by temperature of sheathing



. 5. View of Set-up for Ventilated and Unventilated Attics. Apparatus in reground Used for Measuring Supply of Air to Mechanically Ventilated Attics

Table 5—Attic Ventilation

Test No.	Period No.	Duration of Test	Outside Air Temp, Deg F	Inside Air Conditions		No Ventilation		Natural Ventilation			Mechanical Ventilation		
				Deg F	R. H. %	Attic Air, Temp.	Condensation[a]	Opening, sq in[b]	Attic Air Temp.	Condensation	Air Supplied, cu ft[c]	Attic Air Temp.	Condensation
19	1	54	−10.4	70.3	40.5	4.6	3.01	0.25	−0.4	0.0	3.0	1.8	0.00
19	2–3	68	−10.3	70.0	40.9	4.6	3.33	0.125	1.2	0.16	1.5	2.0	0.03
20	1	66	+15.0	70.1	40.6	26.9	0.0	0.125	24.2	0.0	1.5	24.3	0.00
20	2	99	+10.0	69.9	40.3	22.6	0.0	0.125	19.9	0.0	1.5	19.7	0.00
20	3	117	+5.0	70.1	40.6	17.3	1.16	0.125	13.9	0.0	1.5	14.4	0.00
20	4	72	+5.0	70.0	31.3	17.6	0.78	0.125	14.6	0.0	1.5	15.0	0.00
20	5	72	+5.0	70.1	20.7	16.9	−1.02	0.125	14.1	0.0	1.5	14.4	0.00
20	6	98	+10.0	70.1	20.6	20.5	−1.22	0.125	18.3	0.0	1.5	18.4	0.00
20	7	66	+15.0	70.1	21.0	23.4	0.0	0.125	21.2	0.0	1.5	21.2	0.00
20	12	141	0.0	70.0	21.3	11.8	1.76	0.125	7.8	0.0	1.5	9.6	0.00
20	13	72	−11.4	70.1	19.9	1.43	2.52	0.125	−2.5	0.0	1.5	−0.5	0.00

[a] Condensation in grams per square foot ceiling area per 24 hours.
[b] Opening in square inches per square foot ceiling area in each gable.
[c] Air supplied in cubic feet per hour per square foot ceiling area.

Rowley 1938

- Test conditions: Exterior -10^o F, Interior – 70^o F and 40% RH
- Rowley found that with 2 gable vents providing 1:288 vent area, condensation was reduced over no ventilation
- This is the sum total of the research that verifies the 1:300 standard

Rowley’s Conclusions 1938

4. It is possible to reduce the rate of condensation within a structure by ventilating to the outside. This method may be particularly effective in attics where the condensation occurs on the underside of the roof.

9. For cold attic spaces it is desirable to allow openings for outside air circulation through attic space as a precaution against condensation on the underside of the roof even though barriers are used in the ceiling below.

Rowley also strongly emphasized the need to reduce interior humidity levels.

09 LIGHT AND VENTILATION (cont.)

J Basementless Spaces

1. Provide a sufficient number of foundation wall vents to assure a total ventilating area equivalent to 1/2 percent of the enclosed area plus 1/2 square foot for each 25 lineal feet of wall enclosing that area.

2. Number of vents: minimum 2.

3. Locate vents to provide cross-ventilation wherever possible.

4. No vents required for basementless spaces, one side of which, exclusive of structural supports such as piers, chimney foundations, etc., is open to a ventilated basement, provided the total area of ventilating openings is 2 percent of the basement area plus the area of the basementless space.

5. In each vent opening install corrosion-resistant screening, mesh not less than 8 per inch.

K Attics (Includes air space between ceiling and flat roofs).

1. Provide effective fixed ventilation in all spaces between roofs and top floor ceilings, by screened louvres or by other means acceptable to the Chief Architect.

2. Net ventilation area for each separate space to be not less than 1/300 of horizontally projected roof area. Where possible, locate vents to provide effective cross-ventilation.

3. Use corrosion-resistant screening over openings, mesh not less than 12 per inch.

0 SPACE REQUIREMENTS (Applies also to Existing Construction.)

A Living Unit

Provide space of not less than the areas indicated (inside rough dimension) for each of the following purposes:

FHA 1942

The first time 1:300 showed up in a guideline. It has been passed along ever since.

Issue #1: Condensation Control

Back to Rowley - 1939

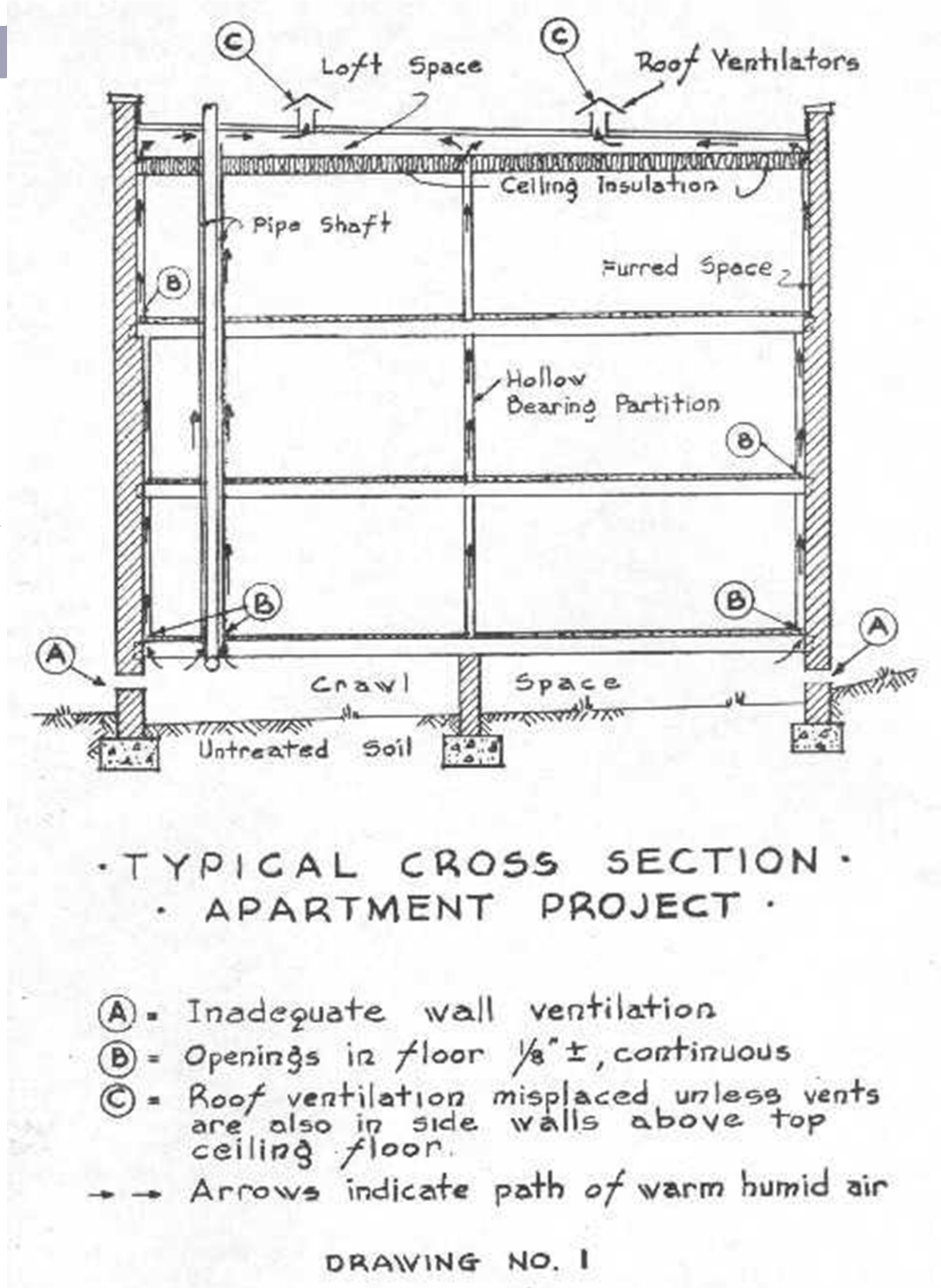
- Condensation control was the stimulus that led to attic ventilation Standards
- Weighed ice accumulation on metal plates
  - 3.3 $g/ft^2/24$ hr (his worst case of the tests)
  - Conditions: -10^o F outside, 40% RH inside. This is very cold, and very wet (given the outdoor temperature)

Critique of Rowley's conclusions

- Assume 1 sq ft. of 3/4" pine sheathing. Weighs about 1000g.
- Safe range of moisture content 10% to 23%, or accumulation range of 130g.
- Assume -10°F, constant, unchanging. Indoor 40%RH
- To go from the dry end to the wet end of the safe range requires:
  - For "unvented" attic: 43 days
  - For "undervented" attic (1:576): 2 years+.
- Rowley never studied attics with vapor barriers in place.
- It is not clear that Rowley's recommendation for attic ventilation is supported by his research

Ralph Britton 1947

Generally supported attic ventilation, but also made this important observation.



Other Research: Jordan – 1948*

- Attic moisture readings of 3 attics in Madison, WI
- Attic moisture conditions corresponded to interior humidity
- Attic vent area made little difference
- Only the house with the highest interior humidity had attic condensation

*Jordan, Peck, Strange, *Attic Condensation in Tightly Built Houses*, HHFA, 1948

Other Research: CMHC – 1991*

- Canadian survey of moisture conditions in attics
- “High attic moisture content was not found in the absence of high house humidities.”
- Other research started emphasizing air infiltration rather than vapor diffusion into the attic

*Buchan, Lawton, Parent, *Survey of Moisture Levels in Attics,* CMHC, 1991

Research – Champaign, IL

- Moisture problems occur in buildings with high moisture loads. A survey of homes in Champaign County IL showed 42 of 670 homes had severe damage to roof sheathing, and all of these homes were on wet crawl spaces.

BRC Attic Research Lab

- In the field laboratory in Champaign IL, with indoor humidity held at 50% during the winter, moisture damage did not occur in any of the flat-ceiling attic cavities.
- Condensation required a hole in the ceiling plane

Cathedral Ceilings

- More prone to moisture damage in cold climates
- Isolated conditions in each cavity, and very limited volume
- Some cavities are nearly impossible to ventilation
- Ridge vents with inadequate make-up air at soffits is a bad recipe


$28,000 Moisture Case Study

Building Shell Characteristics

- Single story ranch style modular on full conditioned basement (18 years old)
- 1,056 sq.ft living area
- Double Pane exterior windows
- Pre Blower Door test 1,857 cfm50
- R-19 fiberglass batts in attic
- Continuous Soffit venting
- **Bath exhaust vented to attic**
- **Moisture problems in the attic**

Weatherization Work

- Replaced primary door on basement entry
- Installed low flow shower head
- Minor air sealing
- Added 4 inches of cellulose in attic (good job)
- Client did not let WX vent the bathroom to exterior (should have walked away)
- Installed 2 high mounted R-44 roof vents
- Post blower door, 1,704 cfm50

PA Case Study

WX added attic ventilation, and . . .

Moisture problems in the attic got worse –
much worse!

If attic ventilation helps protect against moisture, why did this happen?

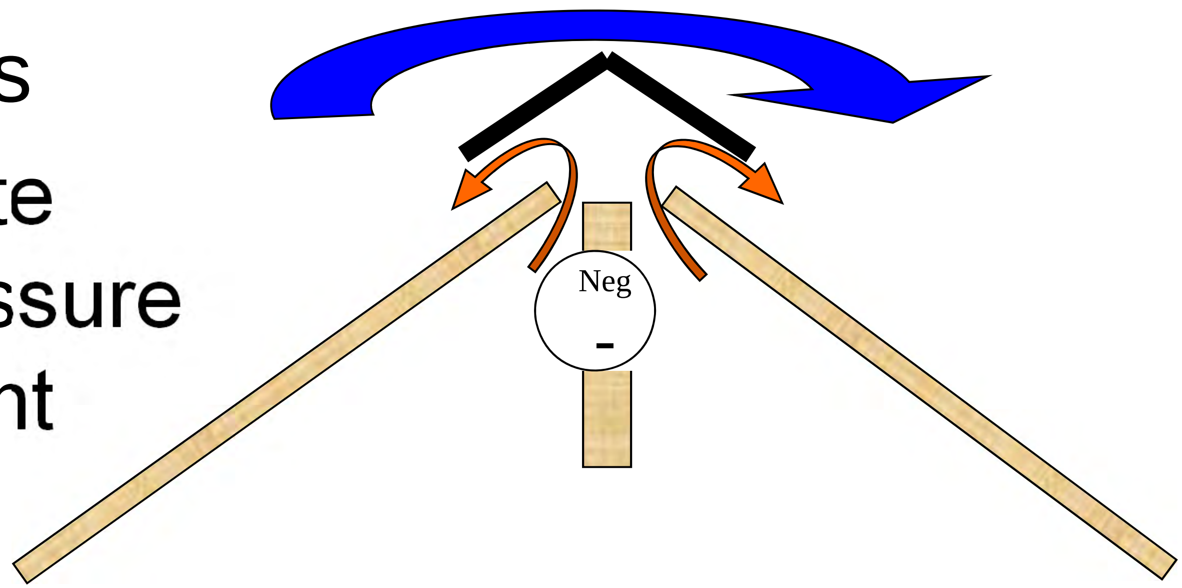
What are the forces that drive air exchange in an attic?

What pressures drive attic ventilation?

- Wind – and that is about it.
  - Little stack effect in the attic – they aren't very tall.
  - Shouldn't be any induced pressures from mechanical systems (we don't want duct leakage in the attic)
- Attic ventilation provides air flow only to the extent that the wind blows.

Wind impact on vents high on the roof

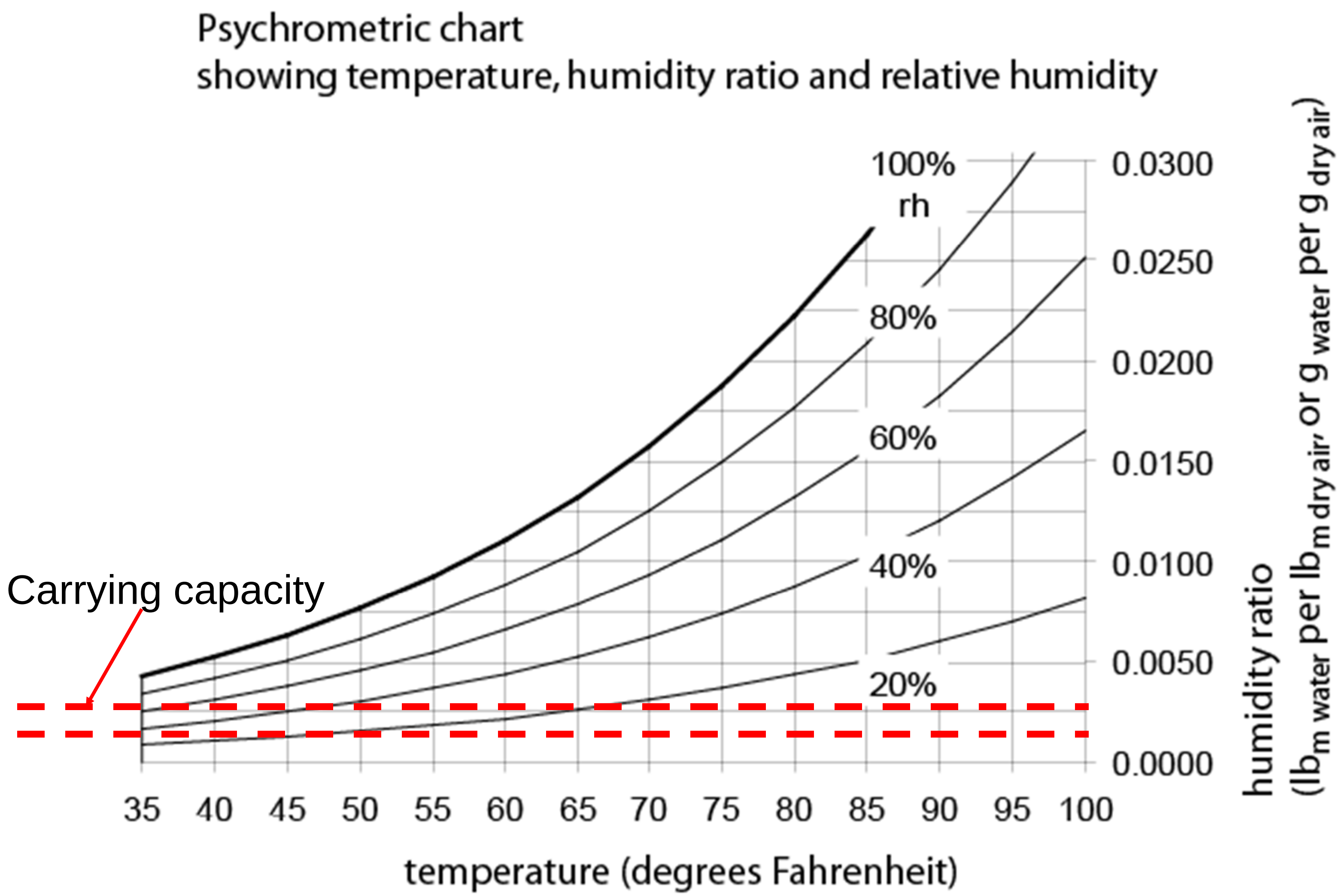
- High vents are exhaust vents
- They generate negative pressure below the vent



PA Case Study

- You can add ventilation, and make the moisture problems in the attic worse!

Psychrometric Chart



Wet, Cold, Coastal Climates

- Computer simulation indicates that attic ventilation results in higher sheathing moisture content, not lower
- Ventilation makes the attic colder, without lowering water vapor levels very much
- Colder means wetter

Forest, Walker, *Attic ventilation and Moisture. Final Report,* CMHC, 1993

Warm and Humid Climates

- No one has ever claimed moisture control benefits in venting attics in warm, humid climates
- Outside air is more humid than inside, and attic venting will tend to increase rather than decrease moisture levels in the attic

Moisture - Conclusions

- The three parameters for attic condensation in cold climates:
  - Interior house humidity
  - Ceiling air tightness and pressures
  - Attic ventilation
- Attic ventilation will have a *slight* positive influence, but it is 3rd in the list.

Ice damming

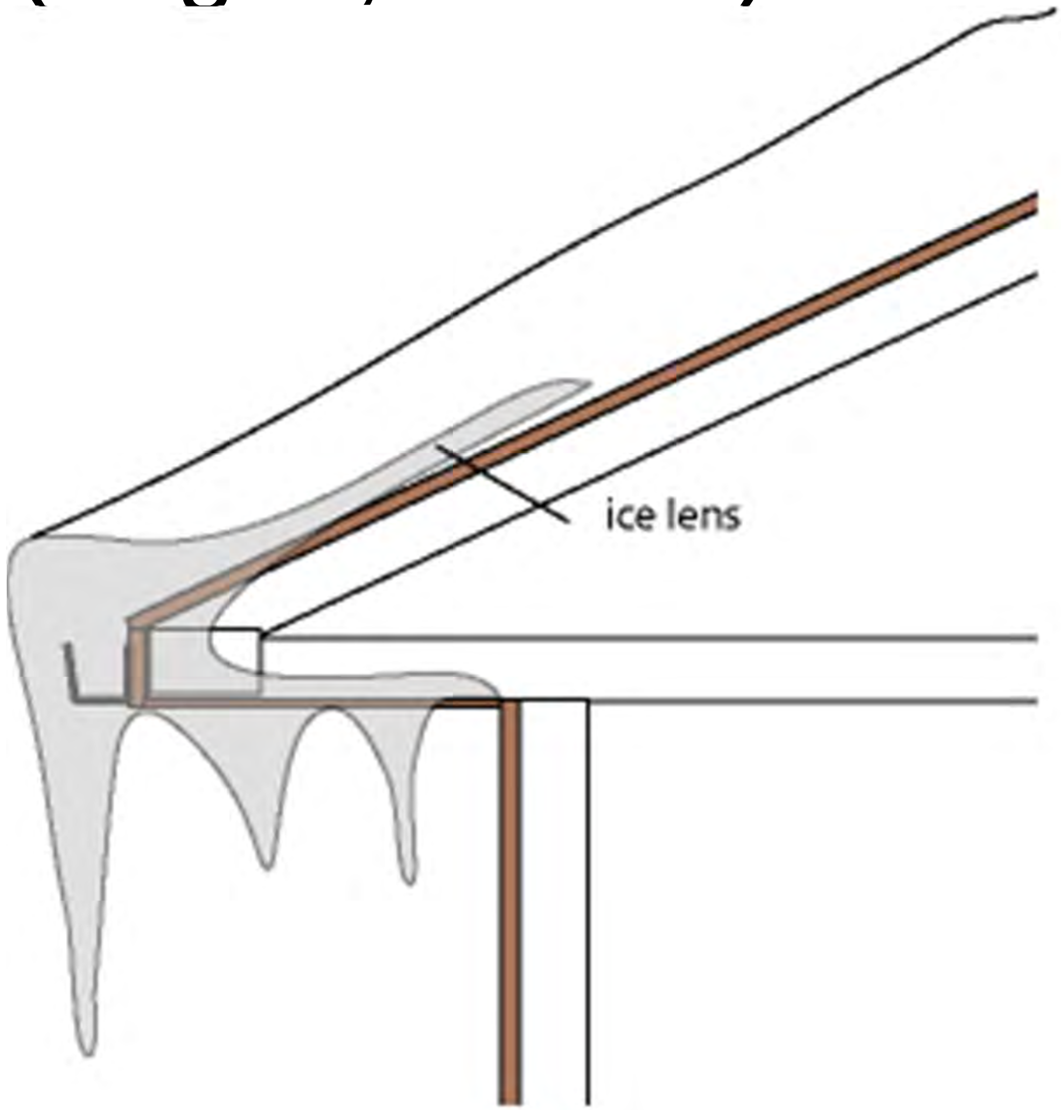
- What does an ice dam look like?
- Prioritizing causal factors
- Run the numbers: Icedam.xls
- Conclusions

Why do ice dams occur? From Rogers 1952.

Cold overhanging eaves often cause ice-dams, leaking roofs and hazardous icicles. Snow on the sloping roof is melted by sun and roof heat losses combined. At the eave melting is slower, forming a snow or ice dam. Overflow may back up under shingles and also form dangerous icicles. Eave vents, creating an air wash under the sheathing, reduce these hazards.

Ice dam profile (Fugler, CMHC)

- Note the ice lens



Research: Canada, 1996

- 33 houses in Ottawa, Canada
- 16 houses had ice dams, 17 control
- All 16 with ice dams had interior chimneys, and were about 7^{o} F warmer than the others
- 16 houses with ice dams had less insulation in the ceiling

Constants				
Density of water	Dwater	62	lb/cf	
Heat of fusion-water	Hf	143.5	Btu/lbm	
Specific heat of air	Cair	0.24	Btu/lbm-degF	
Specific volume of air	Vair	12.5	cf/lb	
Snow r-value	rsnow1	1	hr-sf-degF/Btu-in	
Inputs				
Attic Insulation Area	Aattic	2000	sf	
Roof Area	Aroof	3000	sf	
Snow depth	Dsnow	24	in	
Indoor Air Temperature	Ti	70	degF	
Outdoor Air Temperature	To	22	degF	
Critical Attic Temperature	Ta	32	degF	
Attic Insulation R-value	Rattic	38	hr-sf-degF/Btu	
Vent section area	Avent	3.33	sf	represents 1/2 of
Calculations				
Total snow R-value	Rsnow	24	hr-sf-deg	=rsnow1*Dsnow
Temp. difference across insulation	dTinsul	38	degF	=Ti-Ta
Temp. difference across snow	dTsnow	10	degF	=Ta-To
Heat Loss across insulation	Qinsul	2000	Btu/hr	=Aattic*dTinsul/R
Heat Loss across snow	Qsnow	1250	Btu/hr	=Aroof*dTsnow/F
Heat for melting	Qmelt	750	Btu/hr	=Qinsul-Qsnow
Rate of melting	Vmelt	0.14	cf/hr	=Qsnow/Hf/Dwat
Daily rate	Dmelt	3.37	cf/day	=Vmelt*24
Air flow to prevent melting	Mair	3906.25	cf/hr	=Qmelt*Vair/Cair
Length of air column	Lair	1171.875	ft/hr	=Mair/Avent
Air flow to prevent melting	Mairmin	19.531	cfm	

Bill Rose model of heat loss through by conduction leading to melting on the roof. No air leakage from the house.

“Even an unvented attic is very unlikely to develop to develop significant ice dams unless there are significant heat sources in the attic or significant air leakage from below,

Prioritizing causal factors

Ice dams occur from snow melting to water and refreezing to ice, all up on the roof.

- The principal cause of melting is heat from mechanical equipment or ductwork in the attic.
- The second cause is leaky ductwork.
- The third cause (or first if no ductwork) is air leakage through openings in the ceiling.
- The fourth cause is inadequate insulation
- The fifth cause is sun heating exposed roof

Venting cannot dilute this level of excess heat.

Venting has a minor role

- Venting is limited in its ability to dilute excess heat—limited by low quantities of flow through vents.
- Unfortunately heat losses to unconditioned attics, especially stupid wasteful losses, have no such physical limitations. Identify the vagrant heat source and correct it.

What to do about ice dams?

- Identify the vagrant heat source and correct it.
- For new building design: Keep mechanicals out of the attic, or, construct the attic so that a continuous sandwich of insulation is at the roof plane, thus keeping the equipment in the conditioned space.
- In an unconditioned attic space, avoid locating equipment and ducts there. If already there, make sure any ducts are airtight and well insulation.
- The ceiling should be made airtight.
- Provide adequate levels of insulation in the ceiling.
- Waterproofing underlayment should be used under at the eaves of a roof.

Ice damming - Conclusion

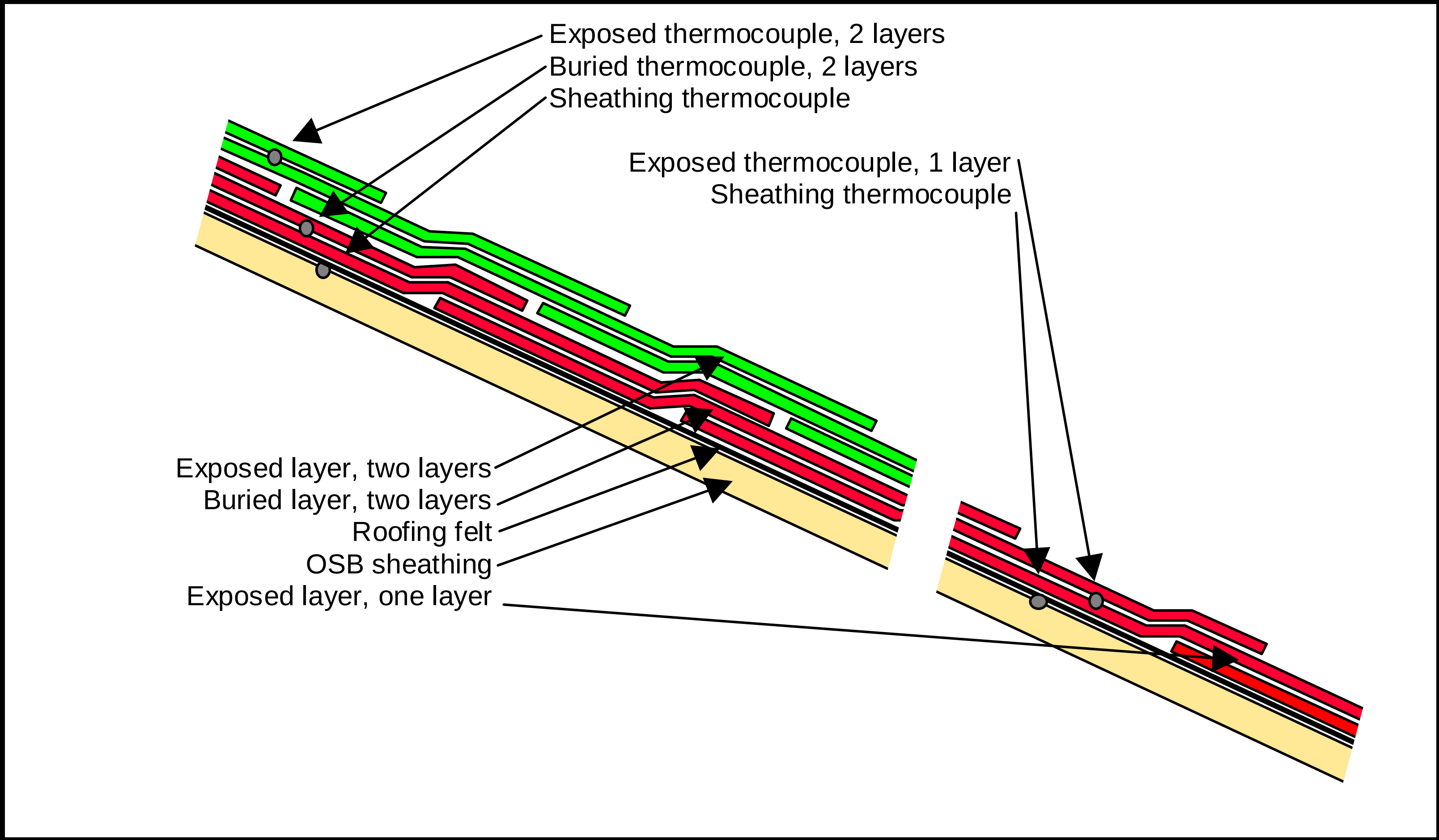
- Ice damming occurs when excess and vagrant heat causes snow on the roof to melt. (In a roof with only conductive heat transfer, melting from below is practically impossible.)
- Melting from exposed roof sections can occur regardless.
- If the heat that causes ice damming is due to mechanical equipment, ductwork and openings in the ceiling, why consider venting as a solution? If considered, it is not likely to be effective.

Shingle Service Life

- Warranties based on 1:300 attic ventilation
- These warranties did not appear until the mid-1980’s
- Why?
- One could be very cynical about this

BRC Attic Research Lab

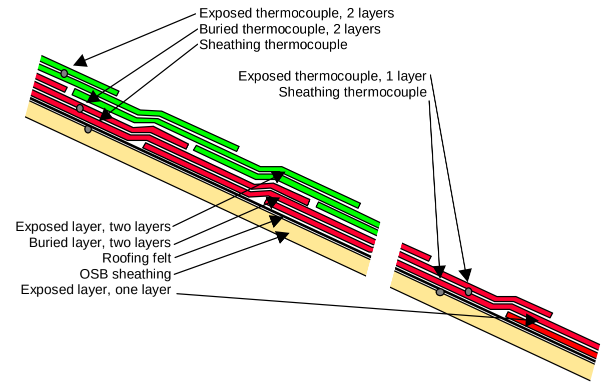
- This is an area where our lab collected a lot of data



Exposed thermocouple, 2 layers
Buried thermocouple, 2 layers
Sheathing thermocouple
Exposed thermocouple, 1 layer
Sheathing thermocouple
Exposed layer, two layers
Buried layer, two layers
Roofing felt
OSB sheathing
Exposed layer, one layer

Table 2.
Shingle temperatures compared to base case (shown in bold)
Summer data, two years

	Bay 1					
Shingles	white	white	white	white	white	white
Vented	yes	yes	yes	yes	yes	yes
Orientation	north	north	south	south	north	south
roof location	eave	ridge	ridge	eave	ridge	ridge
Layers	1	2	2	1	2	2
exposed/buried	exposed	buried	buried	exposed	exposed	exposed
cooler (-) hotter (+)	-32.0%	-34.3%	-23.4%	-22.7%	-38.0%	-27.2%
crossing (ºC)	20.5	21.4	19.6	18.2	22.2	21.0
St. Error of estimate (K)	3.6	3.9	3.6	3.3	4.2	4.0
	Bay 3					
Shingles	dark	dark	dark	**dark**	dark	dark
Vented	yes	yes	yes	**yes**	yes	yes
Orientation	north	north	south	**south**	north	south
roof location	eave	ridge	ridge	**eave**	ridge	ridge
Layers	1	2	2	**1**	2	2
exposed/buried	exposed	buried	buried	**exposed**	exposed	exposed
cooler (-) hotter (+)	-14.9%	-14.5%	-4.3%	**Base case**	-11.1%	3.0%
crossing (ºC)	25.4	29.5	38.5		29.5	12.9
St. Error of estimate (K)	2.7	3.5	2.4		3.1	2.4
	Bay 4					
shingles	dark	dark	dark	dark	dark	dark
vented	no	no	no	no	no	no
orientation	north	north	south	south	north	south
roof location	eave	ridge	ridge	eave	ridge	ridge
layers	1	2	2	1	2	2
exposed/buried	exposed	buried	buried	exposed	exposed	exposed
cooler (-) hotter (+)	-12.5%	-14.3%	0.0%	2.7%	-9.0%	4.7%
crossing (ºC)	28.5	30.6		13.8	32.7	13.0
St. Error of estimate (K)	3.0	3.8	2.3	1.0	3.2	1.2



Shingle Service Life

- Do shingle manufacturers make dark shingles? If so, they accept a 27% increase in shingle temperature.
- Do shingle manufacturers make shingles for the south elevation? If so, they accept a 14% increase in shingle temperature.
- Yet a 2.7% increase in shingle temperature voids the warranty?

Shingle service life?

S

Shingle Service Life - Conclusion

- Research shows there is little basis for thinking that attic ventilation has any significant impact on shingle life

Cooling season energy savings

- Well, we tried to measure energy use, but

This did not work very well.

Limit switches on AC units.

Basically lost in the noise.

Others have had similar results

Research – Dutt and Harrje, 1978

- 6 control and 6 vented townhouses in New Jersey
- Vented attics were cooler, but . .
- “any difference between the air conditioner use between houses with and without ventilation is not discernible from other factors which lead to house-to-house variation in air conditioning use.”
- Attic temperature did not matter much

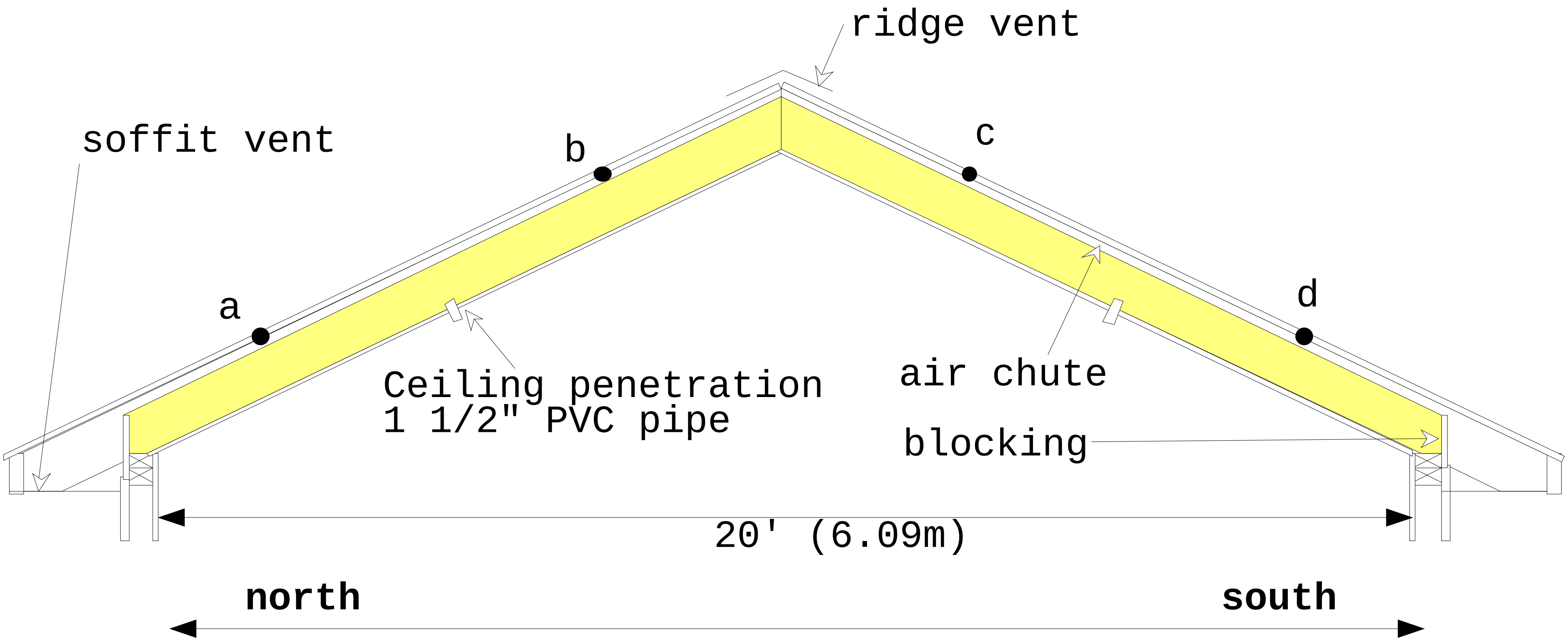
Research – Burch and Treado, 1978

- Compared many types of ventilation
  - None, soffitt, ridge, turbine, powered
- Conclusion: attic ventilation is not an effective energy conservation procedure for houses with more than 6.5” of attic insulation
- Best they got with power vent was a 3% reduction in cooling loads

A Story from Texas

- Our vent manufacture partner - CEO

What about cathedral ceilings?



Venting cathedral ceilings

- You cannot cool the upper part of a cathedral ceiling roof with venting. If a cathedral ceiling cavity is vented top and bottom, and faces south, then air moves through the cavity driven by buoyancy. Air enters at the soffit. As it moves up the vent slot it becomes heated and exits the ridge as heated air. If a cavity has a slot but no vents, the air in the slot will have a certain temperature. The air in the vented slot will reach that same temperature after, say, 10 feet. The remaining higher part of the slot will receive no cooling effect from the moving air.

Cooling season energy savings

- Venting will reduce the temperature in an open attic. The difference in attic temperature between a vented an unvented attic, with R-30 at the ceiling, translates into minuscule savings. No savings have ever been measured. Usually there is a penalty with venting because venting causes greater air pulsing across the ceiling.

Energy Savings

- In mixed climates, savings from delta T must be balanced by losses from delta T in the winter
- In cold climates, this is clearly a net loser

What have we learned about the impact of ventilation on 4 issues?

- Moisture control – can have a some impact, but it is small, and not the determining factor in an attic
- Ice damming – can have a some impact, but it is small, and not the determining factor
- Shingle Life – It is hard to see that it makes any difference, and if so, it is slight
- Cooling cost – It cools attics in summertime, but no one has measured much energy impact

Don’t Get Me Wrong, here . . .

- I never said it is bad
- Effects are mostly positive (but they can be negative)
- It is just that the benefits are small
- Small enough to take it off the “must include” list.
- Both vented and unvented assemblies can work

One more thing . . .

- Are you getting the venting effect you pay for?
- A revisit to Net Free Area

ARTA – Air Flow Resistance Test Apparatus

Q: How do we rate attic vents?

A: By “Net Free Area” = NFA

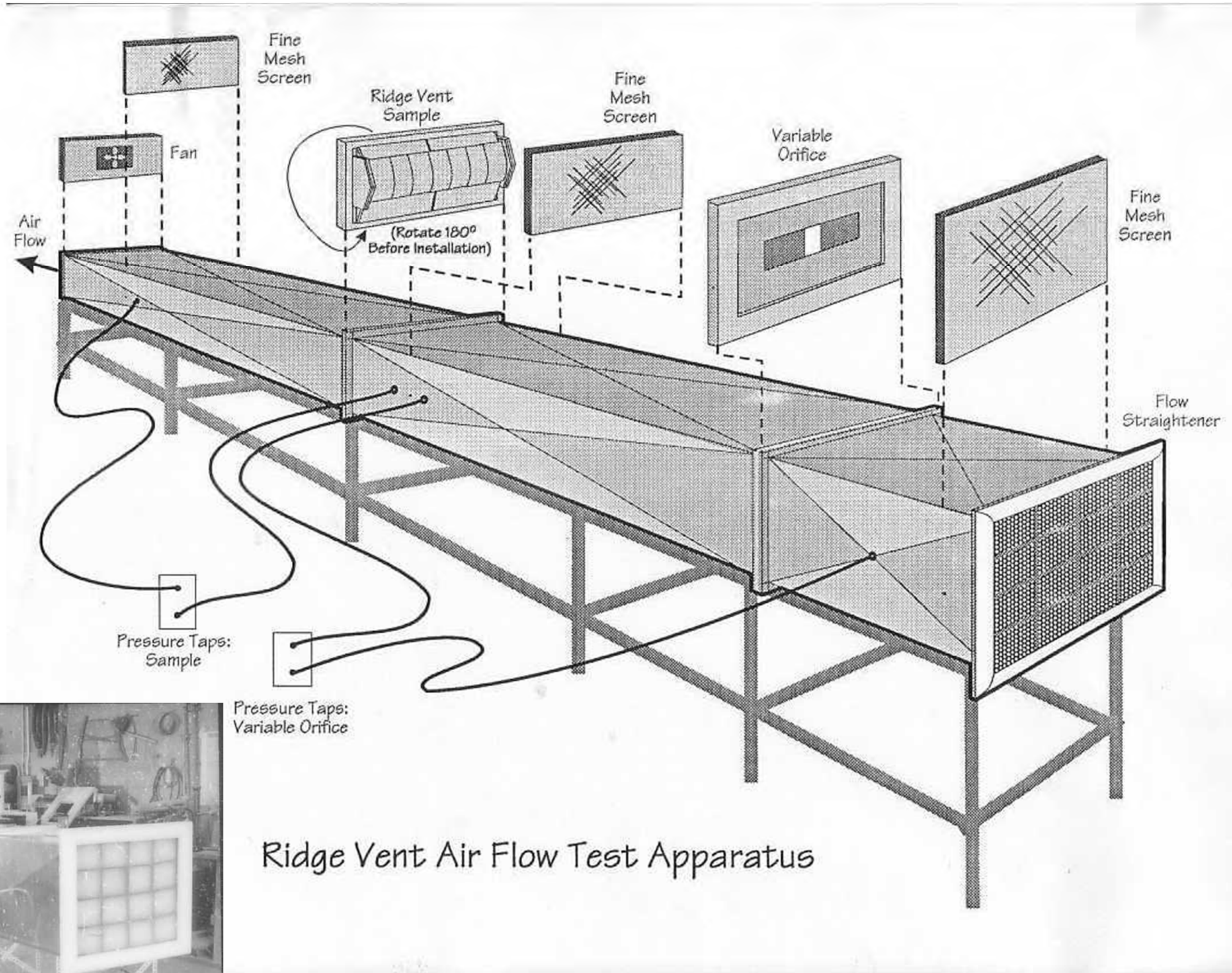
- These numbers are listed on the package, and we can get to the 1/300 rule.

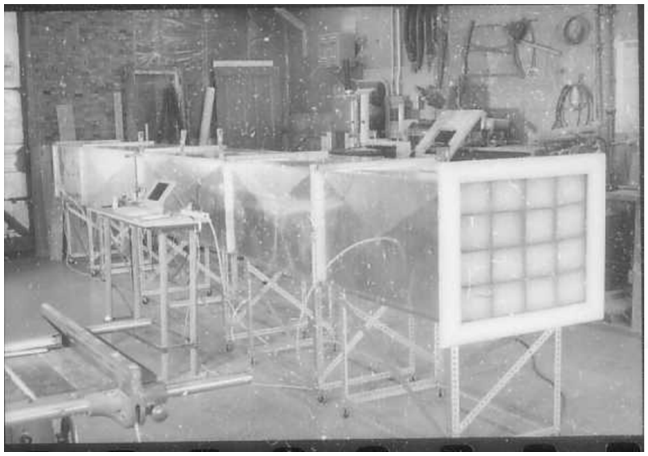
Q: How is NFA measured?

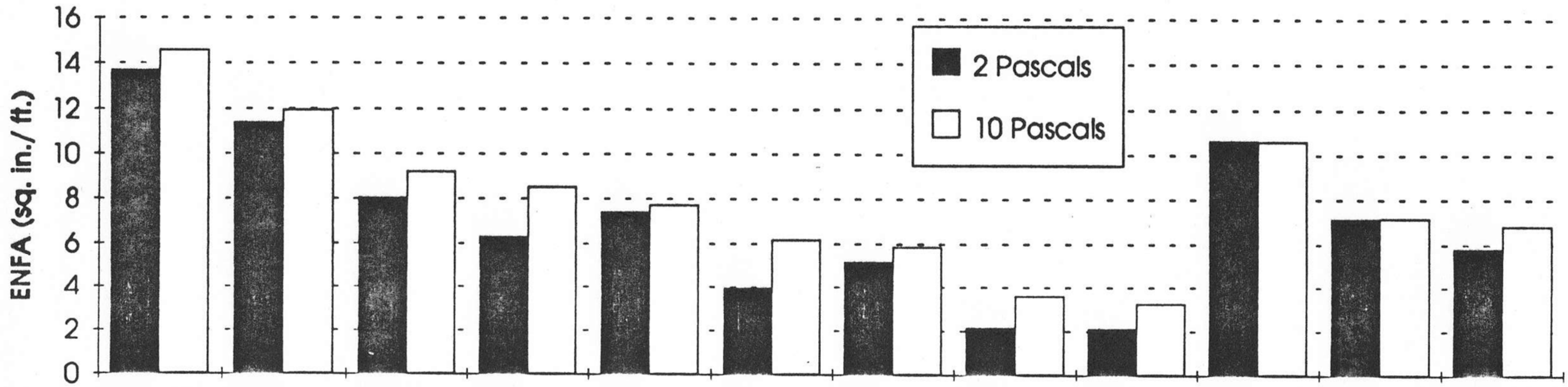
A: There is no standard. Basically, guys with calipers. With some products, in pretty silly ways. Do not account for filters.

What is the truth?

ARTA
Airflow Resistance Test Apparatus







Ridge Vents

'ent Device	Design description	NFA: Claimed	Orifice Size	ENFA		Orifice Size	ENFA	
HINGLE-OVER VENT DEVICES			2 Pascals			10 Pascals		
		18 sq. in. / ft.	6.84 x 4	13.68	sq. in./ ft.	7.28 x 4	14.56	sq. in./ ft.
		18 sq. in. / ft.	5.69 x 4	11.38	sq. in./ ft.	5.97 x 4	11.94	sq. in./ ft.
		18 sq. in. / ft.	4.01 x 4	8.03	sq. in./ ft.	4.60 x 4	9.2	sq. in./ ft.
		18 sq. in. / ft.	3.14 x 4	6.29	sq. in./ ft.	4.25 x 4	8.51	sq. in./ ft.
		18 sq. in. / ft.	3.70 x 4	7.4	sq. in./ ft.	3.86 x 4	7.73	sq. in./ ft.
		12 sq. in./ ft.	1.96 x 4	3.93	sq. in./ ft.	3.08 x 4	6.16	sq. in./ ft.
		12.29 sq. in./ ft.	2.56 x 4	5.13	sq. in./ ft.	2.92 x 4	5.84	sq. in./ ft.
		n.a.	1.07 x 4	2.14	sq. in./ ft.	1.79 x 4	3.59	sq. in./ ft.
		12 sq. in./ ft.	1.06 x 4	2.13	sq. in./ ft.	1.62 x 4	3.25	sq. in./ ft.
			2 Pascals			10 Pascals		
		n.a.	5.31 x 4	10.63	sq. in./ ft.	5.30 x 4	10.6	sq. in./ ft.
		n.a.	3.57 x 4	7.14	sq. in./ ft.	3.58 x 4	7.16	sq. in./ ft.
		n.a.	2.89 x 4	5.78	sq. in./ ft.	3.42 x 4	6.84	sq. in./ ft.

ARTA Results - Ridge Vents

Many ridge vents perform at less than half their listed rating.

The presence of filters to prevent snow infiltration has a significant impact.

ARTA Takeaway

- There are two kinds of ridge vents
  - Liars
  - Damn Liars
- If attic ventilation were serious, then the standard for measurement of net free area should be serious. It isn't.
- Many vented attics aren't vented very much
- Many unvented attics probably are kinda vented
- The 1:300 ratio doesn't mean much in light of this research

Questions?

Further discussion?