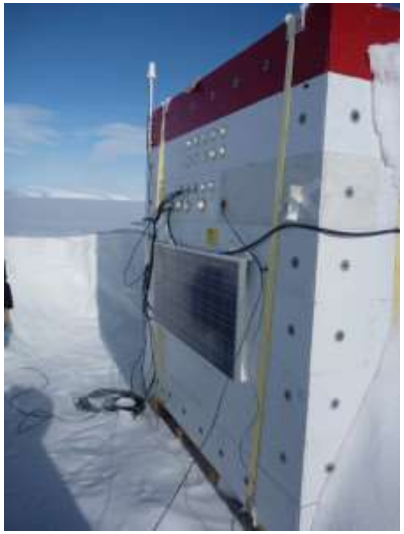
Henri Fennell, CSI/CDT

Henri is an architect and building envelope specialist with over fifty years of experience in the construction industry. He was a pioneer in the solar industry, introduced the installation technique for field-applied closed-cell cavity-fill polyurethane foam, developed a pressurized theatrical fog quality assurance technique and protocol, and has designed and constructed a net-zero energy research structure in Antarctica. He has four energy-related U.S. patents.

Henri Fennell, CSI/CDT

Net-zero energy research structure in Antarctica



The Big Dig in Boston, MA

HCF foam experience

1. First spray foam project was in 1971
2. Foam manufacturing from 1973 to 1979
3. Foam contracting and BE consulting from 1979 to 2009
   - Developed the method for injecting closed-cell foam on site
   - Installed ~ 5 million pounds of foam
4. Foam and BE commissioning from 2009 to present
5. Noteworthy foam projects include:
   - 1977 net-zero solar project in Boston, The Big Dig, Four American Ski Grande Hotels in the Northeast (2001-2007), Net-zero energy weather station in Antarctica, The Guggenheim Museum, Two US patents and numerous technical papers related to foam & foam QA

Fun projects

- Autonomous Remote Research Observatory (2005) – Net-zero energy in Antarctica (.035 CFM50/sf)
- The Solomon R. Guggenheim Museum (2007 & 2008)
- American Skiing Company, Inc. (2001-2007) – Ice dam remediation at the four Northeast Grand Hotels
- Mount Washington Place (1996) – Ice dam remediation
- Kendal at Hanover (1994-1995) – Ice dam remediation
- The Big Dig (2007 & 2008) – largest frozen earth retainage project

Maine Indoor Air Quality Council

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The First Frontier in Home Weatherization: Attics and Cathedral Roof Slopes

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Learning Objectives - At the end of this program:

1. Participants will be able to choose when to use vented and unvented attics and cathedral roofs in their designs.
2. Participants will be able to diagnose insulation and air leakage problems in attics and cathedral roof slopes.
3. Participants will be able to employ tracking of the attic and roof temperatures and pattern analysis during the work to prioritize leakage sites and reduce remediation costs.
4. Participants will be able to verify performance improvements using the same diagnostic tools that they use for other building performance diagnostics.
5. Participants will be able to use diagnostic methods to prioritize remediation work and to maximize return on investment.

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Outline

Attics vs. cathedral slopes

The causes of roof problems

Vented vs. unvented cathedral roof slopes

Diagnostic methods

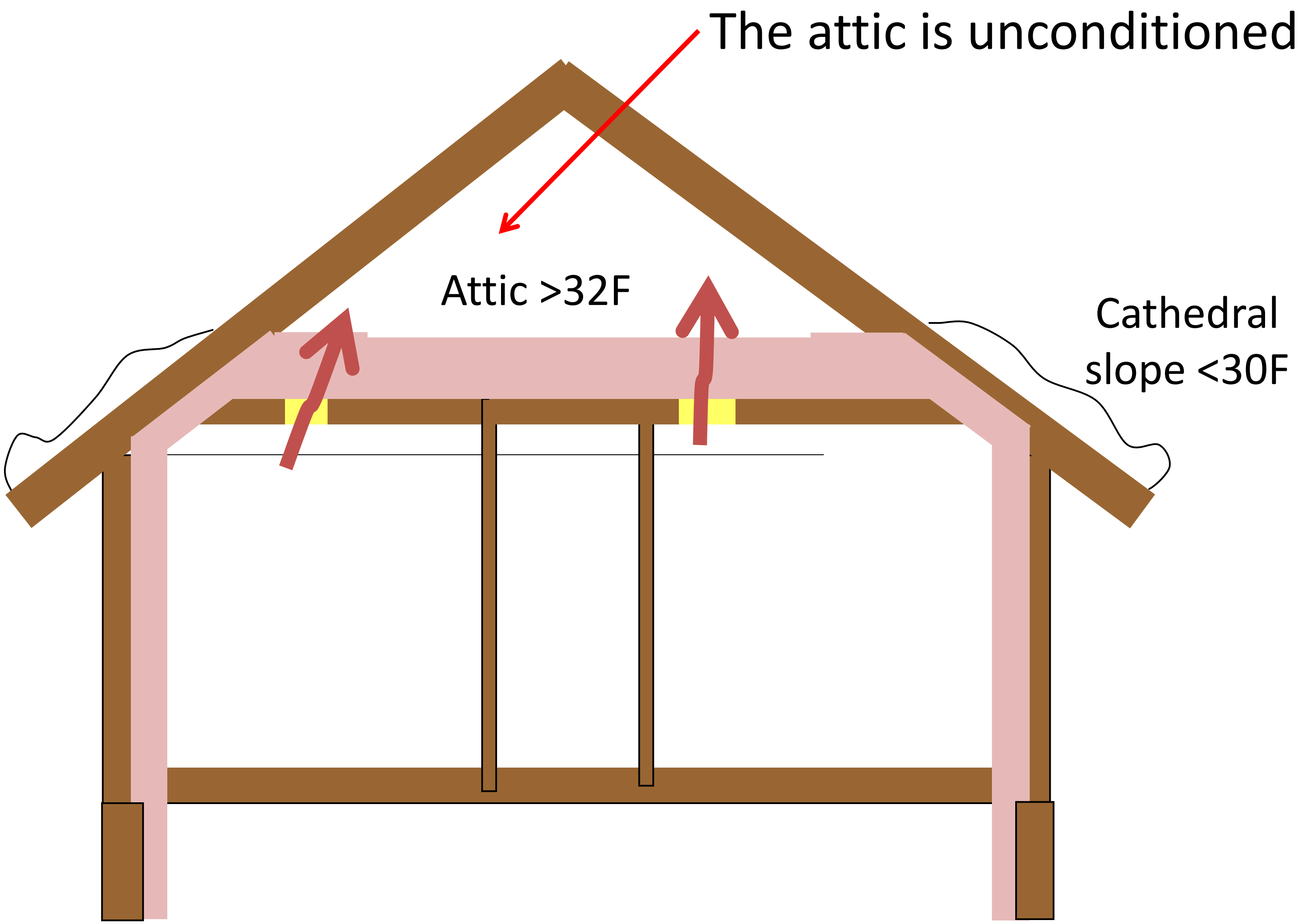
What poor performance looks like

Repair methods and ROI

Attics vs. cathedral slopes

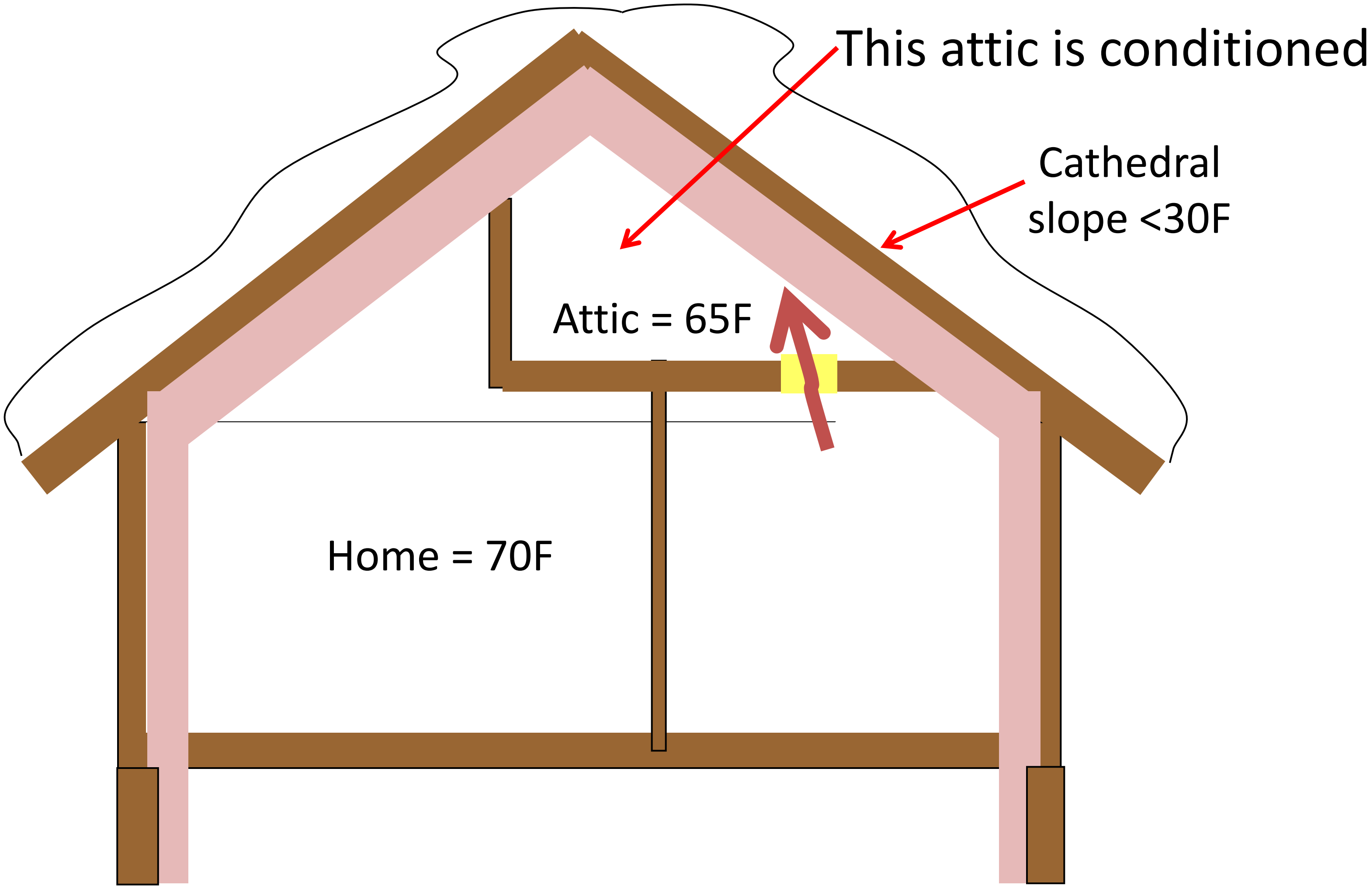
1. Attics typically have their Building Envelopes (insulation, vapor retarder, and air barrier) at the attic floor and kneewalls.
2. Cathedral Roof Slopes have their Building Envelopes at the roofs and gable-end walls.

Building Enclosure (BE) in attics

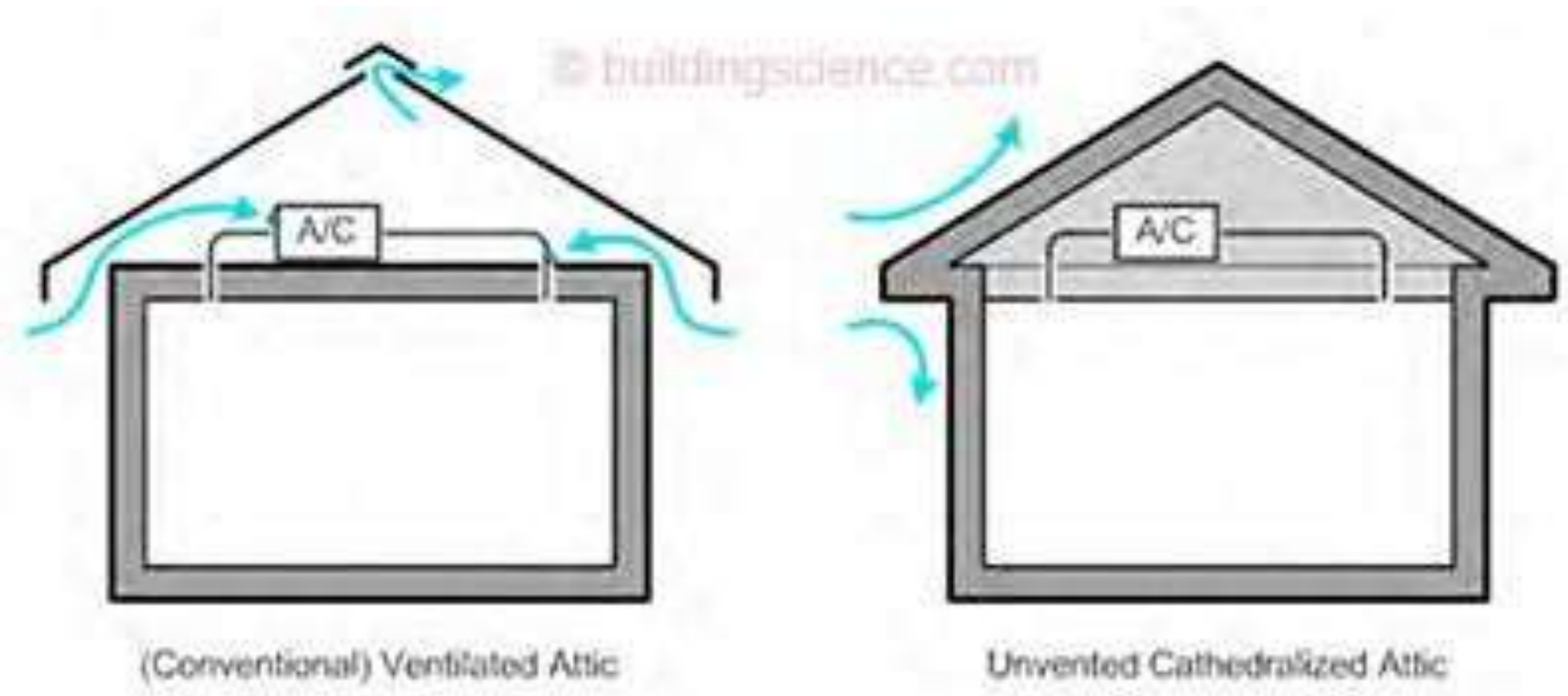


Without venting this attic will have ice dams and mold

Building Enclosure (BE) in cathedral slopes



Building Enclosures (BE) in attics vs. in cathedral slopes



Courtesy: Building Science Corp.

Attics vs. cathedral slopes

Classic cathedral slope melt pattern below a leaky attic's melt pattern

Attics vs. cathedral slopes

Melt pattern shows insulation and air leakage problems in attics vs. cathedral roof slope performance

You have to be in the right place at the right time for this one

Attics vs. cathedral slopes

Classic icing at the bottom of cathedral slopes below leaky attics

Ventilation

1. Ventilation is the movement of air through attics or under the roof deck in cathedral slopes
2. The purpose of ventilation in Attics and Cathedral Roof Slopes is to:
    a. Remove moisture
    b. Keep the roof surfaces cool in winter to prevent icing
3. Ventilation sources must not be indoor conditioned air

Ventilation issues

1. Code ventilation minimums were originally based on how much air flow is required to dry out attics
2. Are code minimums effective?
   - It can depend on how much air leakage is occurring
   - Unvented cathedral roof slopes have very consistent performance (good or bad)
   - Vented attics and roof slopes are not consistent because they have many other possible causes of roof warming
3. Inlet/outlet devices are required to provide adequate air flow, but they must be balanced

Attic designs that don't account for even distribution of inlets and outlets

Complex roof configurations – skylights, dormers, valleys, hips, etc.

Overbuilt dormers usually do not contribute to upper attic ventilation

Complex roof configurations – skylights, dormers, valleys, hips, etc. and No Venting

If a vented roof type is chosen - size, balance, and distribute the ventilation system carefully.

The causes of roof problems

The causes of attic performance problems

1. Attics must be vented.
2. Unvented attics always fail because we don’t have another way to remove moisture and heat loss.
3. Any attics that do work without intended ventilation have enough air leakage to actually provide ventilation.
4. Attics must be isolated from heat sources with insulation and a complete air barrier – vented or not.

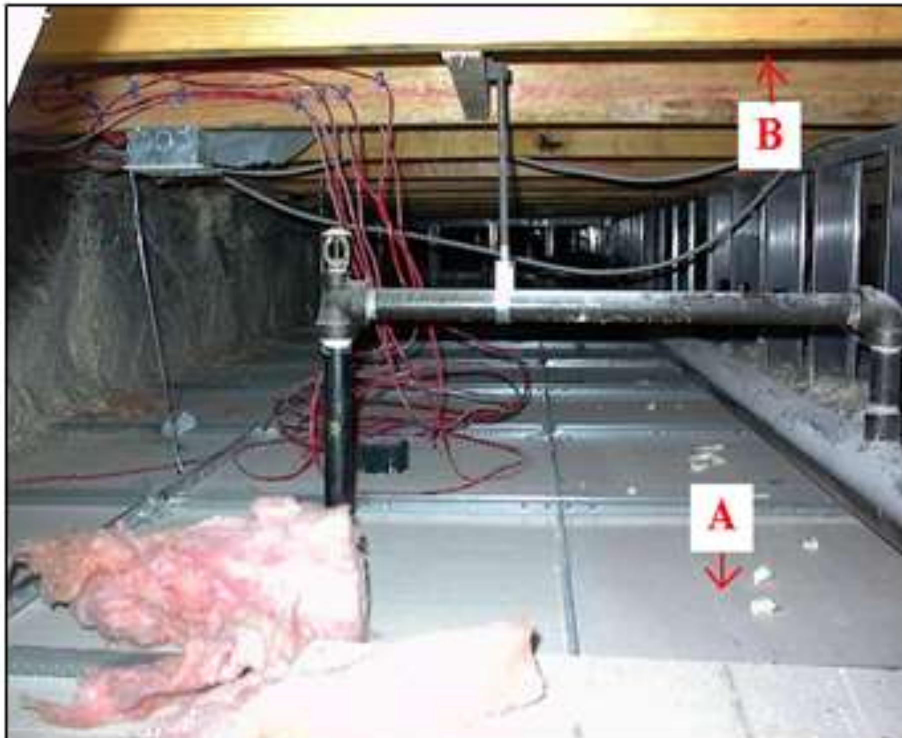
The causes of attic performance problems

Missing or inadequate insulation

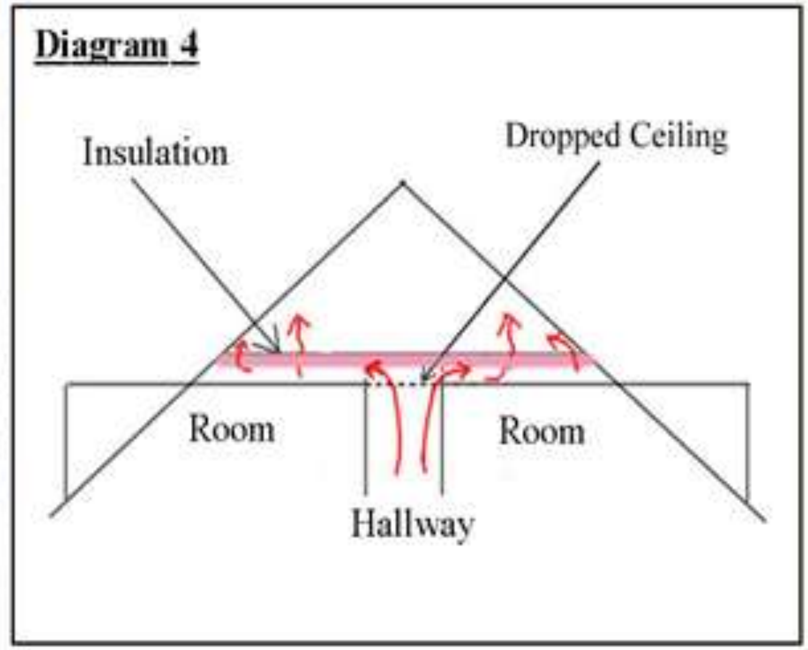
- Use at least the current minimum code-compliant R-value
- Protect air-permeable insulation with a complete air barrier to reduce convection
- Locate the air barrier immediately against the insulation
- Don’t use air-permeable insulation as the air barrier

The causes of attic performance problems

Don’t use air-permeable insulation as the air barrier

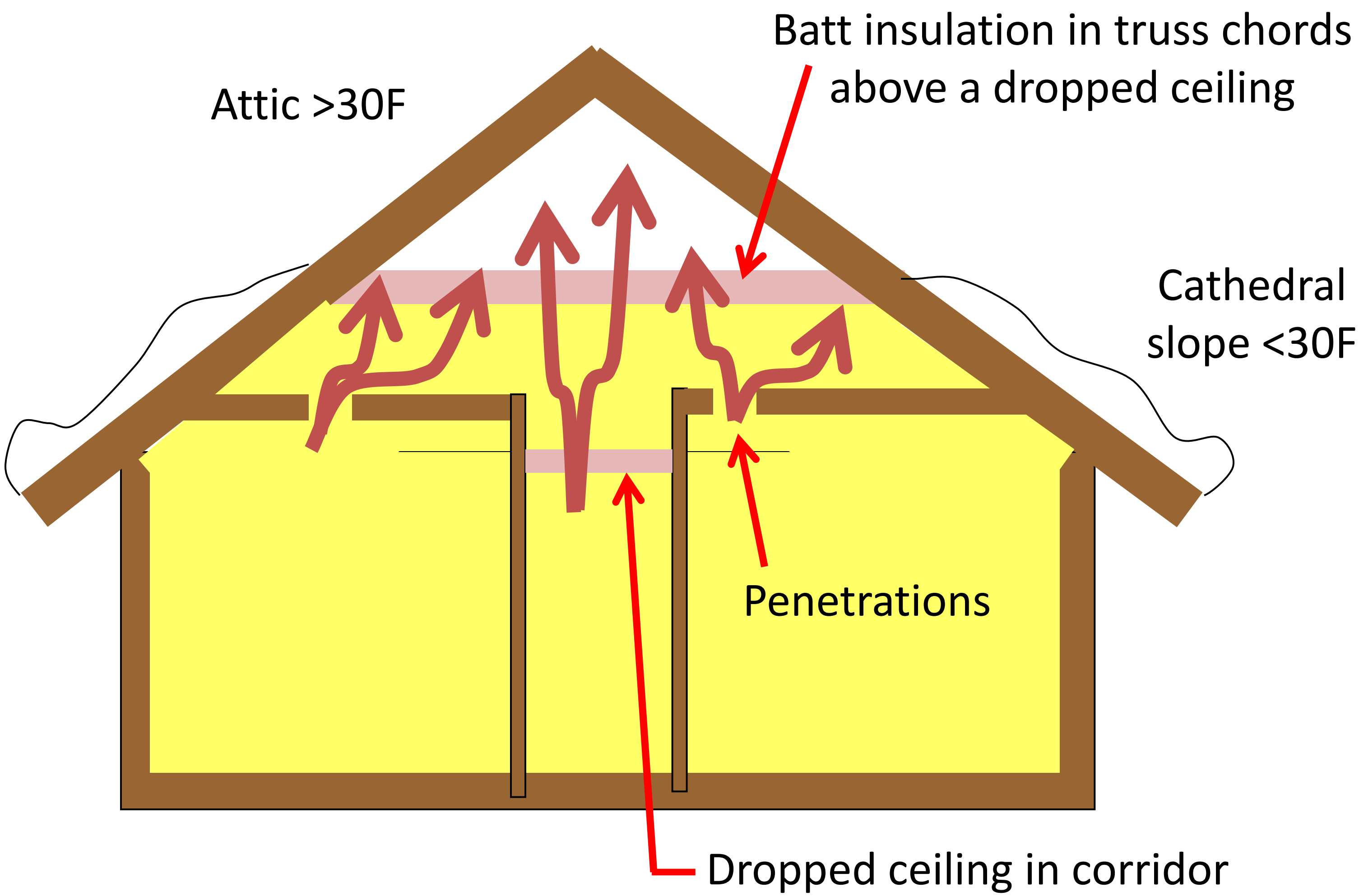


JORDAN - A) Dropped Ceiling above the hallway.
B) Insulation is within the trusses above and provides a very poor air barrier.



The Diagram above shows how the warm air (red arrows) that escapes through the dropped ceiling is able to move laterally until it finds a break in the insulation to exploit.

The causes of attic performance problems



The causes of attic performance problems

Pressure boundaries can be layered!

Large plenum spaces under air flow retarders can conceal the location of air leakage sources by distributing the flow over large areas

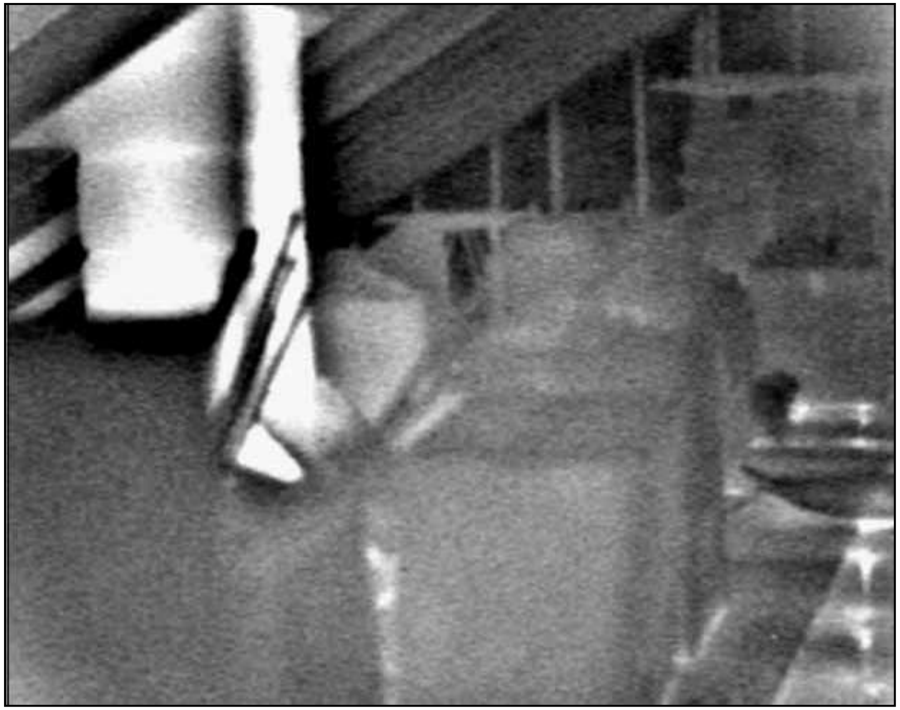
Openings in air flow retarders appear to be the locations of large air leakage sources with most diagnostic tools

Other causes of ***roof*** performance problems

Other attic and cathedral roof slope warming sources

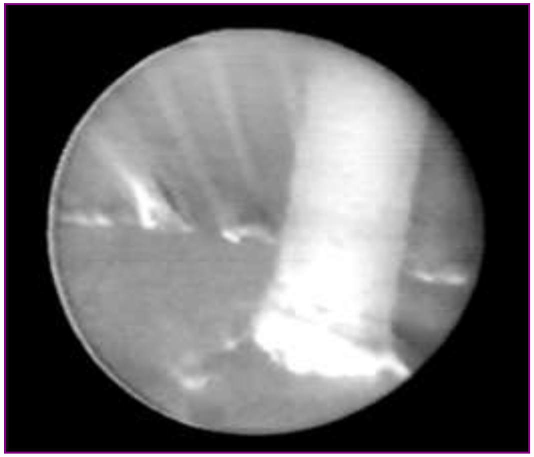
1. Radiant sources (chimneys, solar gain surfaces)
   a. A heat source in an Attic warms the entire roof
   b. A heat source passing through a cathedral roof slope only impacts the local area around the heat source
2. Mechanical sources
   a. Downdraft exhaust fans always produces local melt
   b. Direct-vent appliances below roof vents cause roof melt above, especially in vented roofs

Radiant heat sources

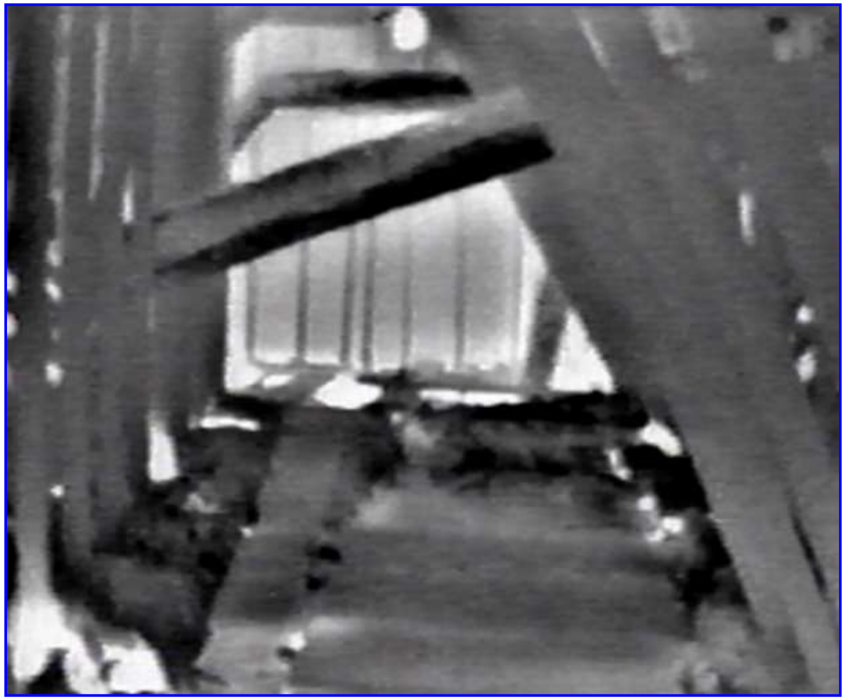


Radiant heat sources

Radiant & Air Leakage Sources



Radiant heat sources



South gable wall at noon, attic temp is about 60 F inside, while the outside temperature is just 10F

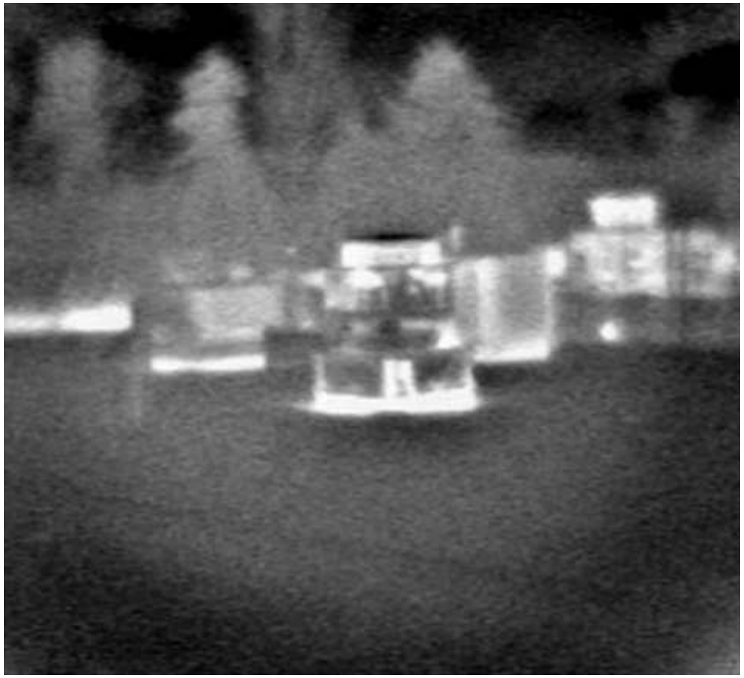
Address solar gain

Melt patterns - External Sources

Use up-draft exhaust fans

Melt patterns - External Sources

Up-draft fans

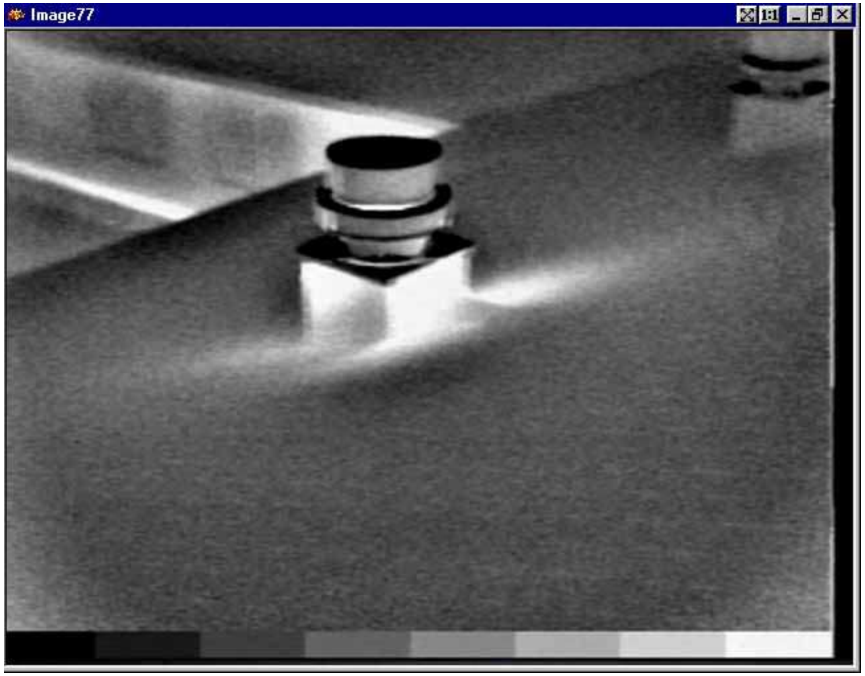


Down-draft fan

Infrared image of the two exhaust fan options

External heat sources

Down-draft fans

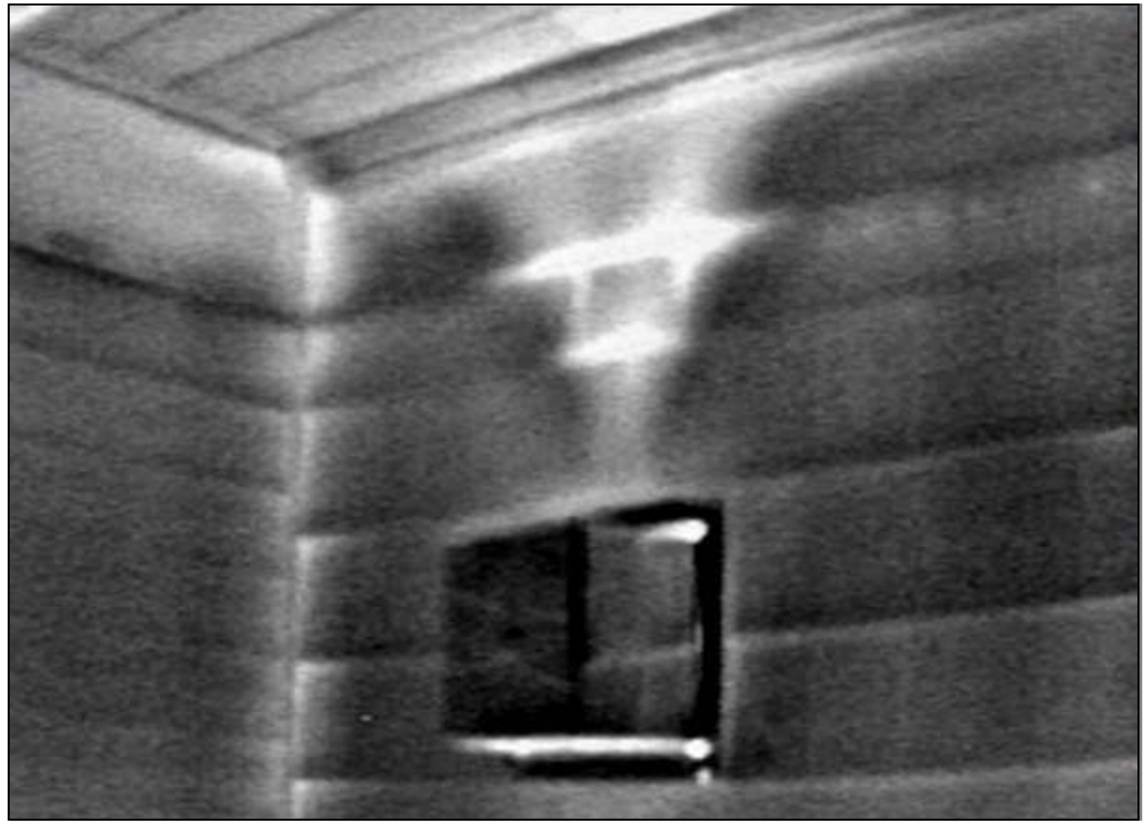


Infrared image of two exhaust fans in use

External heat sources

Heating system exhaust vents on wall below soffit (inlet) vents

Blocked the soffit vents above this



Infrared image of heat rising into the perforated soffit (roof vents)

External heat sources

Heat escaping from exhaust vents flows up into the roof slope vents. Steam condenses into water inside the vent chutes on surfaces that are below the dew point.

Other causes of roof performance problems

Other attic and cathedral roof slope warming sources

1. Mechanical penetrations
    a. Chimneys and flues
    b. Solar gain surfaces
    c. Mechanical system penetrations and leaks

Mechanical system heat sources

Mechanical systems are not insulation or air barrier components

Keep mechanical systems on the interior side of the building enclosure

Mechanical system heat sources

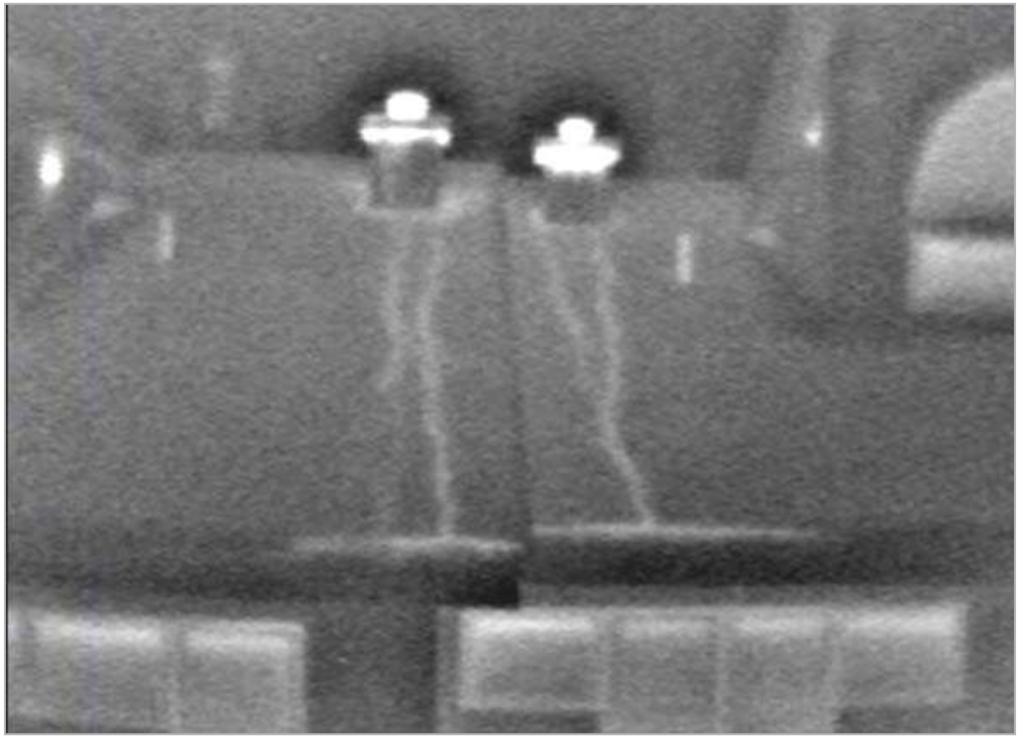
Mechanical systems leaks

Difficult access in attics can compromise the ducts. Move them inside the envelope!

Mechanical system heat sources

- Damaged or Missing Duct Insulation

Mechanical system heat sources



Surface tension at the snowpack frontier prevents drainage and induces horizontal spreading of the ice formation

Vented vs. unvented cathedral roof slopes

Vented vs. unvented cathedral roof slopes

Unvented cathedral slope only have localized failures at areas with missing insulation and air barrier penetrations

Vented cathedral slope have failures at and above areas with air barrier penetrations

1. Interior sheathing penetrations
2. Exterior vent space penetrations
3. Where the cathedral oof slope air barrier does not connect to the wall air barrier

Air barriers issues

Vented rigid foam board insulation

Vented 12” batt insulation

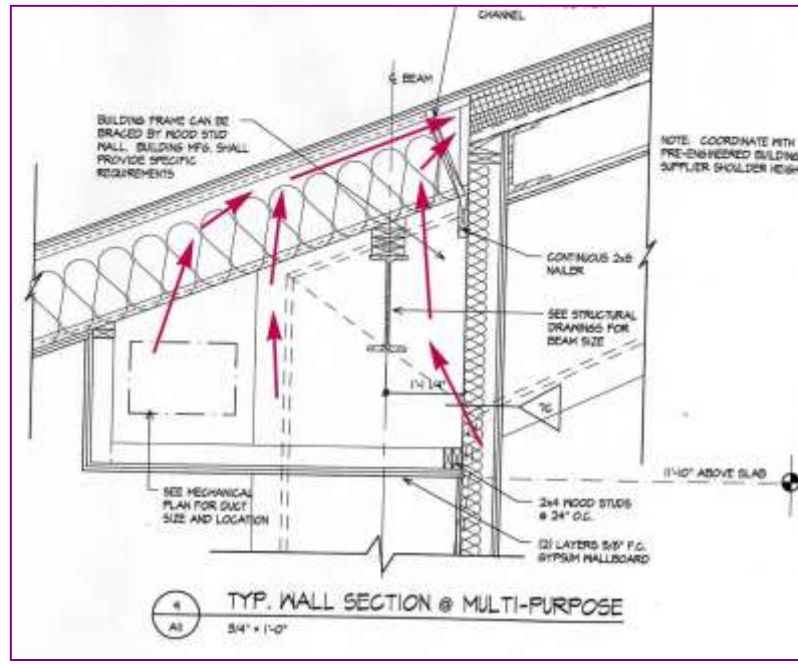
What does this melt pattern tell us?

Do we need more insulation, ventilation, or air sealing?

Air barriers issues

There is no air barrier in the lower vented slope with batt insulation

The upper cathedral roof is vented SIPS, which provide an air barrier



Diagnostic methods

Diagnostics

Diagnosing insulation and air leakage problems in attics and cathedral roof slopes

1. Diagnostic methods
   a. Visual inspections
   b. Melt patterns
   c. Cutting the snowpack to isolate melt sources
   d. Infrared camera and a Blower Door test
   e. Using attic temperature monitoring in diagnosing and prioritizing the remediation work

What do we learn from melt patterns?

Look at roofs over unheated structures and compare

What do we learn from melt patterns?

Missing or inadequate insulation

Snow melt over bathroom dropped ceiling

This bathroom has batt insulation, but no air barrier.

Note that the cathedral vented slopes are working!

What do we learn from melt patterns?

Melt pattern due to roof warming from an uninsulated and open chimney chase passing through an attic

What do we learn from melt patterns?

Melt pattern due to roof warming from an uninsulated and open chimney chase passing through an attic

Diagnostics

Visual inspections

Look at the snow depth along the gable or rake. Often, in deep snow conditions you will see that the snow depth is wedge shaped or tapered from the bottom to the top, not parallel to the roof plane. This doesn't look like a melt pattern from the front, but from the side it indicates melt is occurring progressively from the bottom to the top as the warm air (from heat loss or solar warming on the gable walls or the roof slope) flows to the top in the vent chute or soffit. If there is an attic above a cathedral roof slope, the wedge may start at the change in roof type (cathedral to attic).

Melt patterns show roof performance problems

"Snowpack taper" indicates inadequate R-value and/or ventilation – warming increases as the flow progresses up the vent chute.

Diagnostics

Melt patterns

a. Frost melt – without snow
b. Snow melt

Frost melt pattern

Reflected solar gain

Melt patterns show roof performance problems

Use melt patterns to verify interior inspection data

Air barriers issues

R=38 batts in both roofs. Photos of before (left) and after (right) repairing the existing air barrier

Melt patterns show roof performance problems

One air leak in an attic can melt the whole roof, defects in cathedral slope only affect the area where the defect is. Whole roof should look like the overhang.

Melt patterns show roof performance problems

Unvented roofs with air-permeable insulation vs.
vented roofs with air-permeable insulation

Melt patterns show roof performance problems

Heavy timber pattern

Masonry fire wall pattern

VT pool building

Before

and

After

Can also be used to demonstrate effective repairs!

Where does the ice form?

Cause(s) = ? Use a heat tape to isolate the two sides

Kendal at Hanover (1994-1995)

Attic above cathedral roof slopes – same R-values but cathedral works better than a vented attic

Melt patterns show roof performance issues

Missing or inadequate insulation?

This home has the current minimum code-compliant R-value

Even R-30 can work in Vermont if everything is done perfectly (1998) – still no icicles or ice dams in 2025

Melt patterns show roof performance issues

Unvented R-60 roof in Vermont with light snow cover. This roof has a framing pattern but has never had ice dams.

Melt patterns show roof performance issues

Unvented roofs – no melt

Melt patterns show roof performance issues

Unvented roofs where winds exceed 60 mph

Highridge Sports Center – 2-13-18

Original installation in 1986

Melt patterns show roof performance problems

Dartmouth Skiway base lodge with no air barrier behind T&G plank decking and no air sealing at penetrations/chimney perimeter

Melt patterns show roof performance problems

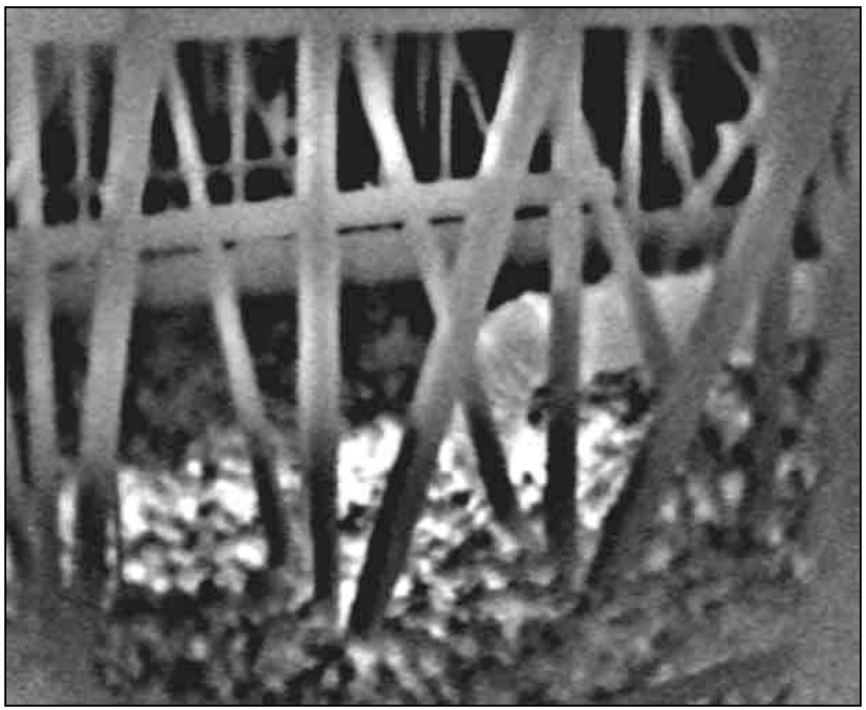
Diagnostics – Infrared analysis

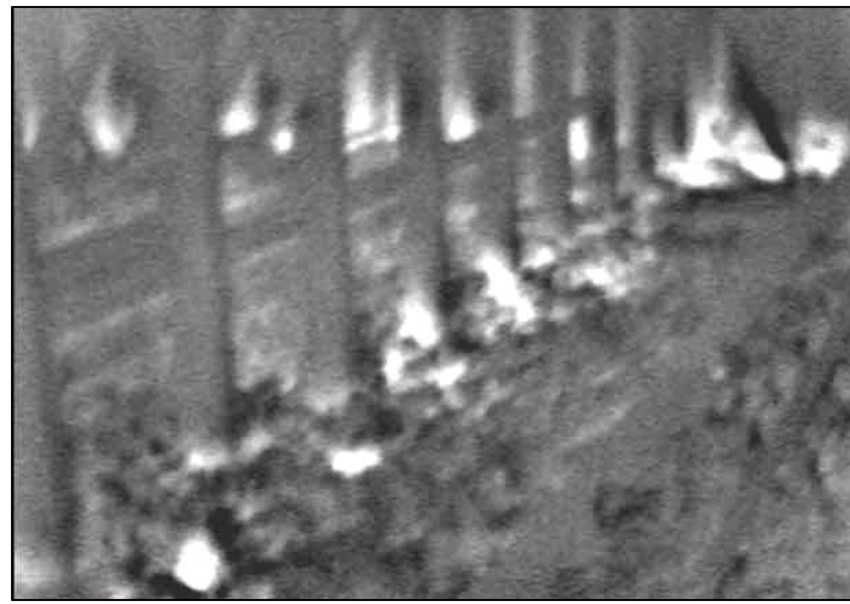
Infrared imaging and Blower Door tests

1. Use the IR temperature and patterns to locate the insulation defects to prioritize the ROI.
2. Use the IR temperature and patterns at the radiant sources and exhaust fans to prioritize the ROI.
3. Note: When infrared scans are performed inside an attic during the day, they show that the solar gain doesn't reach the sheathing through the snow (Killington IR images). Sheathing temperatures will be cold under the snow, but warm where the wind (or raking) has blown the roof clear.

Diagnostics – Infrared analysis

Locating hidden air leakage sites under the insulation is only visible when using infrared analysis (250,000 sq. ft. of attics)

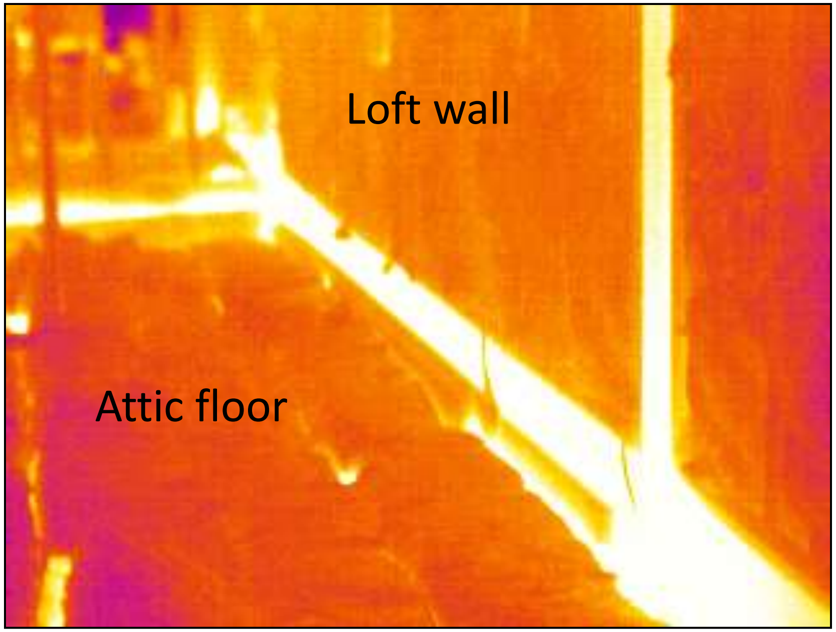




Flagging and repair work done in cycles until the attics were below 20F

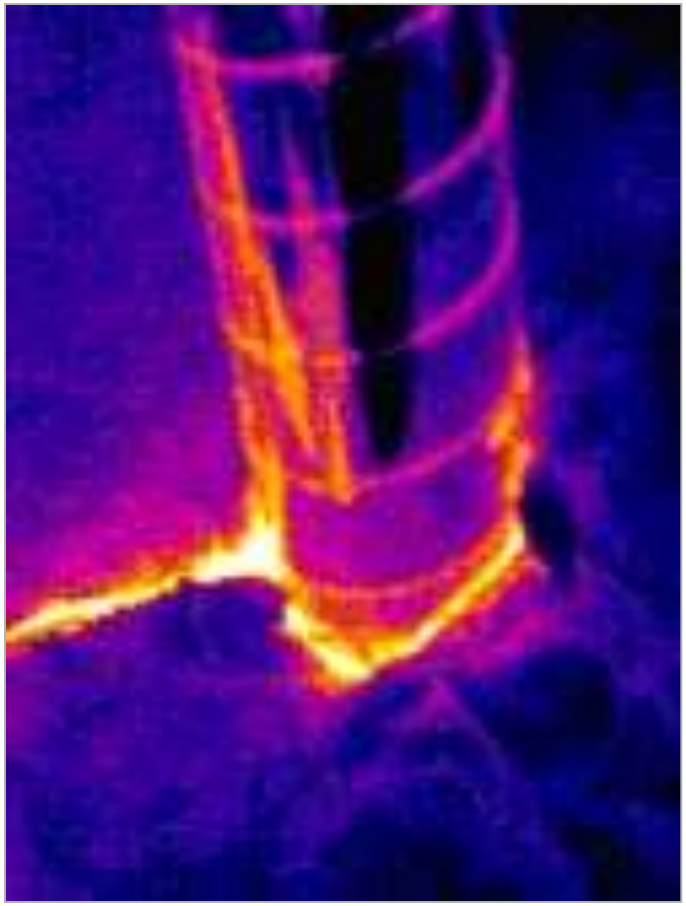
Diagnostics – Infrared analysis

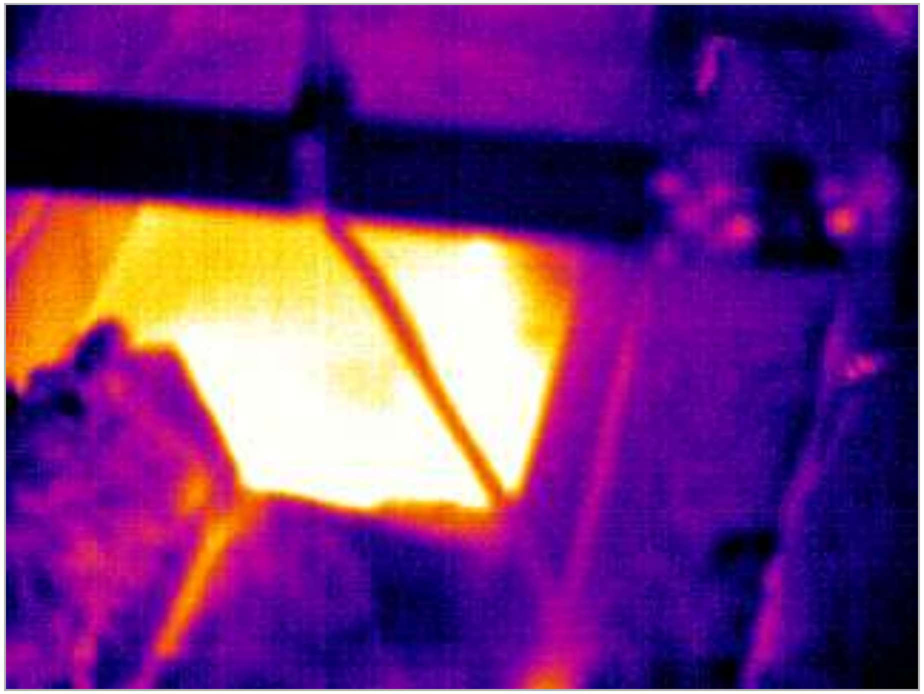
Identify the air leakage sites



Intersection of wall and floor, gaps in the insulation and open at the edge of the raised floor above Unit 331. Air temperature in the attic is 67 F, 10 F outside.

Diagnostics – Infrared analysis





Compare the temperature of the air leaks to prioritize the repairs

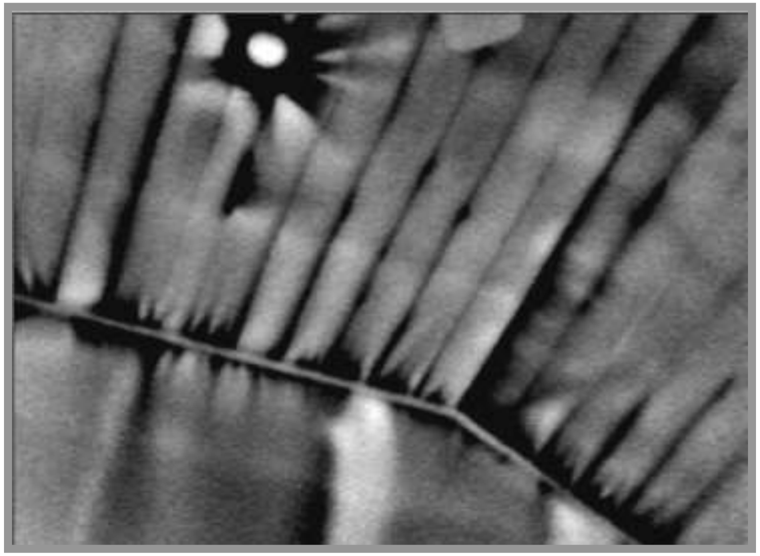
Diagnostics – Infrared analysis

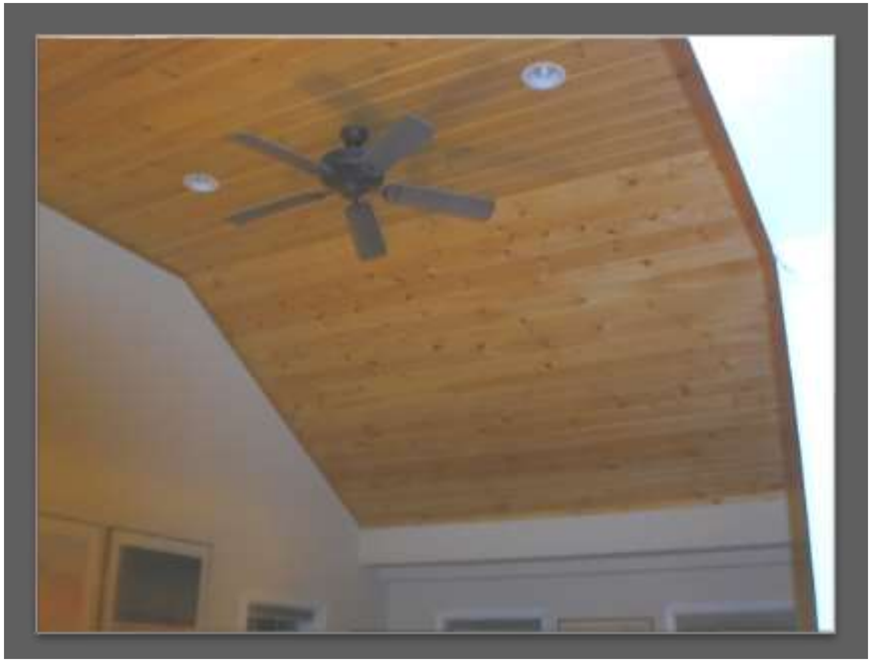
IR at ambient pressure – first floor of timber frame home

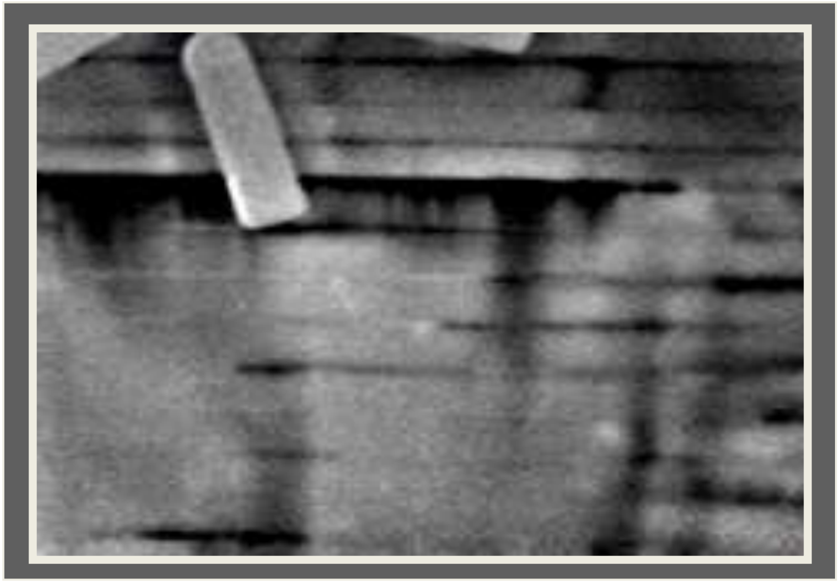
Hints: Measure temperatures at leakage sites to prioritize air sealing work

Diagnostics – Infrared analysis

Infrared image of R=30 insulation under depressurization

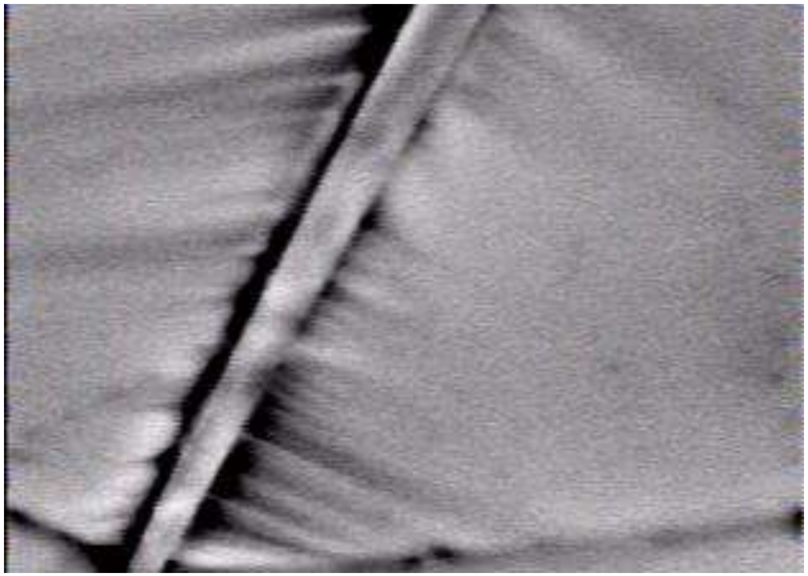


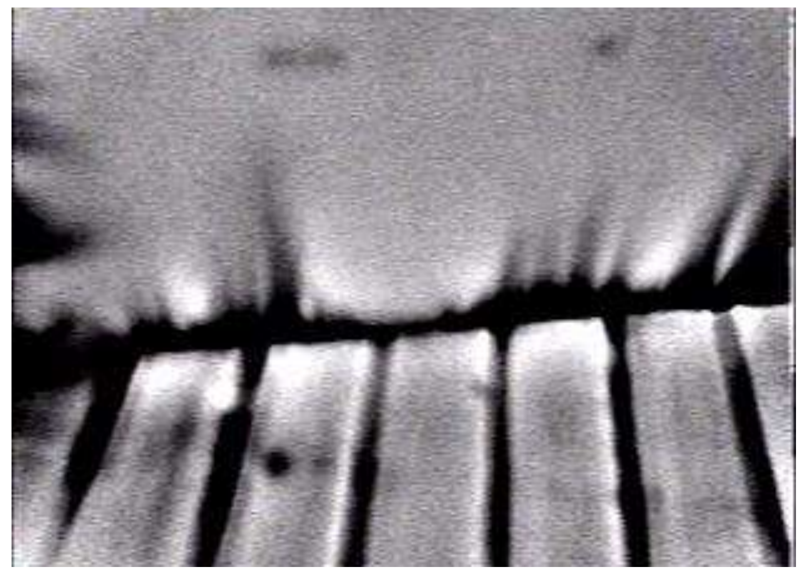




Diagnostics – Infrared analysis

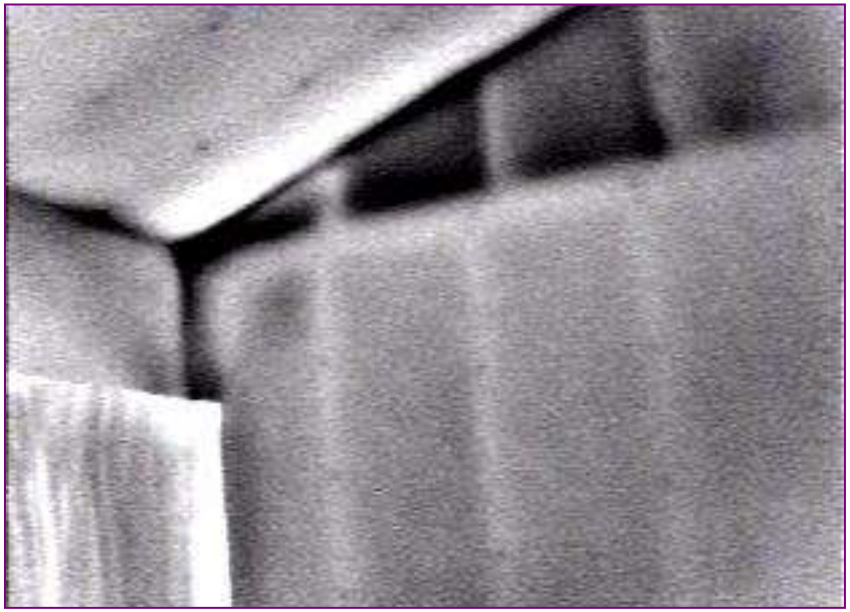
Locating air leakage paths by reversing pressures



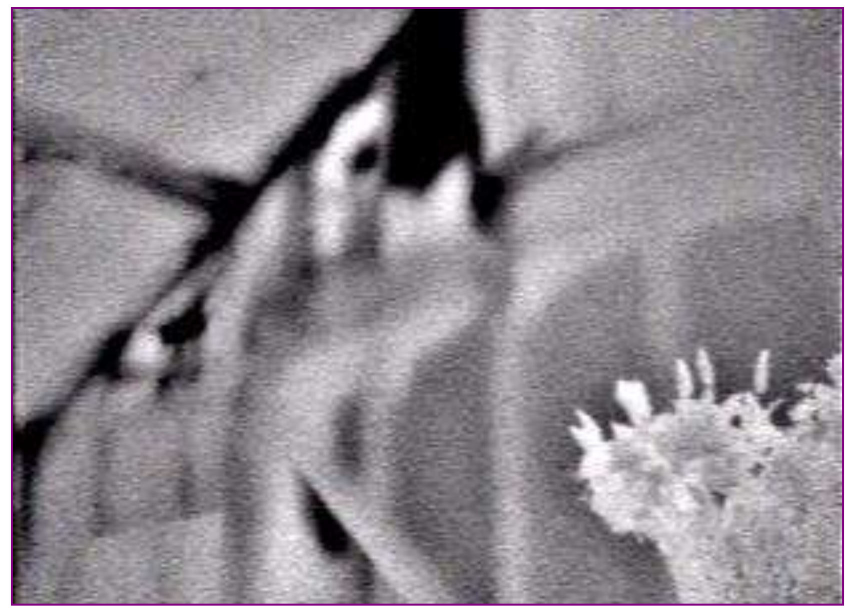


Diagnostics – Infrared analysis

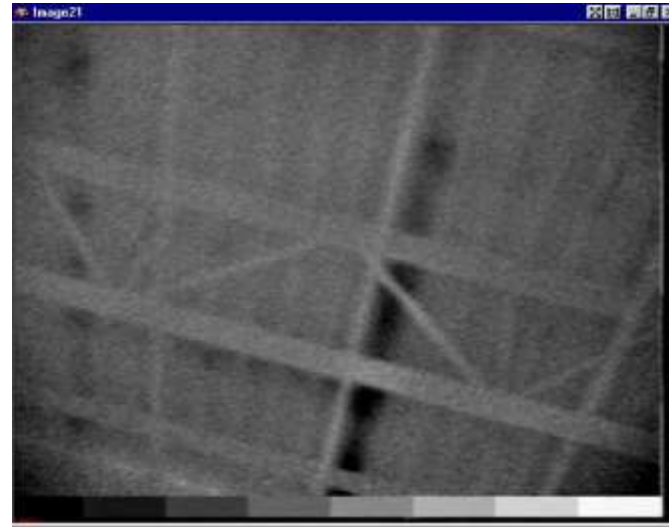
Conductive & infiltration losses at interior walls

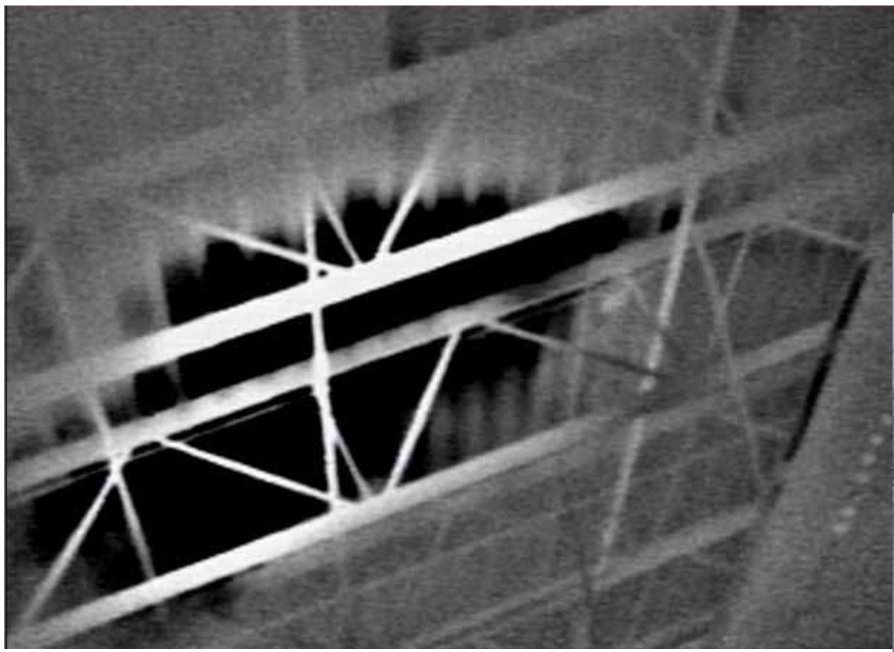


Support batt insulation to prevent heat loss into attics



Method - Depressurize the building with a blower door and use an IR camera to map out and prioritize air flow in the panel joints.



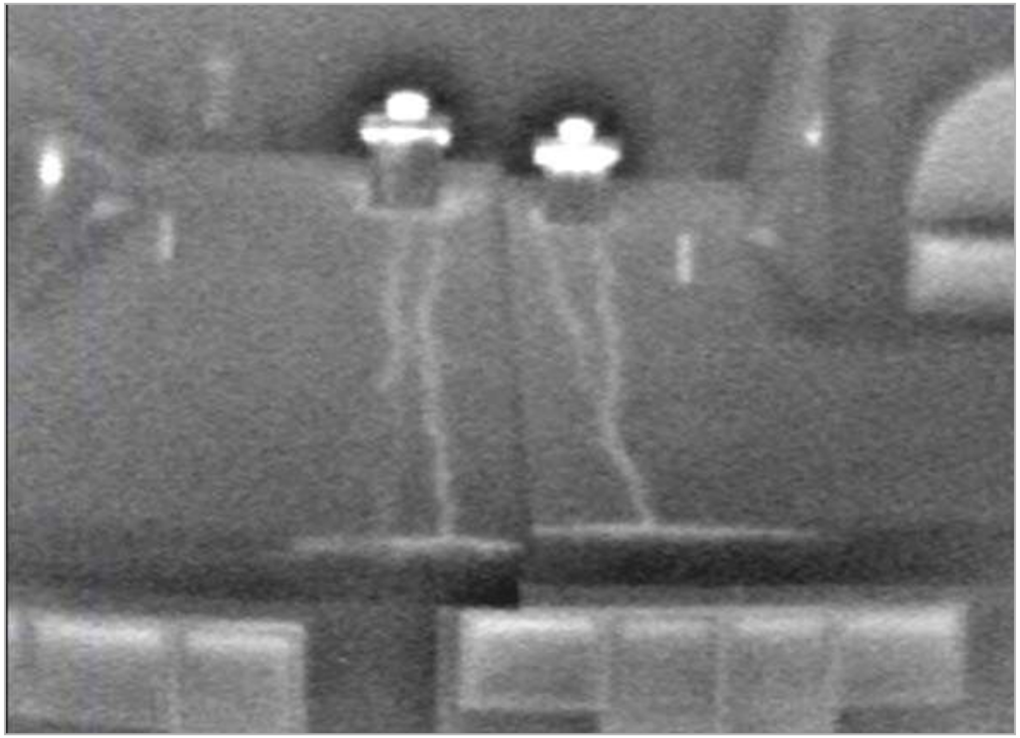


Rivendell High School - 2002

Diagnostics – Infrared analysis

Only the gable end soffit has an icicle. Why?

Diagnostics – Infrared analysis



Localized heat source at the top of the furnace flue chases

Surface tension at the snow pack frontier prevents drainage and induces horizontal spreading and ice formation at the eaves

Diagnostics – theatrical fog

Pressurized theatrical fog testing

1. Theatrical fog lets you see the air
2. Theatrical fog lets you see both ends of the air leakage path
3. Theatrical fog does not require seasonal temperature differences like infrared does

Air barriers issues – Fog testing

Air barriers issues – Fog testing

Pressurized theatrical fog

This method locates both ends of the flow path

Diagnostics – temperature monitoring

Using attic temperature monitoring in diagnosing and prioritizing the remediation work.

1. Modern temperature monitoring is inexpensive.
2. Temperatures can easily be monitored in person or remotely.
3. Temperature monitoring shows how much heat loss there is in any given section of an attic and allows you to prioritize the remediation work.
4. Datalogging systems provide good records.

Temperature and RH Monitoring

Temperature Monitoring & Melt Patterns

- Vented attics usually have the lowest up-front cost but are the most prone to whole-roof problems due to air leakage and mechanical system warming the entire attic.

- Flaws in one area of the thermal envelope impact the entire attic roof area.

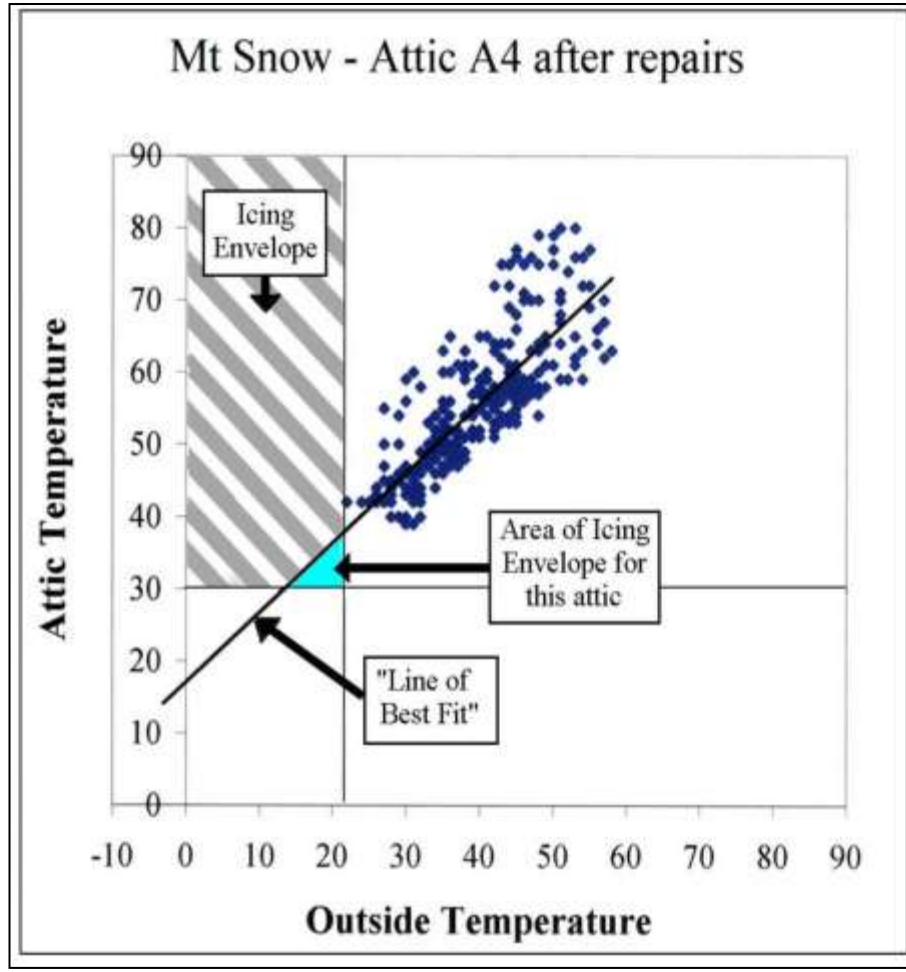
Temperature and RH Moisture Monitoring system

Monitoring and control systems with Wifi and Cellular access are now available. No sensor wiring and no land line is required.

We eliminated ice dams in 80,000 square feet of attic using monitoring to plan and prioritize strategic remediation work.

Temperature Monitoring

The temperature parameters necessary for the formation of ice dams define the area known as the "Icing Envelope." The ratio of the roof/attic indoor-to-outdoor temperatures are plotted to determine the envelope performance. (CRREL)



Data shows how closely the outside and the attics or roof slopes are coupled

Temperature Monitoring

Temperature monitoring – results from Phase 1

Mt Snow Data Table			(80,000 sq. ft. of attic)			
Attic	Area of Icing Envelope 'before period' (12/24 - 1/3)	'after period' (3/25 - 4/7)	% improved toward exiting the icing envelope	"m" before (slope of 'line of best fit')	"m" after	% change
A1	15.2	2.5	84%	0.50	0.96	92%
A2	23.2	5.2 ←	78%	0.49	0.85	73%
A3	30.7	6.9 ←	78%	0.44	0.82	88%
A4	10.6	1.7	84%	0.55	0.97	74%
B1	28.3	12.7 ←	55%	0.40	0.71	79%
B2	26.2	2.9	89%	0.43	0.92	112%
B3	51.5	4.2	92%	0.44	0.86	93%
B4	38.3	3.5	91%	0.41	0.93	124%
B5	30.4	6.6 ←	78%	0.42	0.83	99%
B6	19.7	13 ←	34%	0.45	0.71	56%
C2	5.5	0.4	93%	0.64	1.02	59%
C3	7.0	0.3	96%	0.56	1.03	86%
C4	5.7	3.2	44%	0.58	0.80	38%
C5	7.6	1.4	82%	0.56	0.95	68%
C6	16.7	3.2	81%	0.46	0.87	89%

Scatter plot of data collected for use with CRREL icing calculations (0.0 is ideal, but <5.0 provided adequate performance to prevent ice dams)

Icing Envelope theory

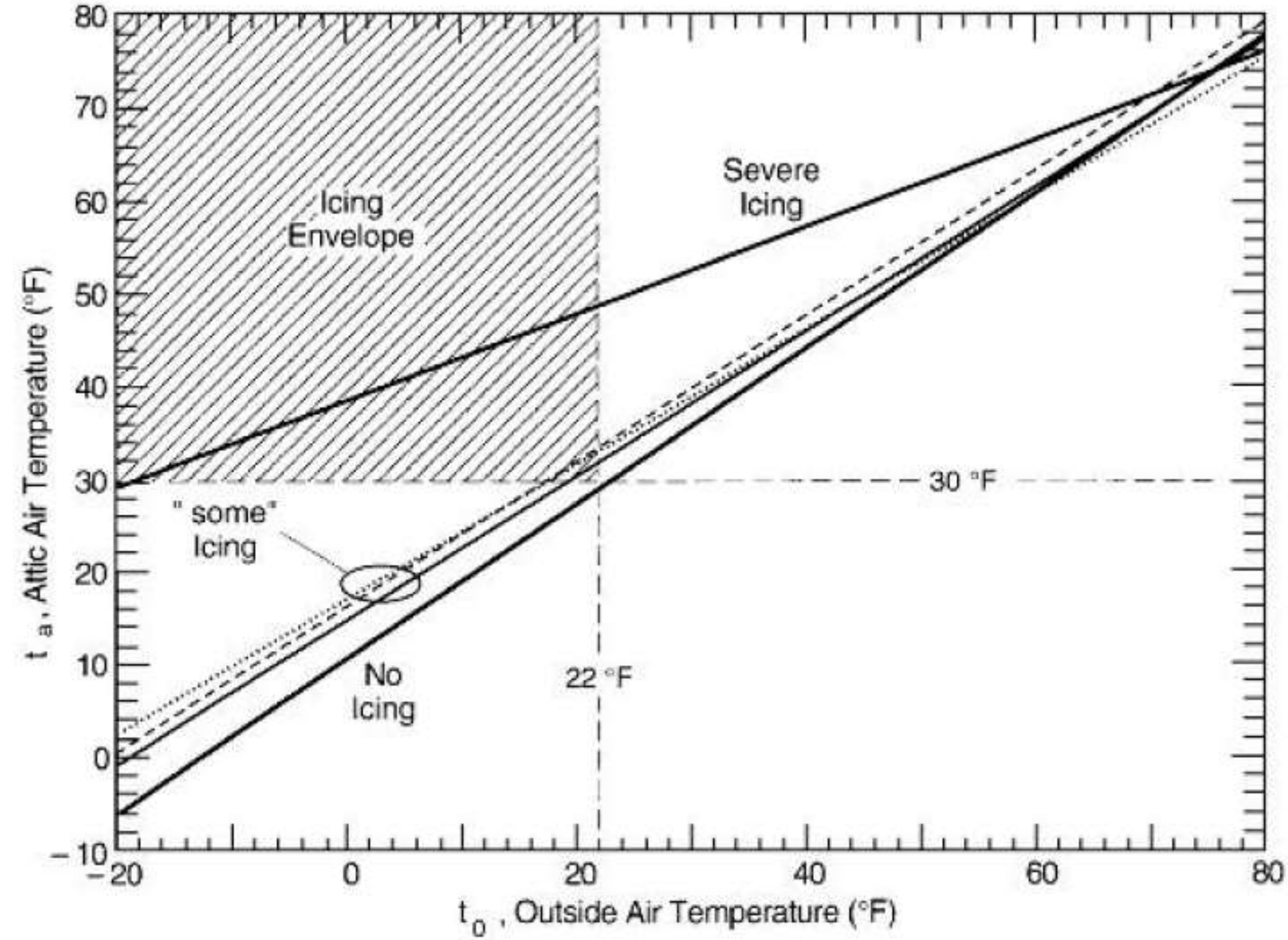
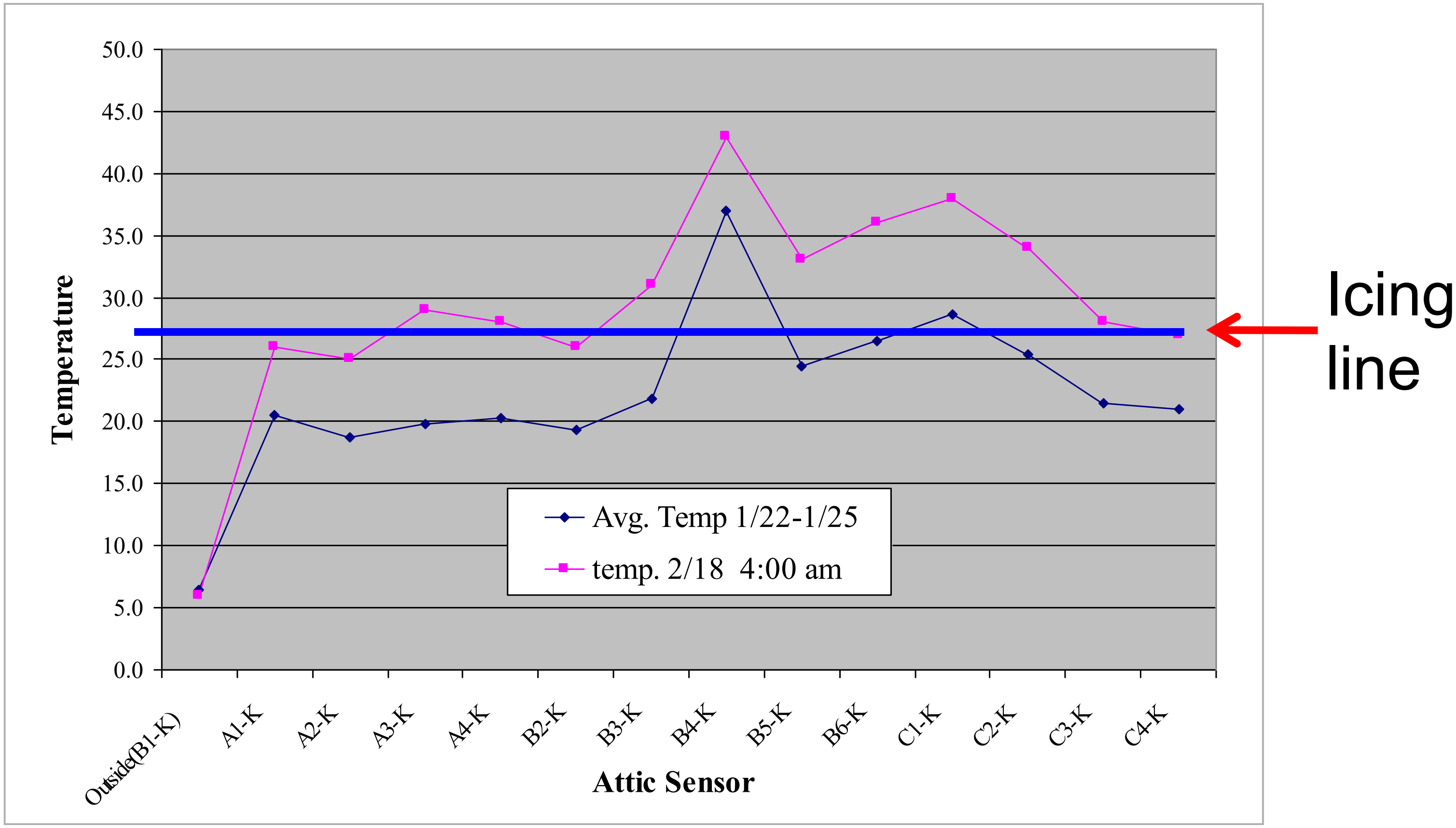


Figure 3. Lines of best fit for the roofs shown in Figures 1 (bottom line) and 2 (top line). The three circled lines are for other roofs with "some" icing problems.

Diagnostics – When do I need ventilation?



Attic temperatures before (dk. blue) and after (pink) a snow event. The temperature spike in B1-K is the attic that has the elevator penthouse in it.

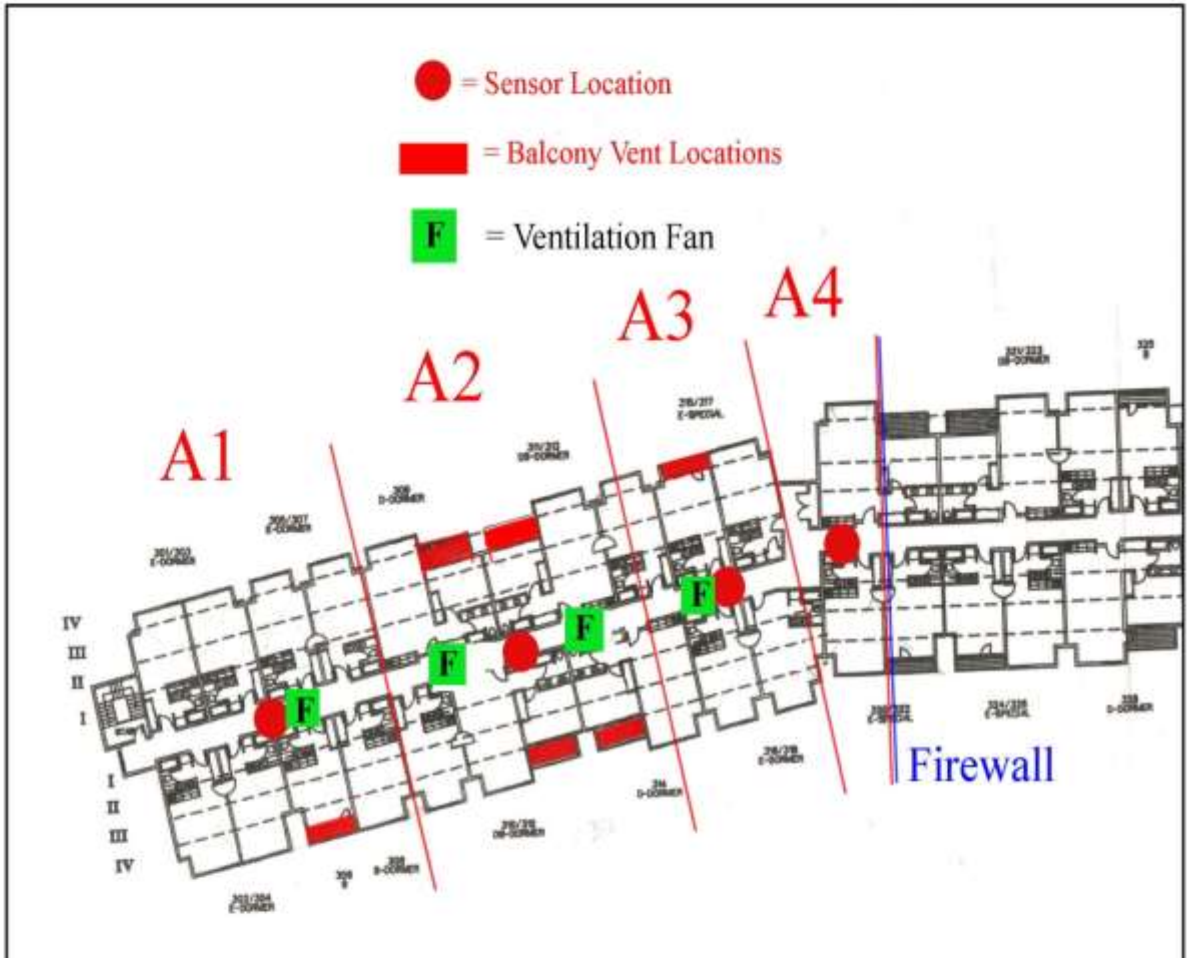
Unexpected air leakage sources

Like pistons, elevators pump hot air into the attics

Sometimes relief vents are open into the attic, exacerbating this problem

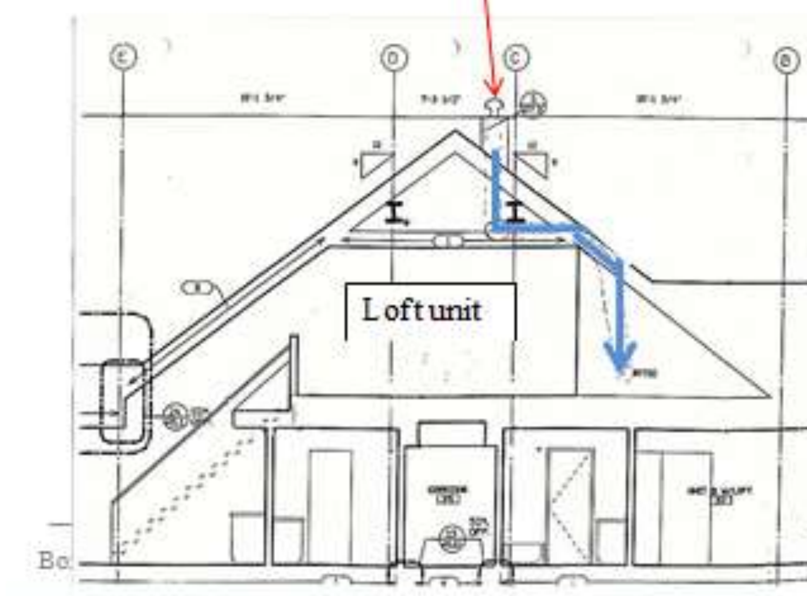
Ventilation Problems – Attics

Poor ventilation distribution



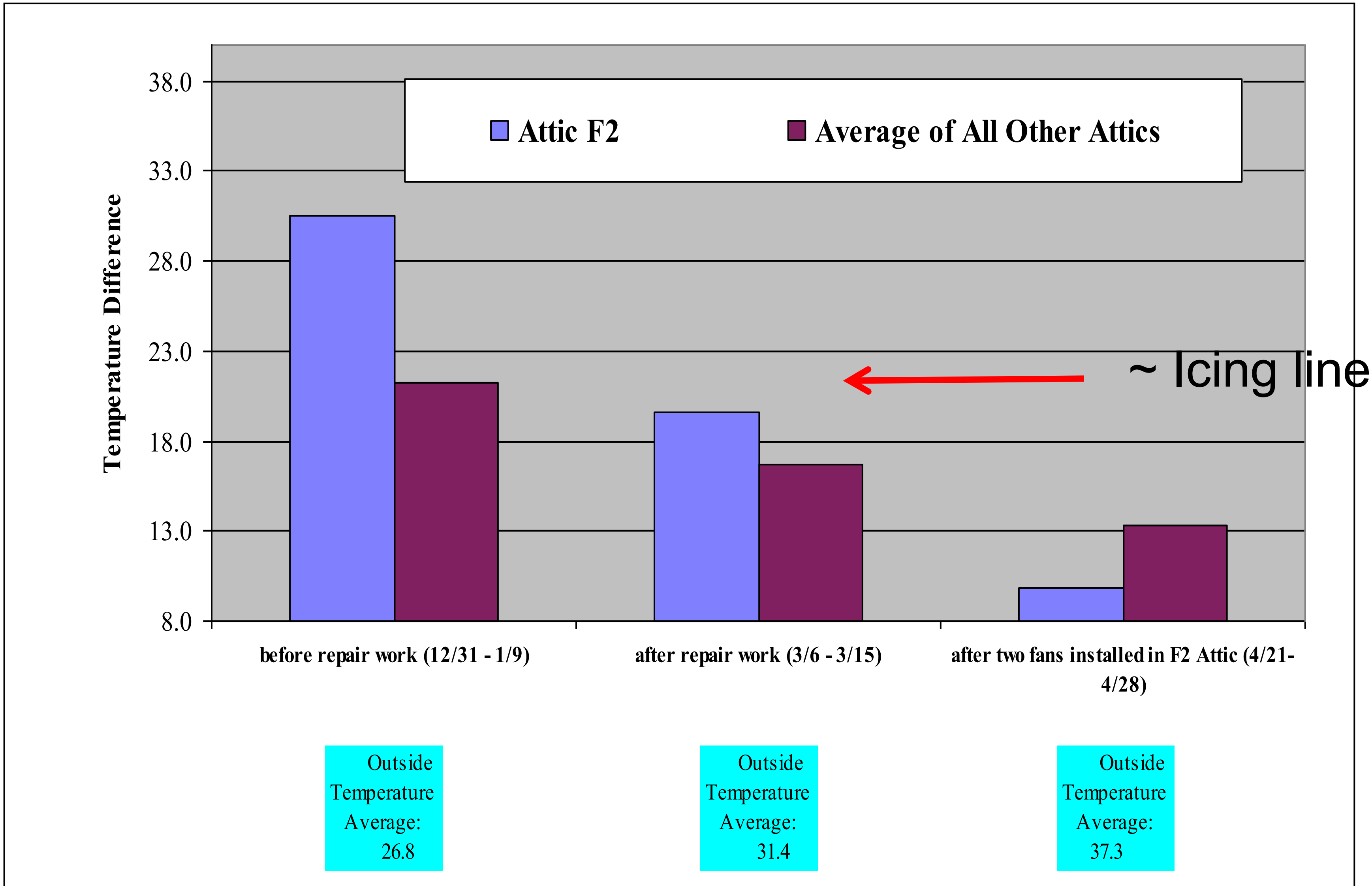
Balcony attic inlet vents (Red)

Additional inlet ventilation from above



Downdraft fans provide cooling for isolated kneewall attics

Diagnostics – Data and controls



What poor performance looks like

The problem - Roof performance problems in cold climates

Ice dams are the most common symptom of roof building enclosure performance problems

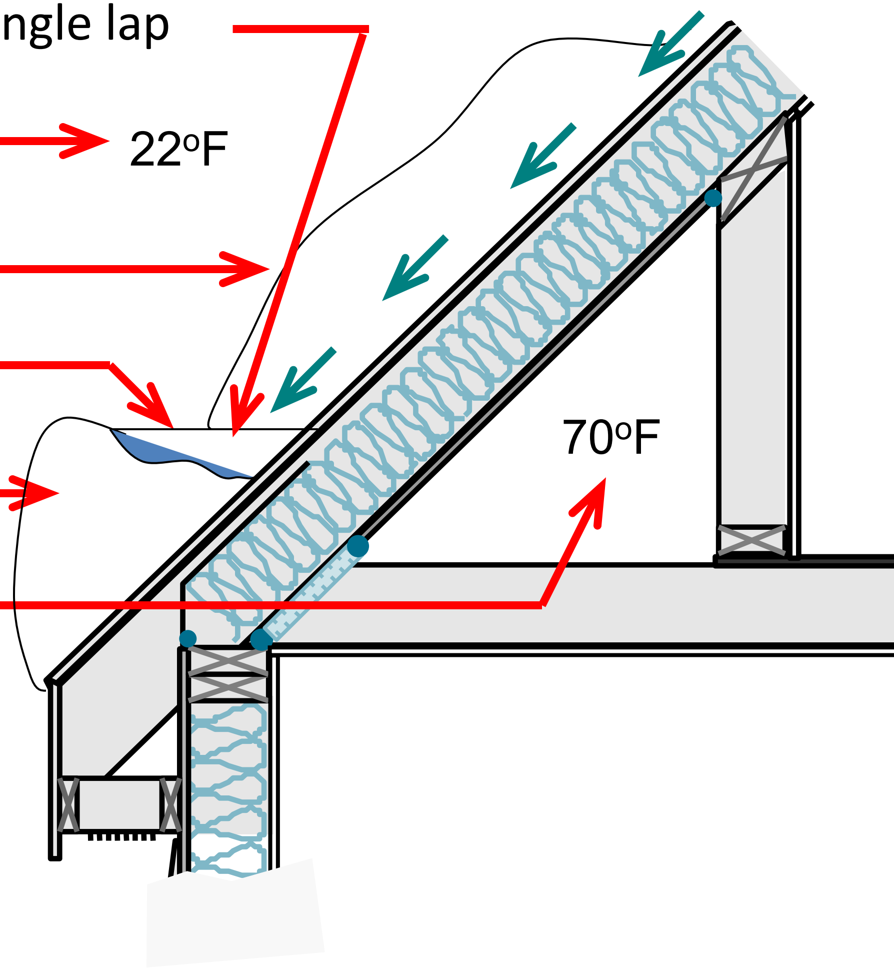
The problem - Roof performance problems in cold climates

Ice dams

- Naturally you have to rule out a roofing or flashing problem when you consider the causes of roof leaks, but generally if you don't have leaks in the summer, the ice is the culprit.
- How and where do they form
- Ice dam roof leaks are not where the melt is – look upstream for the melt.
- Surface tension in the snowpack prevents melt drip – turns the water sideways (widens the ice formation).
- See the handouts sheet for more science on this.

How Ice Dams are Formed

- Water level above the top of the shingle lap
- Outside Ambient
- Snowpack
- Melt pond
- Ice dam forms at frontier
- Interior ambient



The anatomy of a typical roof with an ice dam

Roof performance problems in cold climates

What do these problems look like?

Significant snow loads form large ice dams and icicles.
Ice can penetrate walls in corners.

Flow →

Side view of an insulation batt showing how air flows from an interior air leak up to the vent space above the batt in a vented cathedral slope.

Where does the ice form?

The heat loss is occurring where the ice is forming and the leaks are occurring - Agree?

Address the attic or the vented cathedral roof?

Repair methods and ROI

Remediation

1. Vented attics
   a. Eliminate sources of attic warming
      i. Strategic air sealing
      ii. Upgrade insulation values
   b. Maintain evenly distributed ventilation in attics
      i. Balance inlet and outlet sizes
      ii. Mix the attic air to prevent hot spots

Remediation

- In attics where gable walls were hundreds of feet away, supply air (inlets) was provided with inexpensive inflatable ducts, usually down low on the slopes.
- Exhaust openings (outlets) were provided by fans spaced evenly along the ridge, with flow rates equaling the inlet air fan flow rates.

Inflated ducts

- Ducts were hung from the rafters and then inflated with the inlet vent fan.

Inflated ducts

Outlet holes in the ducts evenly distributed the air over its length.

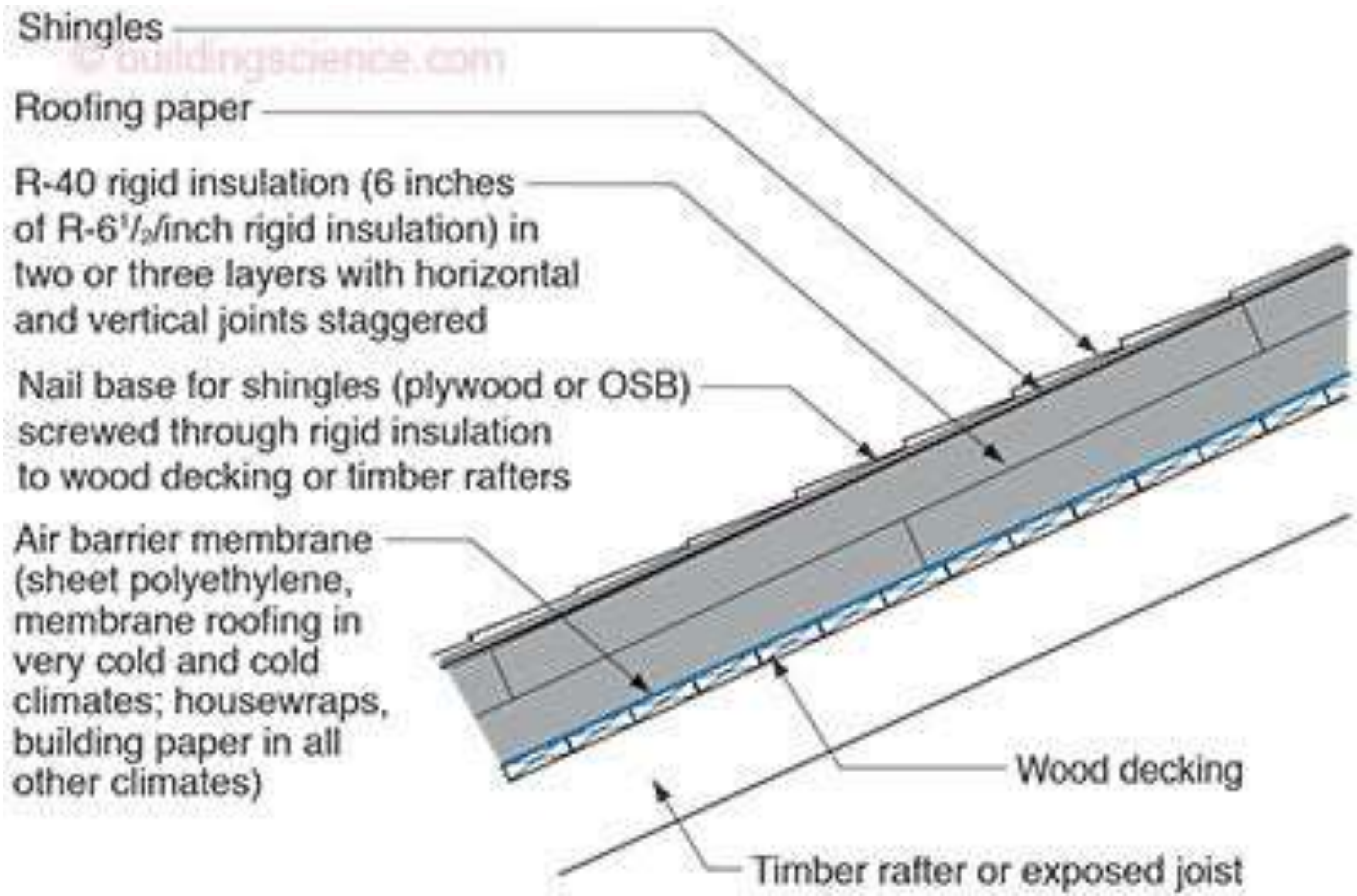
Mix the air in the attic to eliminate dead zones

Mixing fans are used to cool “dead zones” in attics with areas where there were no inlets.

Remediation

3. Unvented attics
   a. Convert unvented attics to one of the other methods (vented attics, vented or unvented roof slopes)
   b. Use the hot roof approach to prevent melt and moisture accumulation
   c. Add (code-compliant) venting and QA the air barrier – venting with indoor air will cause failures

Convert to unvented roof assembly



Courtesy: Building Science Corp.

Panel joint failure

Wall insulation – air barrier

Roof insulation – air barrier - Not connected

Remediation

4. Unvented cathedral roof slopes
    a. Eliminate sources of roof warming.
    b. Higher R-values are required to prevent ice dams than in vented systems, they are equally efficient, and are less expensive to build.
    c. Changing to an unvented roof slope method can be a good remediation strategy for vented roof slope problems. This raises the R-value and eliminates the air leakage.

Remediation

2. Vented cathedral roof slopes
   a. Make sure the vents stay open in snow events
      Eliminate sources of roof slope warming
      i. Inadequate insulation
      ii. Air leakage into vent chutes from inside
      iii. Eliminate radiant sources
      iv. Eliminate mechanical system warming
   b. Remediate ineffective ventilation systems
      i. Maintain balanced flow in vented systems
      ii. Stir the air to avoid hot spots
      iii. Change to an unvented roof approach

Building Envelope performance issues

Missing or inadequate insulation

Snow melt over bathroom dropped ceiling

Roof melt and ice dams before occupancy



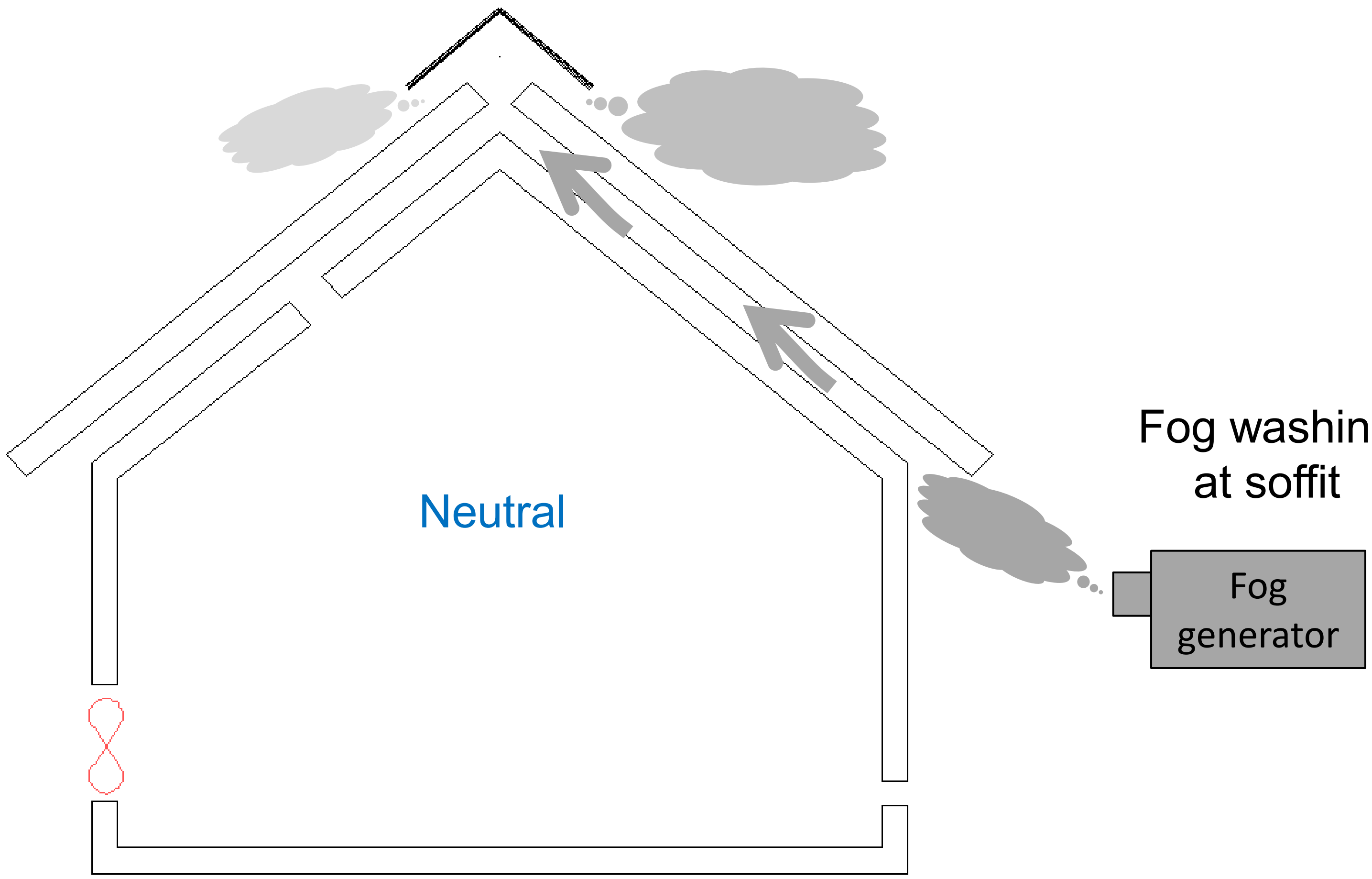

Symptom = roof leaks, dangerous ice falls
Problem = roof warming

Vent outlets should be located above the snowpack elevation to avoid blockage

GC blamed a too-small ventilation space?

Diagnostics – theatrical fog

Timing roof vents to calculate the flow rate



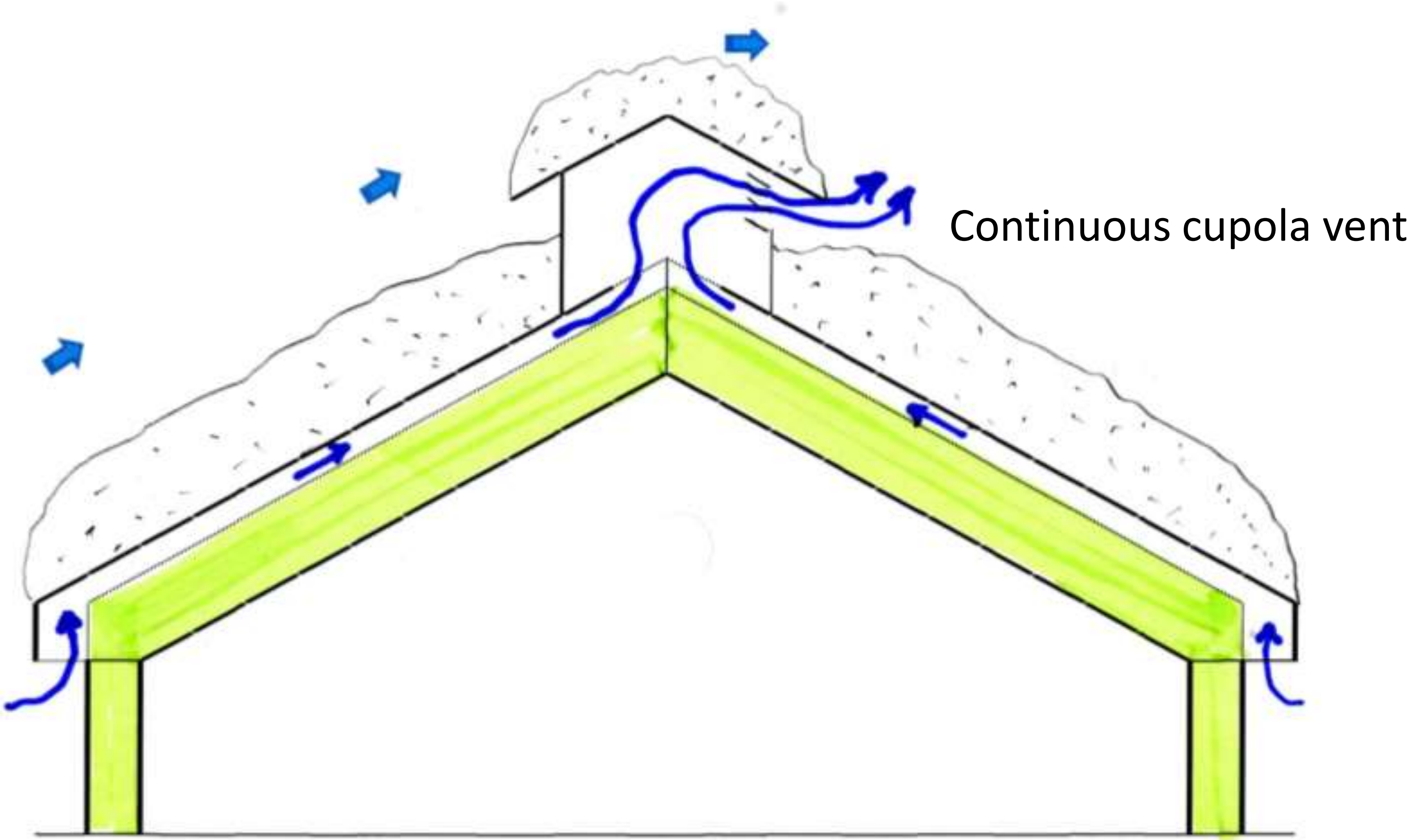
Diagnostics – theatrical fog

Fill the room and pressurize method

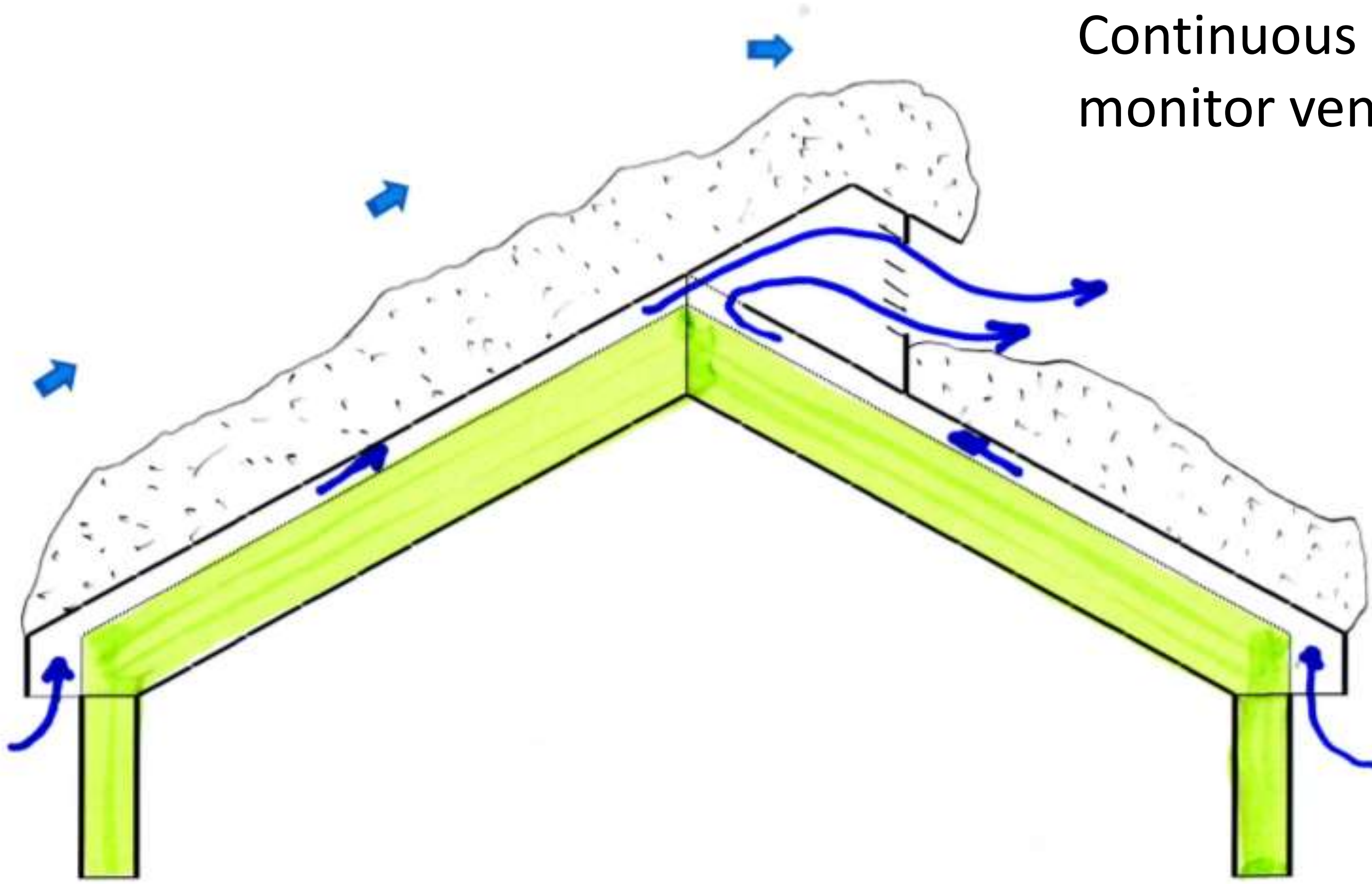
Ventilation?

- Adequate volume of cold air flow per unit of "loss" surface area to provide adequate roof cooling.
- Sizes of inlets and outlets – must be balanced.
- Long runs need larger vent spaces to provide adequate flow.

Vents that work in deep snow cover



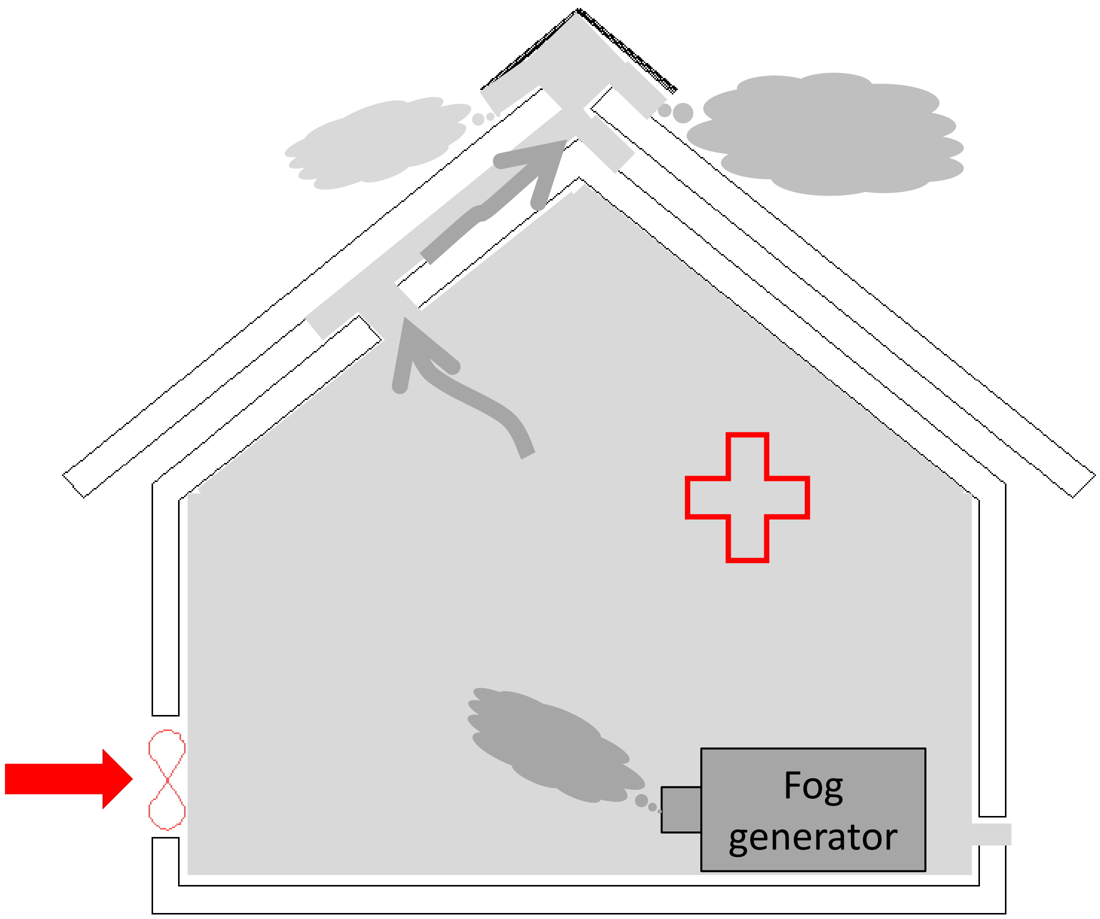
Vents that work in snow cover



Continuous roof monitor vent

Fill the interior volume diagnostic approach

Verify air leakage is occurring from the interior up into the roof vent space



Don't vent the roof with indoor air!

Low slope above-deck system

Acoustic metal deck under membrane and foam board

Perforated metal deck is not an air barrier

How to remediate problems by changing from one strategy to the other

Rivendell School

How to remediate problems by changing from one strategy to the other

How to remediate problems by changing from one strategy to the other

How to remediate problems by changing from one strategy to the other

Thermal bridging through fasteners but no air leakage from inside

After

Before

VTC Pool building

OSB wrinkles, heat loss, and icing

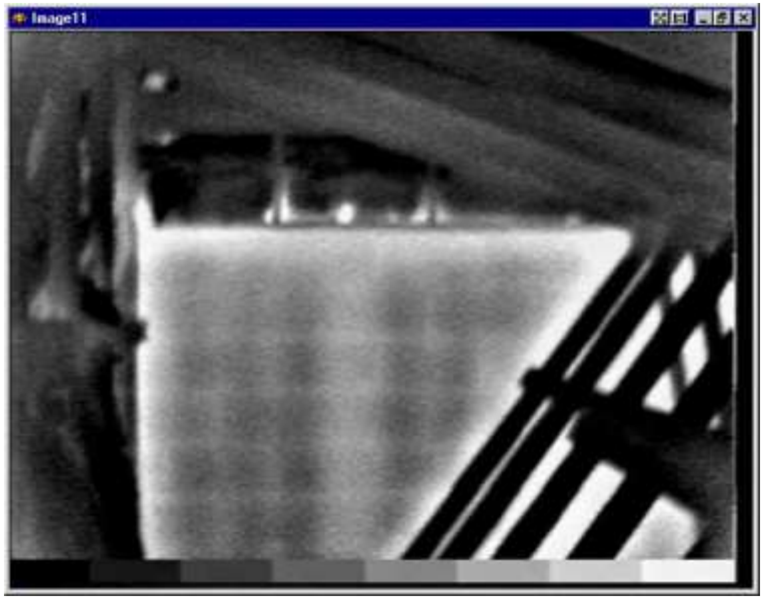
OSB wrinkles, heat loss, and icing

Remediation

5. Insulate solar radiant sources
6. Insulate block radiant sources
7. Eliminate and/or redirect mechanical system warming
8. Problems in structural insulated foam roof panel (SIP) installations
   a. It is all about the joints!
   b. Vented SIPs can work if the joints are sealed, but are prone to widespread air leakage issues
   c. Unvented SIPS can work if the joints are sealed making them less prone to air leakage – changing to this is a good remediation strategy.

Building Enclosure performance issues

Some areas just aren't obvious to contractors, but the IR shows it is an exterior wall with respect to the occupied space



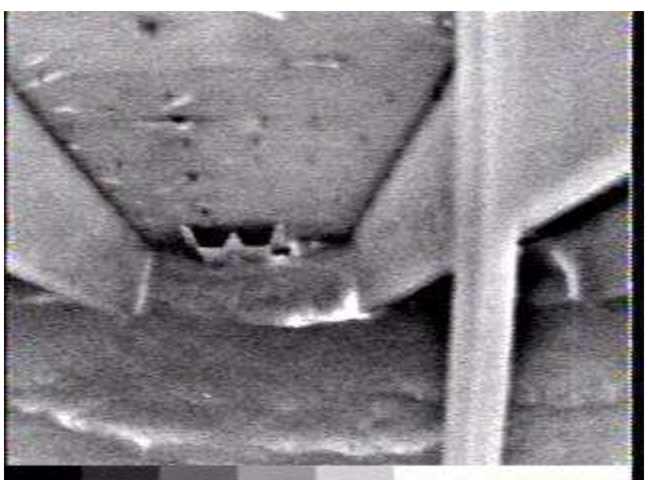
Rigid foam board applied to the block wall

Loft bathroom plumbing is exposed

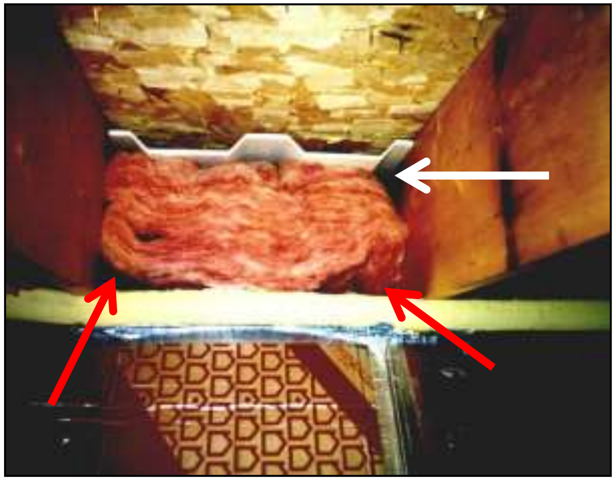
Okemo, VT side-by-side performance test

Pressure barrier strategy

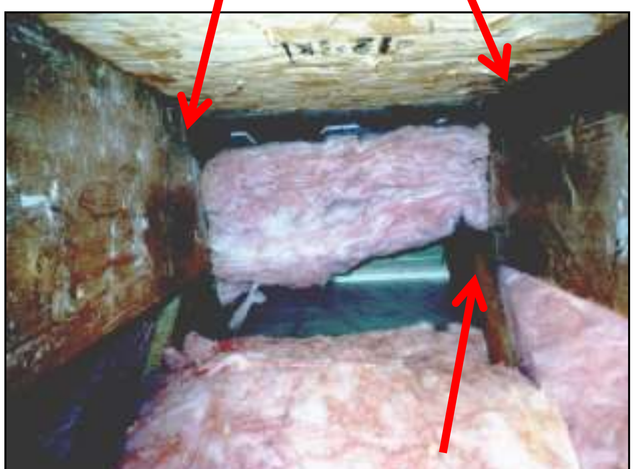
Flow paths from slope leakage sites



Flow paths from slope leakage sites

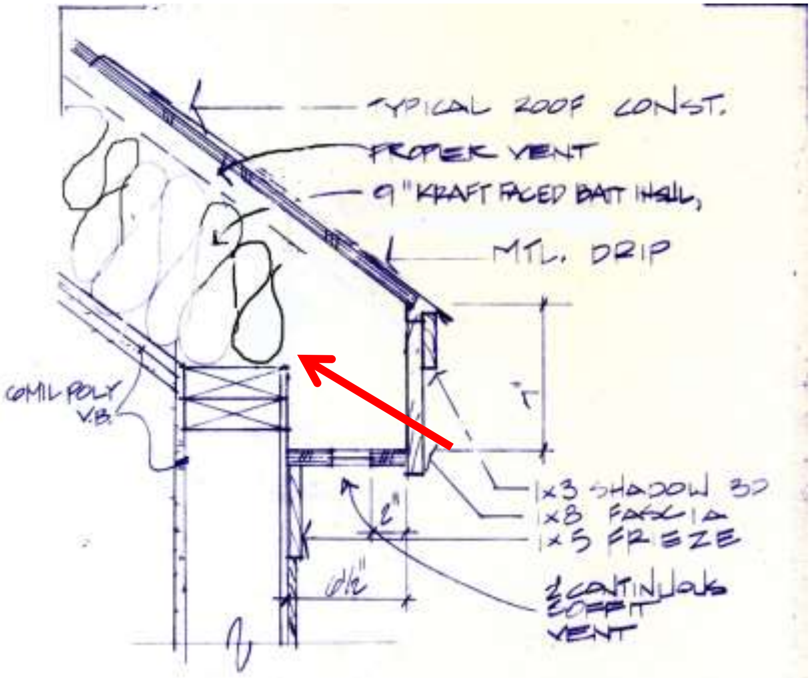


WRB over loose-fill insulation sealed to the firewall and vent chutes completes the air barrier



Note moisture on rafters

SOFFITS

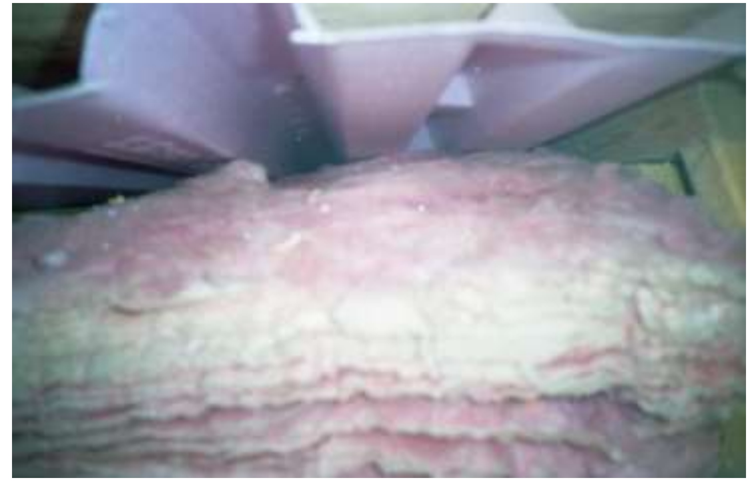


Section at top of typical outside wall - No blocking or end dams to prevent wind washing

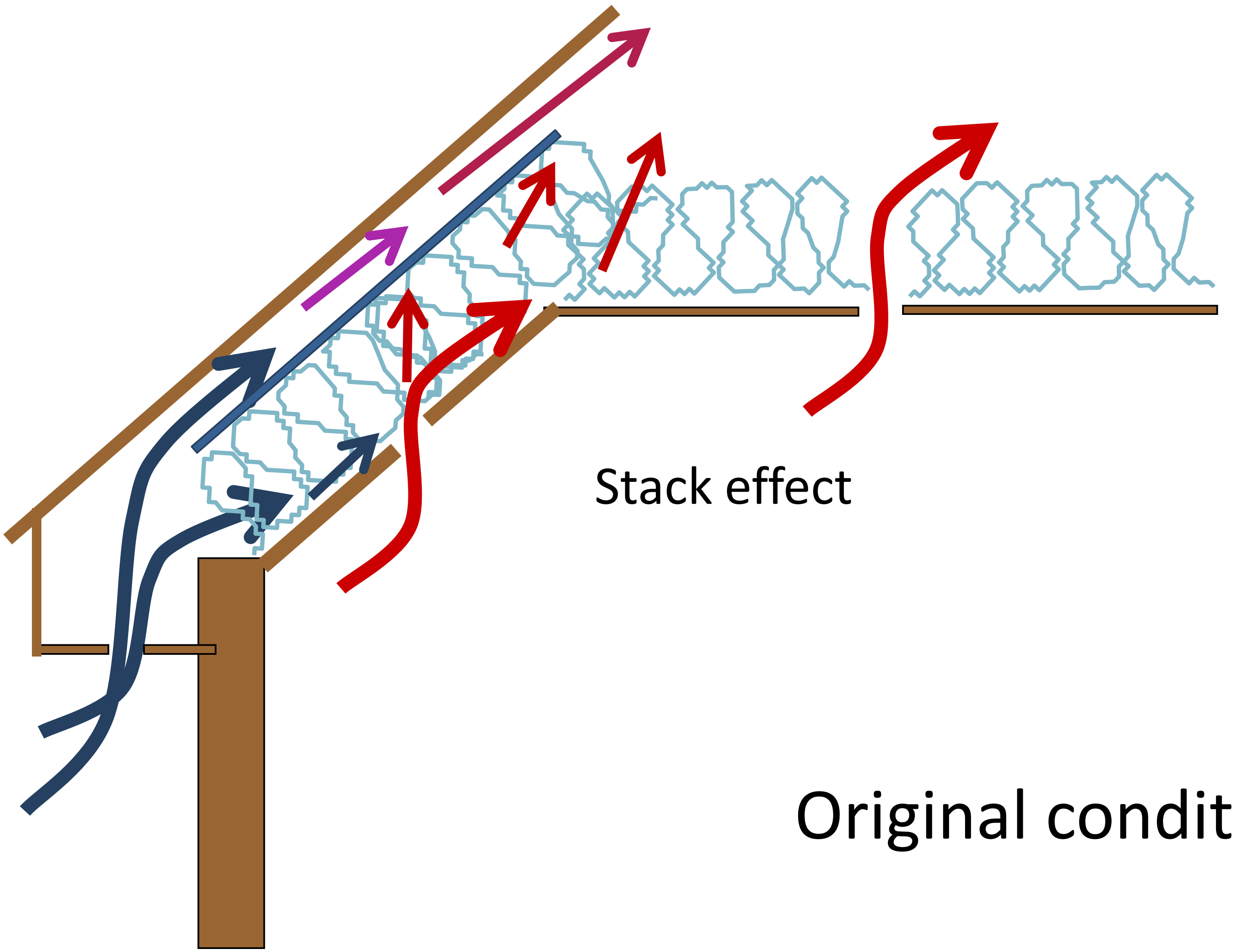
Typical soffit access including uninsulated narrow framing bays

SOFFITS

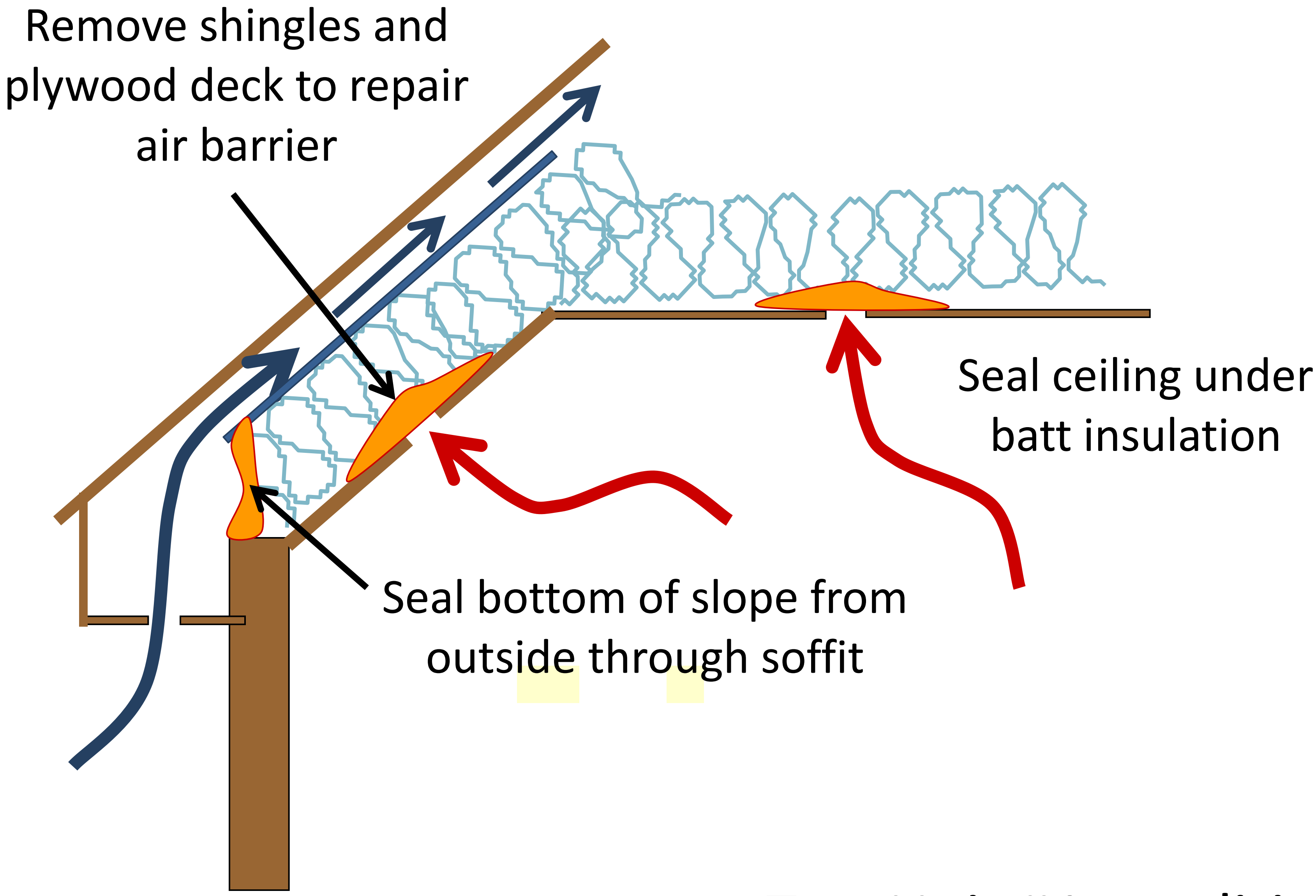
Uninsulated roof bay



After air sealing

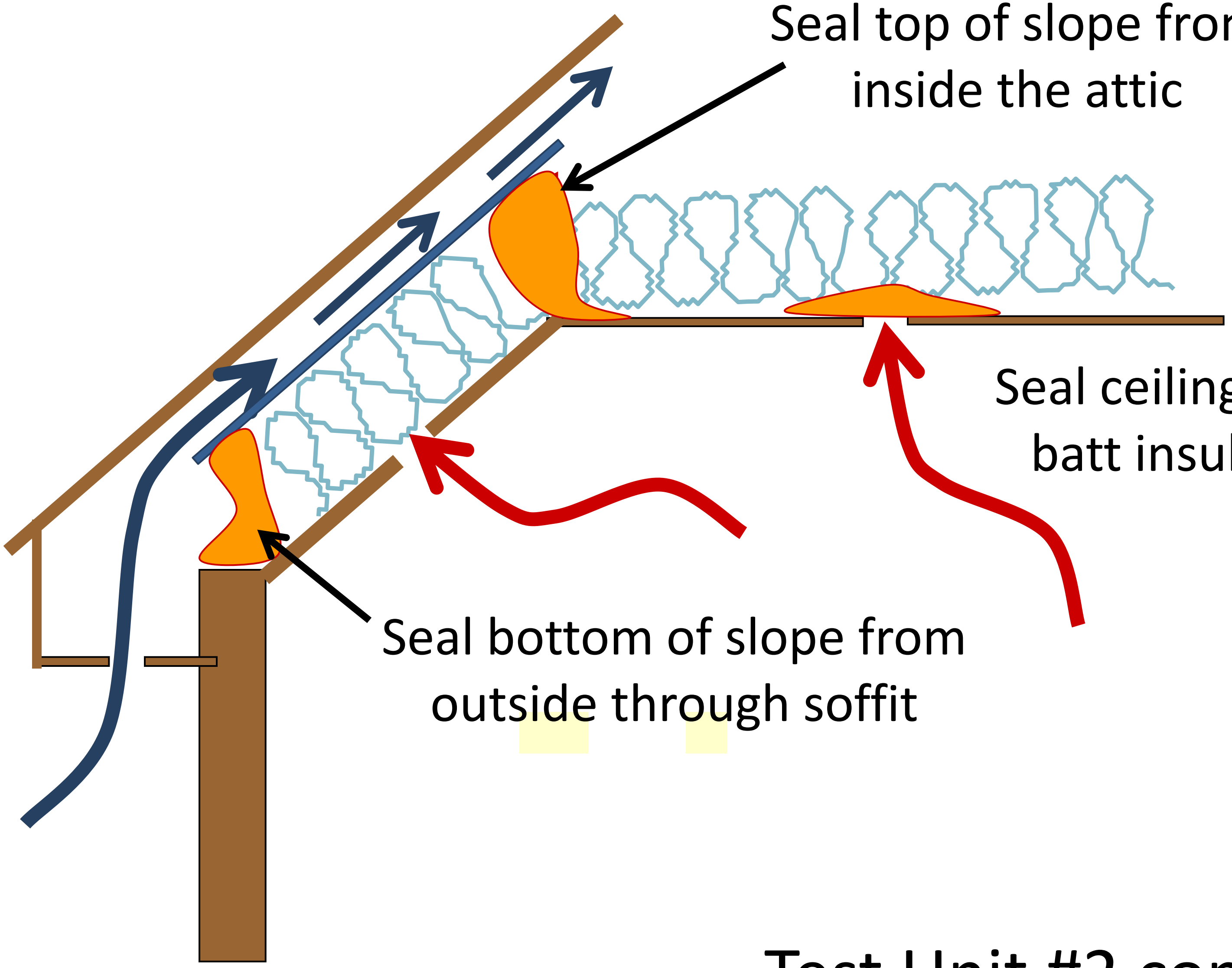


Original condition



Test Unit #1 condition

Open roof approach



Test Unit #2 condition

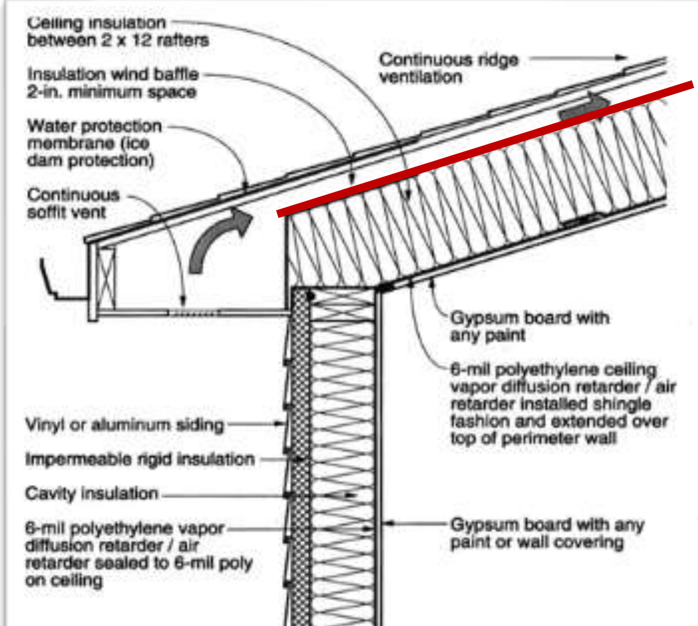


Figure 4-20: Roof 2—heating climate.

Chapter 4—Moisture Control Practices for Heating Climates

Page 114 Moisture Control Handbook

Roof line of adjacent unit in red

The two test units have minimal melt and no icing

Other unmodified units have significant melt

Remediation - ROI

1. How to prioritize remediation work to maximize return on investment
   a. Project size and complexity matters
   b. Temperature at the defect can be used to prioritize the problem
   c. Air barriers first, then ventilate, then add more insulation!

Remediation - ROI

Air barrier and insulation repairs

1. Use defect and melt location temperatures to prioritize the repair work.
2. Using a phased approach in the strategic method
   a. Set the project goal including thresholds.
   b. Monitor the attic inside temperature and outside melt patterns – set a baseline.
   c. Start the repairs at the locations with the worst conditions and progress to locations with conditions that are less serious until the project goal has been met.

Maine Indoor Air Quality Council

IAQ & ENERGY CONFERENCE 2025

Thank you for your time!

QUESTIONS??

The First Frontier in Home Weatherization:
Attics and Cathedral Roof Slopes (2025)

By: Henri Fennell, CSI/CDT

www.polyurethanefoamconsulting.com
Cell: 802-222-7740

Extra case study if I finish early

Cause – Off-ratio foam & HVAC defects

Avoiding the "remove and replace" costs with IPF

Project date: 2012

What are the causes of foam problems?

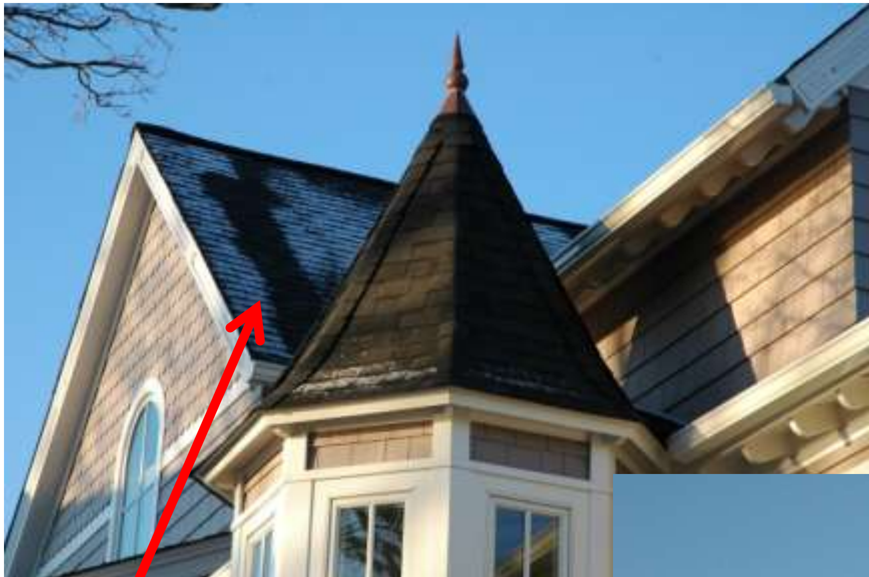
A roof "repair and stabilize" project

Photo DSCN1993.jpeg

Photo DSCN2003.jpeg

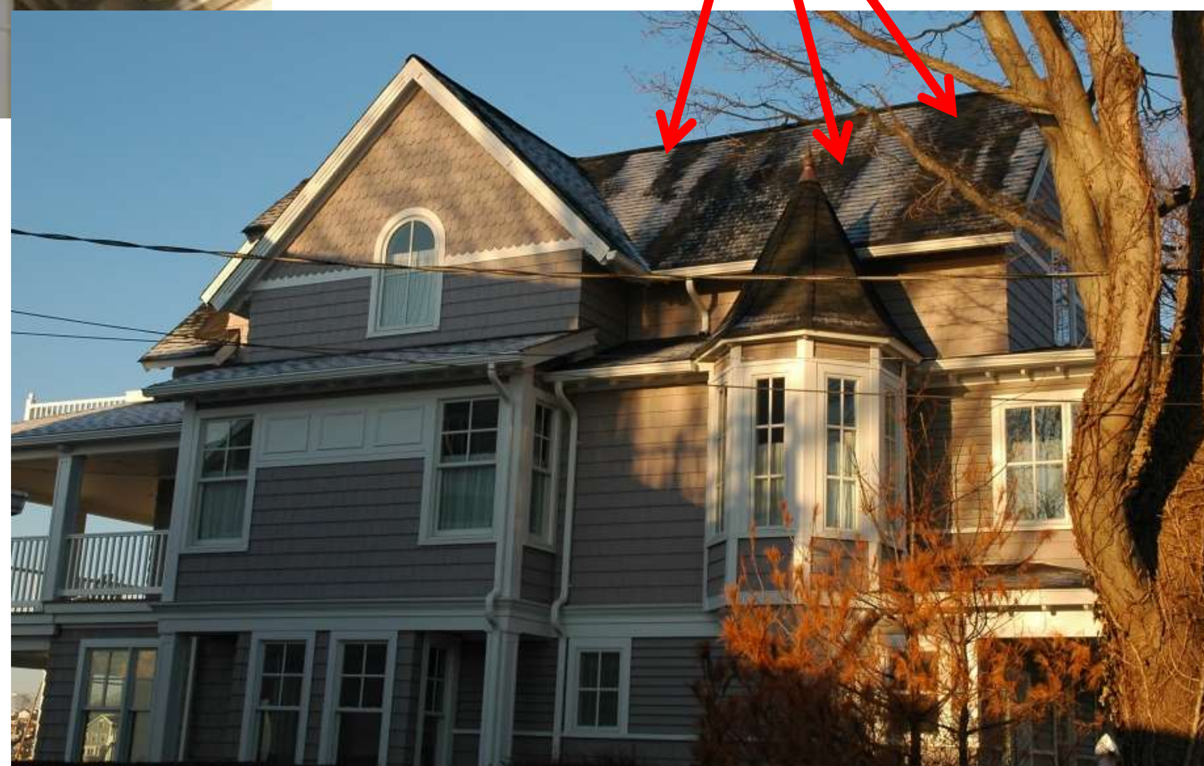
Pictures of cracks along rafters in the House attics. The one on the right has been temporarily stuffed with batt insulation until the remediation work begins.

Cause – Off-ratio foam & HVAC defects



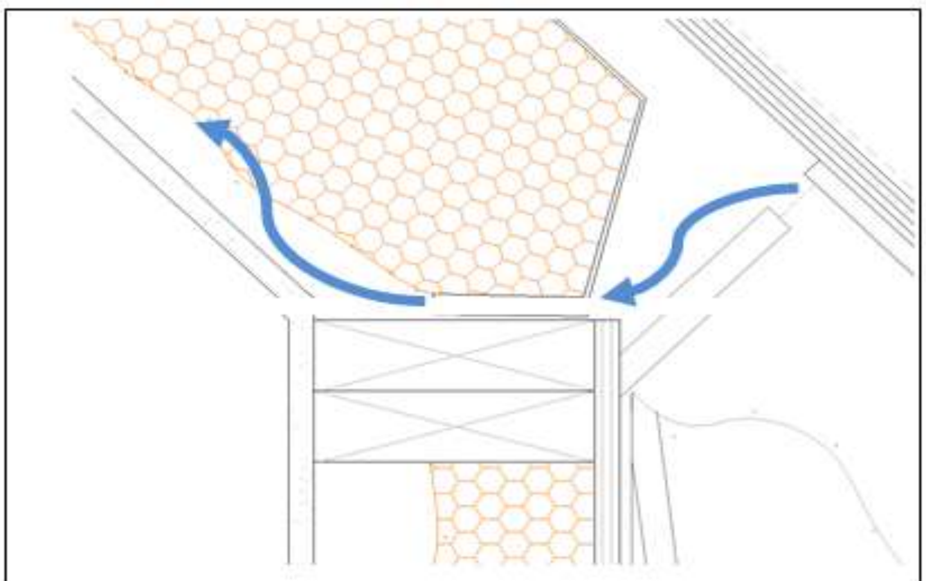
Melt from ducts in the vented roof slopes

Melt patterns before the repair of cracks in the SPF

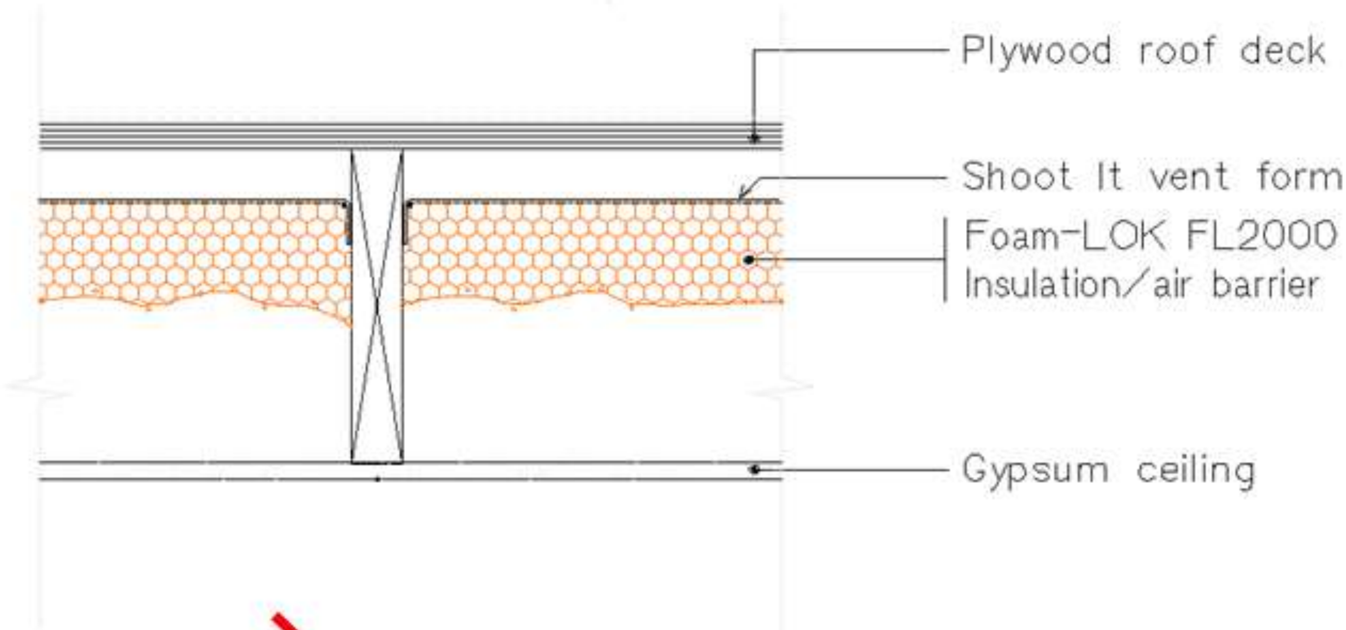


Daylight is visible under the cardboard vent chute form

Photo DSC_4966.JPG



Air bypass under the cardboard vent form


Plywood roof deck
Shoot It vent form
Foam-LOK FL2000
Insulation/air barrier
Gypsum ceiling

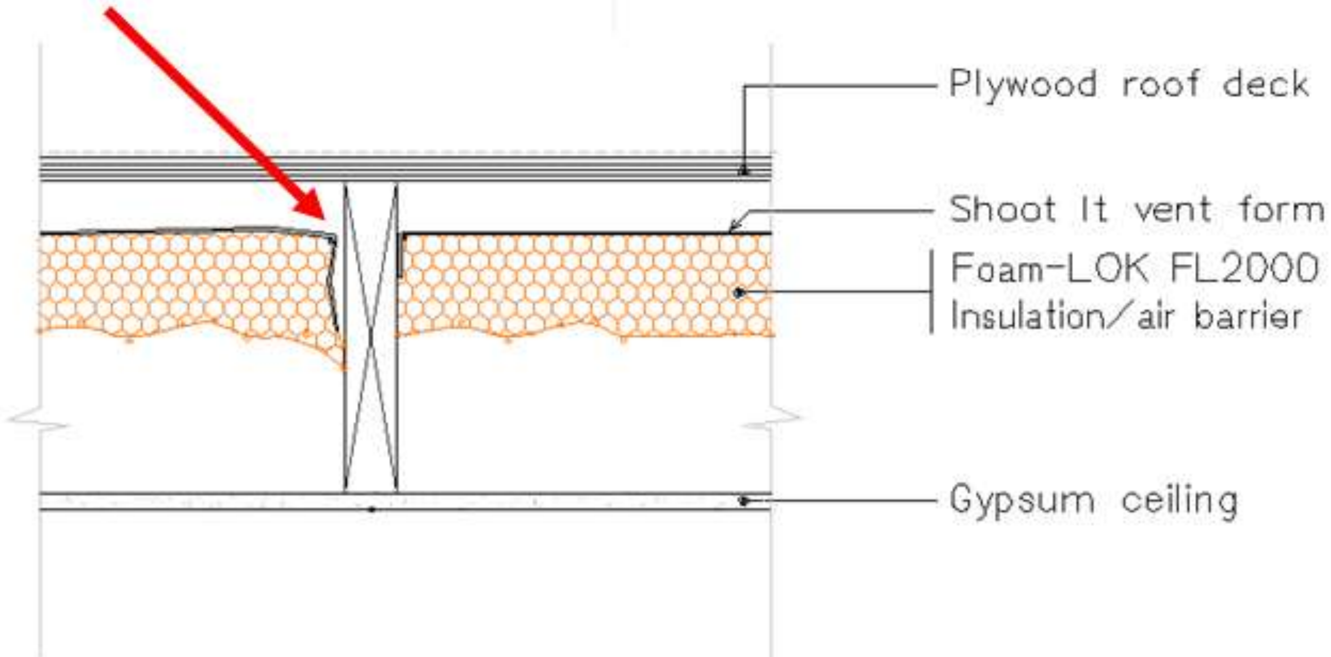
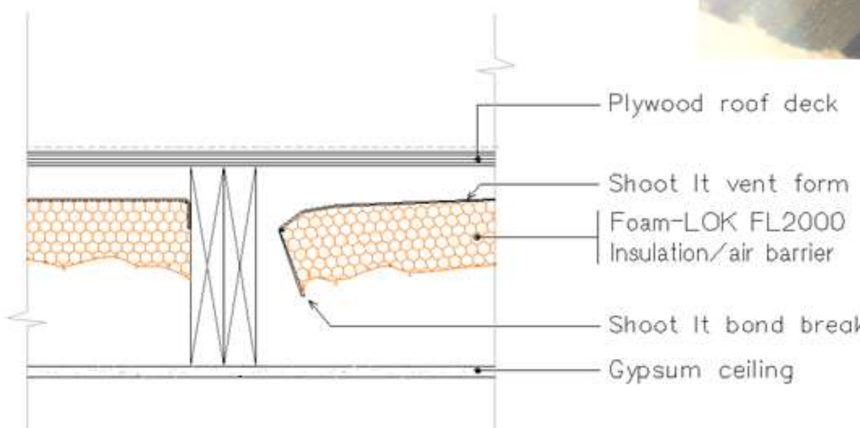

Plywood roof deck
Shoot It vent form
Foam-LOK FL2000
Insulation/air barrier
Gypsum ceiling

Photo DSCN1781.JPG

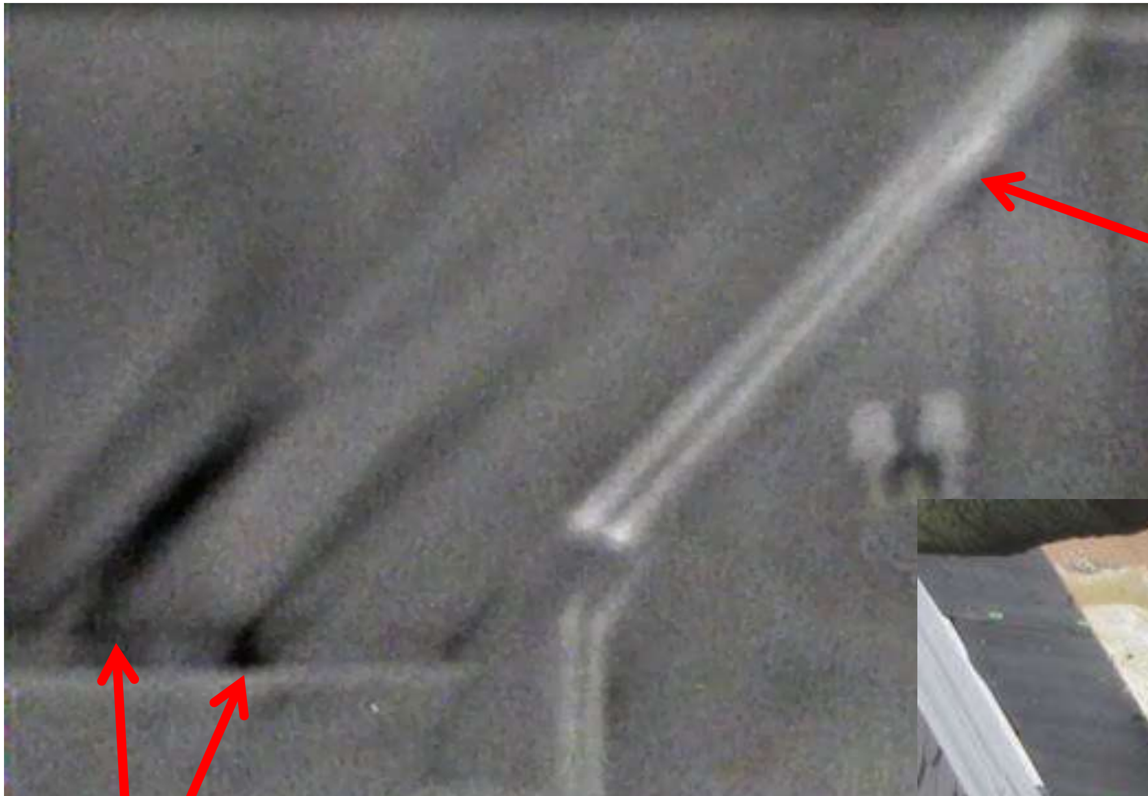
The Shoot fold slot pattern is visible on the side of the rafter - no foam was sprayed below the cardboard to create a bond

Photo DSCN1780.JPG



The Shoot vent form is folded down farther in a narrow bay creating a full bond break between the 3" of foam and the rafter

The remediation process

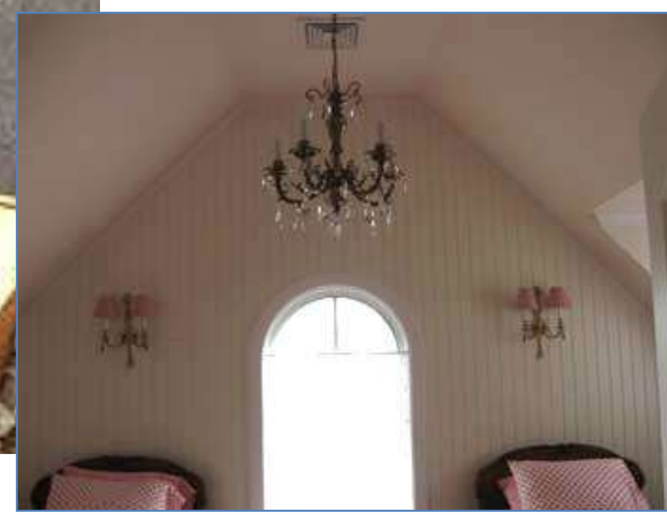


Ducts installed in roof bays – no foam here

Holes discovered in soffits

The remediation process

A roof "repair and stabilize" project



The remediation process

The IPF method

Melt patterns before and after

North side soffit areas

Holes in framing and missing foam sealant discovered in soffits using pressurized theatrical fog test method

0.54 CFM50/sf before remediation
0.19 CFM50/sf after remediation