A New Slant on Roofs

Recent Trends and Building Science Solutions for Residential Roof Systems

Presented to: CACEA Canadian Association of Consulting Energy Advisors

Presented by: Trevor Trainor, M.A.Sc.
President, Building Science Specialist
Bawating Building Science

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Typical Roof Systems

Typical Residential Roof

- Simple
- Sloped
- Vented

Typical Commercial Roof

- Simple
- Flat
- Unvented

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Modern Residential Roof Systems

- Complex
- Mixed sloped and flat
- Often poorly vented

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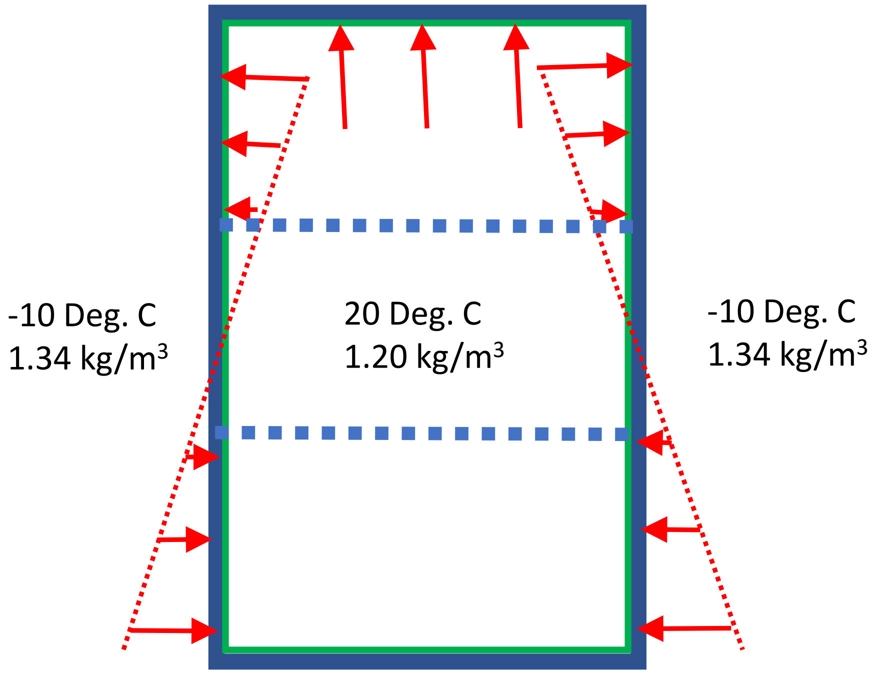
Building Science Fundamentals

Stack-Effect Pressure in Buildings

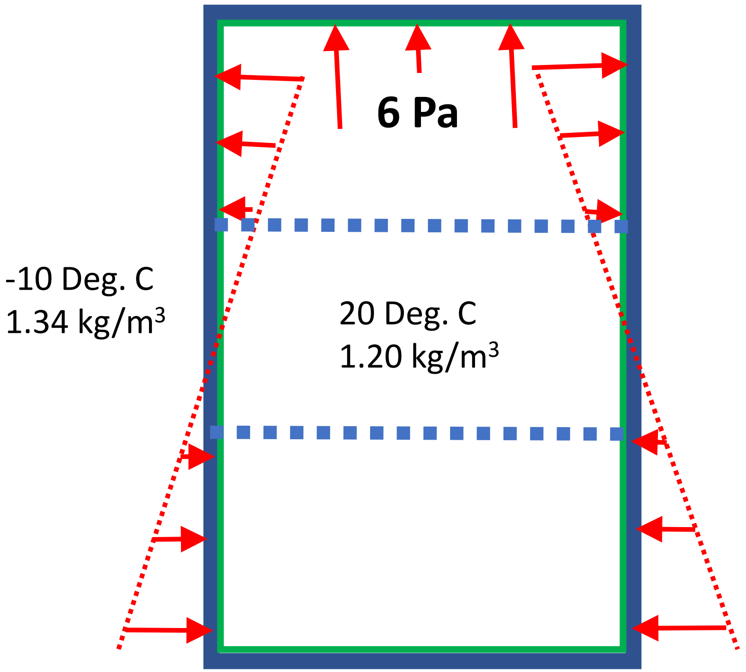


- Stack pressure is a result of the varying density of air
  - Air at 20 deg C = 1.20 kg/m^3
  - Air at -10 deg. C = 1.34 kg/m^3

Building Science Fundamentals

Stack-Effect Pressure in Buildings

$p_s = .0342\ h\ p_t\ (1/T_{out} - 1/T_{in})$



- Stack Pressure is directly proportional to
  - Difference in air temperature
  - Height from the neutral pressure plane to the top opening
  - Under winter conditions, this can results in a pressure of:

2 to 4 Pa pressure per floor

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Building Science Fundamentals
Stack-Effect Pressure in Buildings

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Building Science Fundamentals
Wind Effects on Buildings

- Wind pressure is a function of wind speed, building geometry and local topography

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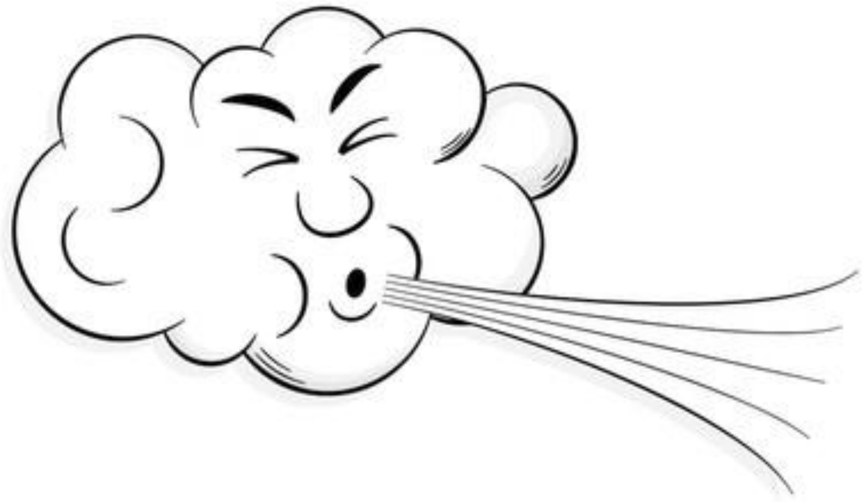
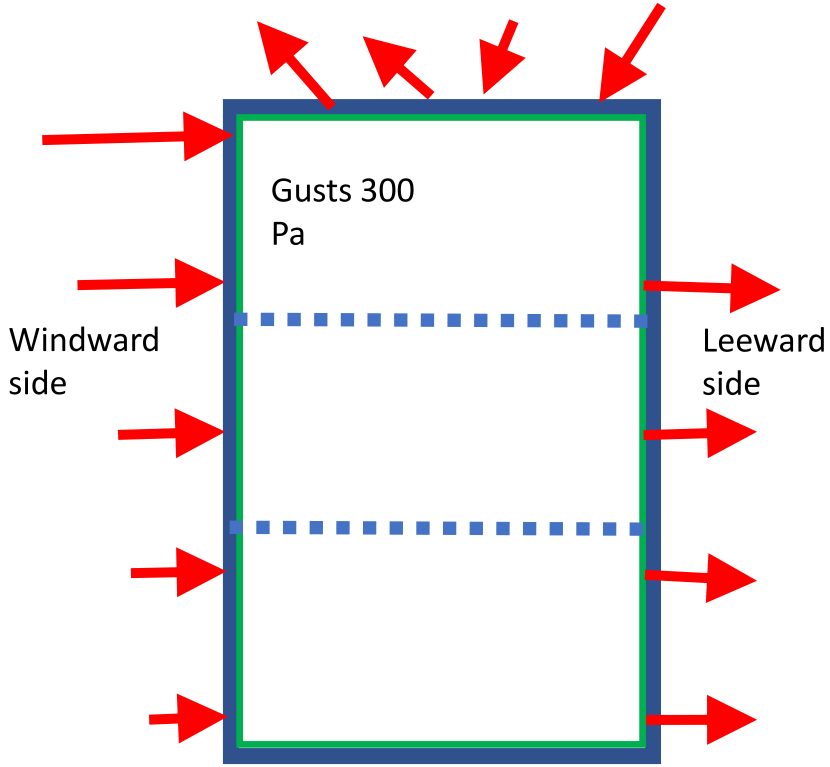
Building Science Fundamentals
Wind Effects on Buildings



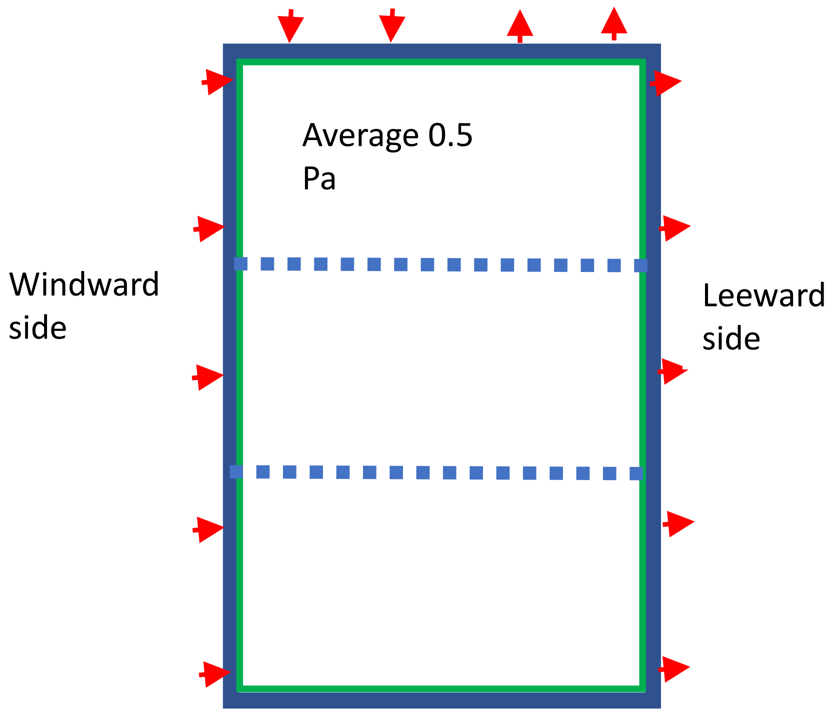
- Peak pressure effects of wind can be 30 X greater than stack effect (1)
- Very important for structural considerations and rain penetration



1) Hutcheon and Handegord, 1984

Building Science Fundamentals
Wind Effects on Buildings

- Average pressure effects of wind are approx. 1/10 of stack effect in a long term average (1)
- Not that important for energy analysis or natural ventilation strategies
- Wind can **not** be relied upon as a significant contributor to attic ventilation



1) Hutcheon and Handegord, 1984

Vented Roofs

Why they usually work…and some times don’t

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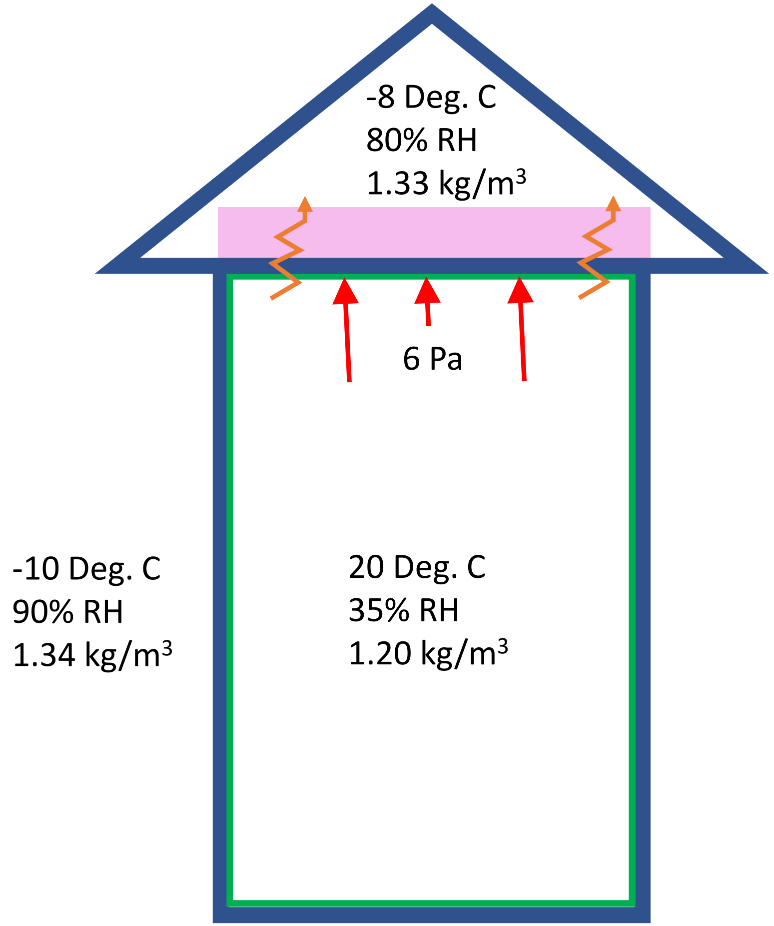
Residential Vented Roofs:

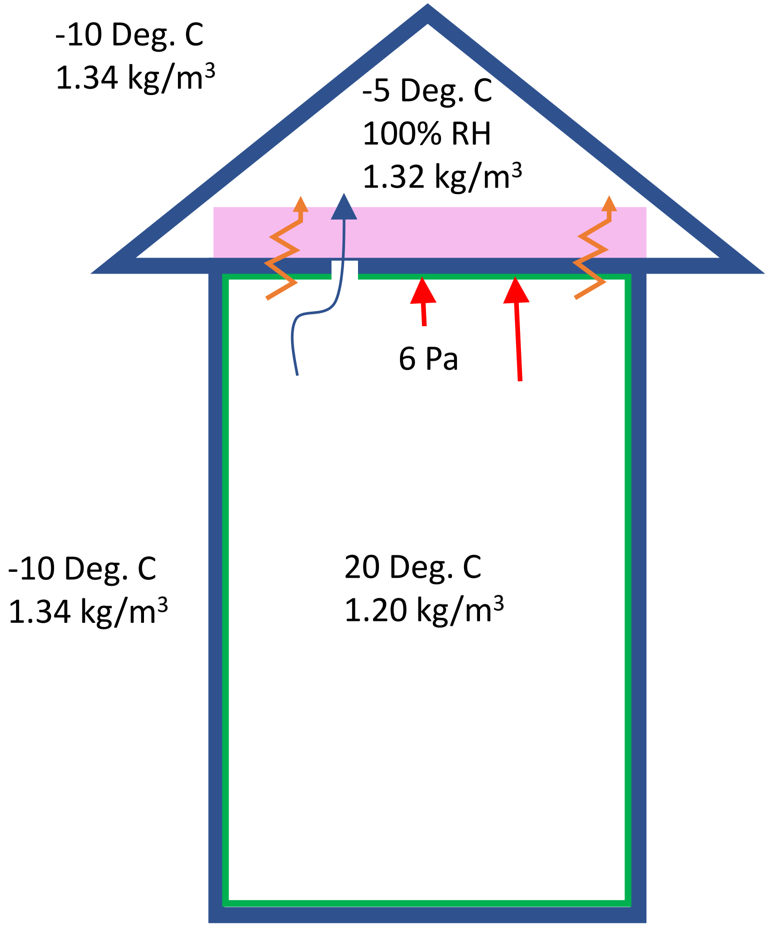
Why they work (usually)



If you have a perfect air barrier- you don’t need ventilation

Residential Vented Roofs:

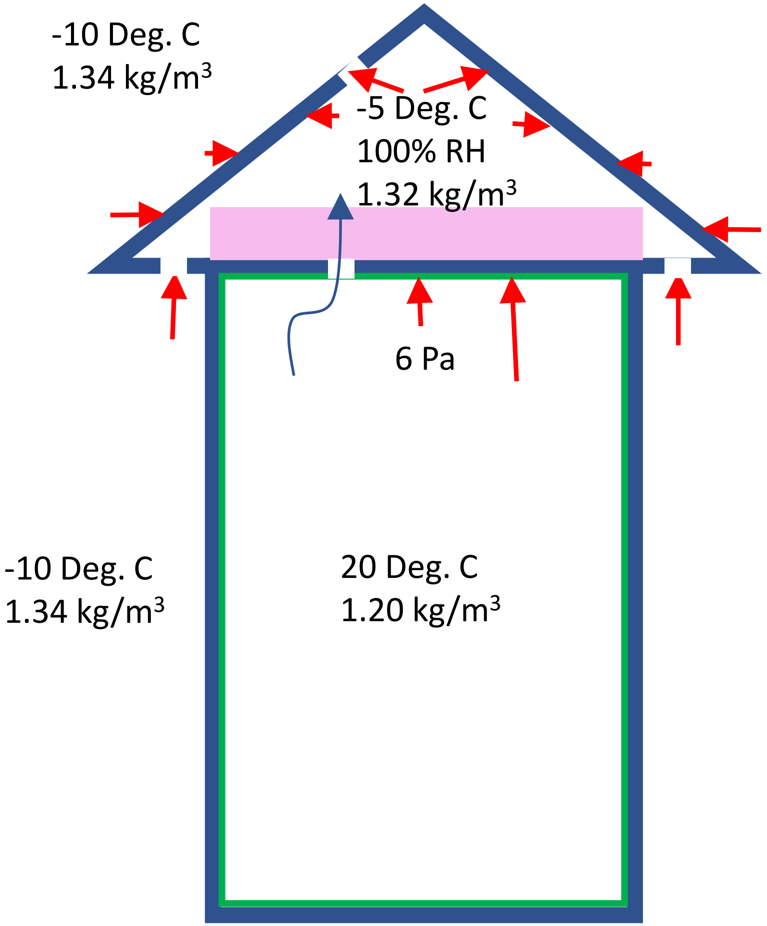
Why they work (usually)



If you don't have a perfect air barrier- moisture will collect in the attic

Residential Vented Roofs:

Why they work (usually)



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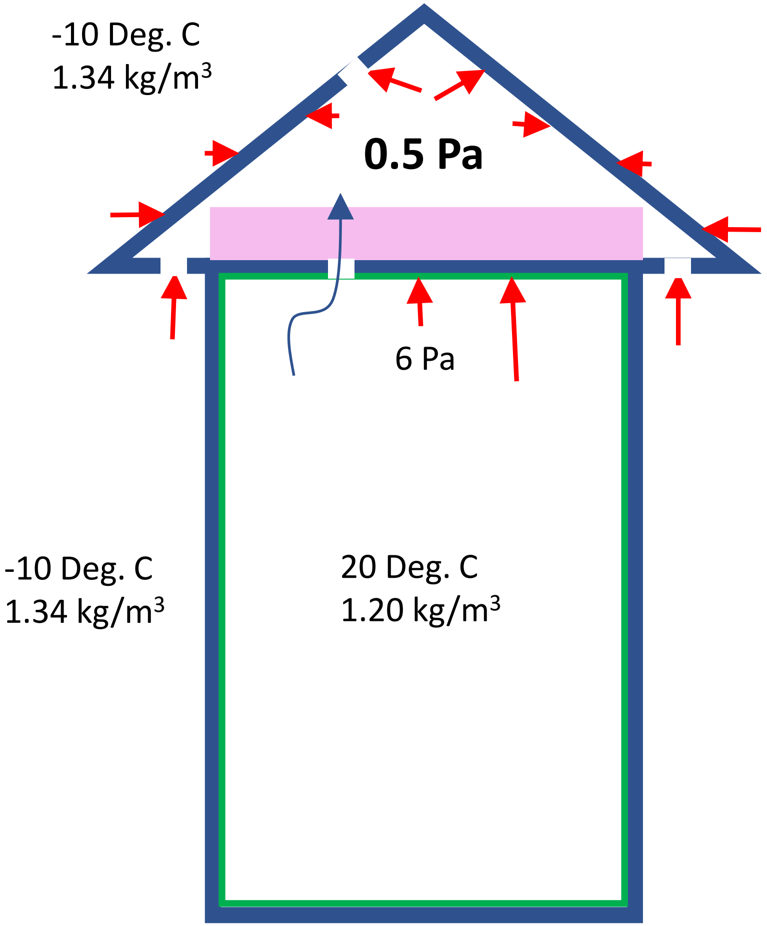
Residential Vented Roofs:

Why they work (usually)



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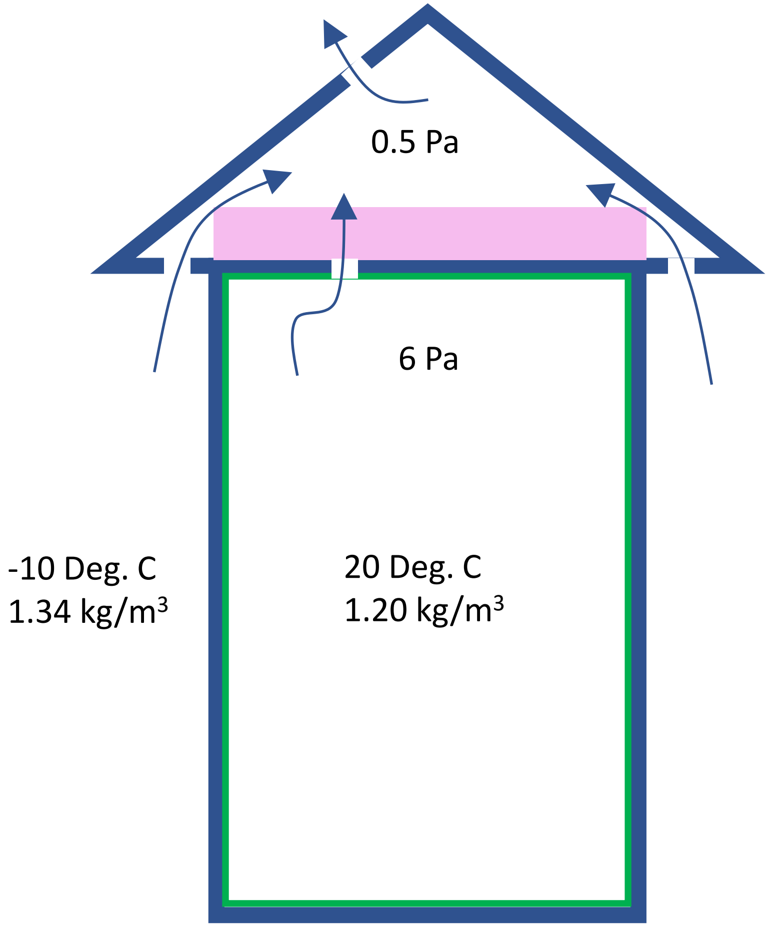

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The Ventilation/Air Leakage Balancing Act

Moisture levels in the attic are a function of:

1. Ceiling air leakage rate
2. Attic ventilation rate
3. Interior relative humidity

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Canadian Code : NBC/OBC Part 9

Section 9.19. Roof Spaces

9.19.1. Venting

9.19.1.1. Required Venting

1) Except where it can be shown to be unnecessary, where insulation is installed between a ceiling and the underside of the roof sheathing, a space shall be provided between the insulation and the sheathing, and vents shall be installed to permit the transfer of moisture from the space to the exterior. (See Note A-9.19.1.1.(1).)

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Canadian Code : NBC/OBC Part 9

A-9.19.1.1.(1) Venting of Attic or Roof Spaces. Controlling the flow of moisture by air leakage and vapour diffusion into attic or roof spaces is necessary to limit moisture-induced deterioration. Given that imperfections normally exist in the vapour barriers and air barrier systems, recent research indicates that venting of attic or roof spaces is generally still required. The exception provided in Article 9.19.1.1. recognizes that some specialized ceiling-roof assemblies, such as those used in some factory-built buildings, have, over time, demonstrated that their construction is sufficiently tight to prevent excessive moisture accumulation. In these cases, ventilation would not be required.

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Canadian Code : NBC/OBC Part 9

9.19.1.2. Vent Requirements

1) Except as provided in Sentence (2), the unobstructed vent area shall be not less than 1/300 of the insulated ceiling area.

2) Where the roof slope is less than 1 in 6 or in roofs that are constructed with roof joists, the unobstructed vent area shall be not less than 1/150 of the insulated ceiling area.

3) Required vents may be roof type, eave type, gable-end type or any combination thereof, and shall be distributed

a) uniformly on opposite sides of the *building*,
b) with not less than 25% of the required openings located at the top of the space, and
c) with not less than 25% of the required openings located at the bottom of the space.

4) Except where each joist space is separately vented, roof joist spaces shall be interconnected by installing purlins not less than 38 mm by 38 mm on the top of the roof joists.

5) Vents shall comply with CAN3-A93-M, "Natural Airflow Ventilators for Buildings."

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Canadian Code : NBC/OBC Part 9

9.19.1.3. Clearances

1) Except as provided in Sentence (2), not less than 63 mm of space shall be provided between the top of the insulation and the underside of the roof sheathing.

2) At the junction of sloped roofs and exterior walls, where preformed baffles are used to contain the insulation, the baffles shall

- a) provide an unobstructed air space, between the insulation and the underside of the roof sheathing, that is
  - i) not less than 25 mm in dimension, and
  - ii) of sufficient cross area to meet the *attic or roof space* venting requirements of Article 9.19.1.2., and
- b) extend vertically not less than 50 mm above the top of the insulation.

3) Ceiling insulation shall be installed in a manner that will not restrict the free flow of air through roof vents or through any portion of the *attic or roof space*.

9.19.1.4. Mansard or Gambrel Roof

1) The lower portion of a mansard or gambrel style roof need not be ventilated.

2) The upper portion of roofs described in Sentence (1) shall be ventilated in conformance with Articles 9.19.1.1. to 9.19.1.3.

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Case Studies

When vented roofs don't work

Case Study 1:

- Residential, vented roof
- No roof overhangs
- Integrated gutter system
- Steep pitch at perimeter and flat in center

- Ductwork in the Attic (covered in ocSPF)

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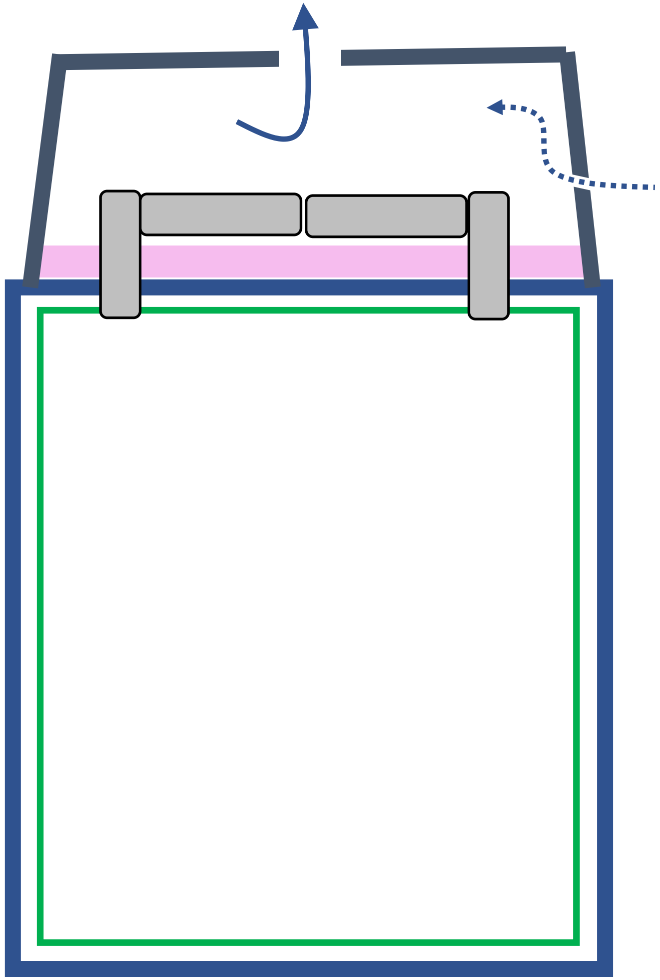
Case Study 1:



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Case Study 1:

Issues-

1) Water staining at second floor ceiling following long cold spell

2) Excessive amounts of frost build-up on roof sheathing

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Case Study 1:

Sufficient high ventilation

Insufficient low ventilation

- 6 – 1” X 8” vents

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Case Study 1:

Causes

1) Leaky ductwork
    - introducing warm humid air while running

2) Insufficient low ventilation
    - can not draw in sufficient exterior air (when furnace is not running)

3) Air leakage at ceiling plane

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Case Study 1:

Recommendations:

1) Air seal ductwork and ceiling plane with spray foam

2) Install additional low vents

    - could not add enough

3) Installation of in-line fan as temporary measure to dry out attic this winter. Consider permanent use.

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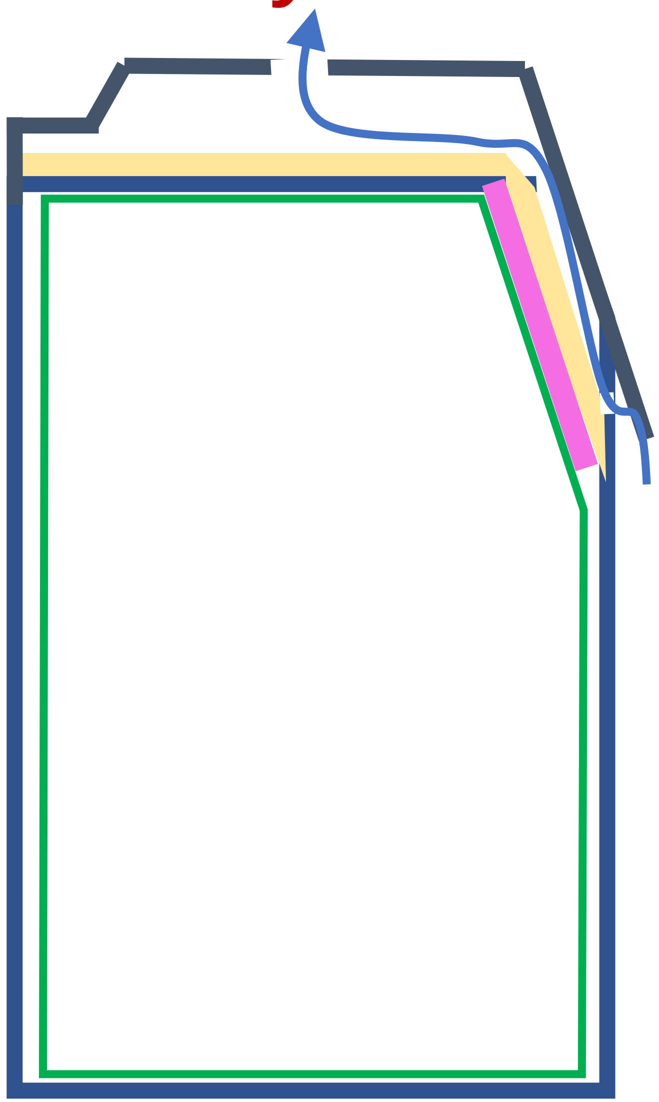
Case Study 2:

- Residential, vented roof
- Some vented soffits
- Steep pitch at perimeter and flat in center
- Sloped ceiling areas
- ccSPF as ceiling level air barrier
- Ductwork in the Attic (covered in ccSPF, not yet in operation)

Case Study 2:



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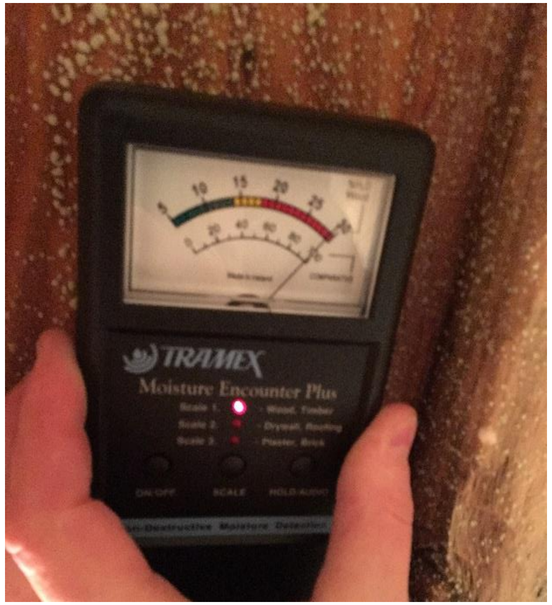
Case Study 2:

Issues:

- Extreme amounts of condensation on sheathing
- Dripping and puddles in attic
- Ice damming



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Case Study 2:

Ventilation:

Sufficient low ventilation in some areas, none in others

Insufficient high ventilation

10 – 3” diameter vents

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Case Study 2:

Causes:

- Insufficient high ventilation
- Ineffective ceiling air barrier

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Case Study 2:

Discontinuities in ceiling air barrier

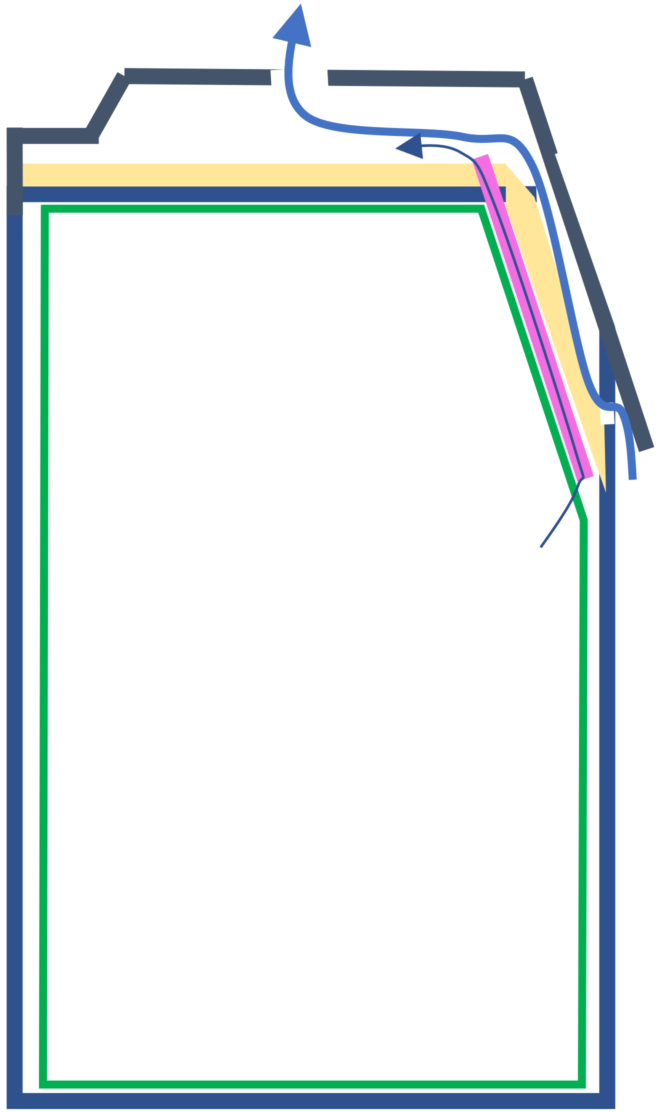
At built-up trusses

Case Study 2:

Discontinuities in ceiling air barrier

At pot lights

Case Study 2:



Discontinuities in ceiling air barrier

Where sloped ceiling
meets flat ceiling

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Case Study 2:

Recommendations:

- Remove loose fill fiberglass
- Identify ceiling air barrier leaks using depressurization, IR imaging and visual inspection
- Seal ceiling air barrier leaks with additional layer of ccSPF
    - Inspect and further touch-ups
- Turn off attic lights when not up there
- Run inline fans as temporary measure to over ventilate attic
- Replace insufficient high vents with appropriate venting

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Residential Vented Roofs:

Benefits

1) Cheap and Easy
- Loose fill insulation
- Polyethylene AVB
- Trades familiar with methods

2) Can tolerate some air leakage
- To reduce moisture accumulation

3) Can dry out
- When weather conditions allow

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Residential Vented Roofs:

What can go wrong

1) Too much air leakage

- Pot lights
- Attic Hatches
- Over pressurization of building
- Negative pressurization of attic

2) Not enough ventilation

- Insufficient vent free area (VFA)
- Insufficient stack effect
- Blocked by framing
- Dead areas

3) Other moisture sources

- HVAC ducts
- Rain/snow penetration
- High interior RH

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Unvented Roofs

Why they usually work…and some times don’t

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When to Consider an Unvented Roof:

→ Complex roof lines

→ Vaulted ceilings

→ Flat roofs

→ Ductwork in the attic

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Commercial Unvented Roofs:

Why it works (usually)

- → Multiple layers acting as air barrier
  - → Gypsum sheathing
  - → Air barrier membrane
  - → Rigid insulation (multi-layers, staggered)
- → Insulation exterior to structure
- → Beware penetrations and transitions

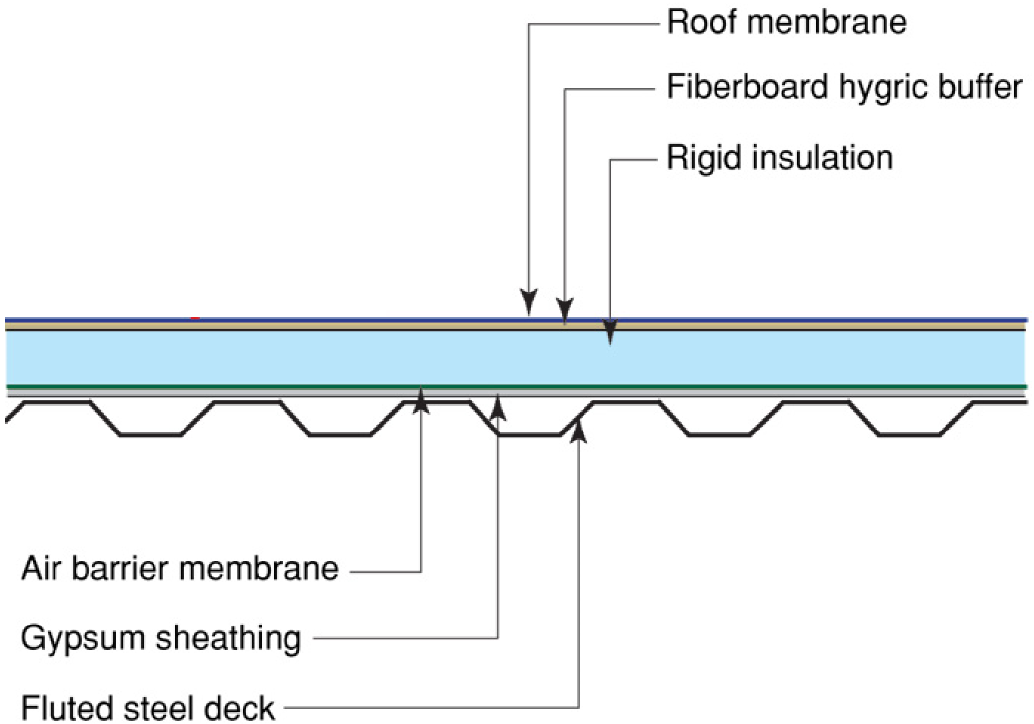

Image credit: Building Science Corporation

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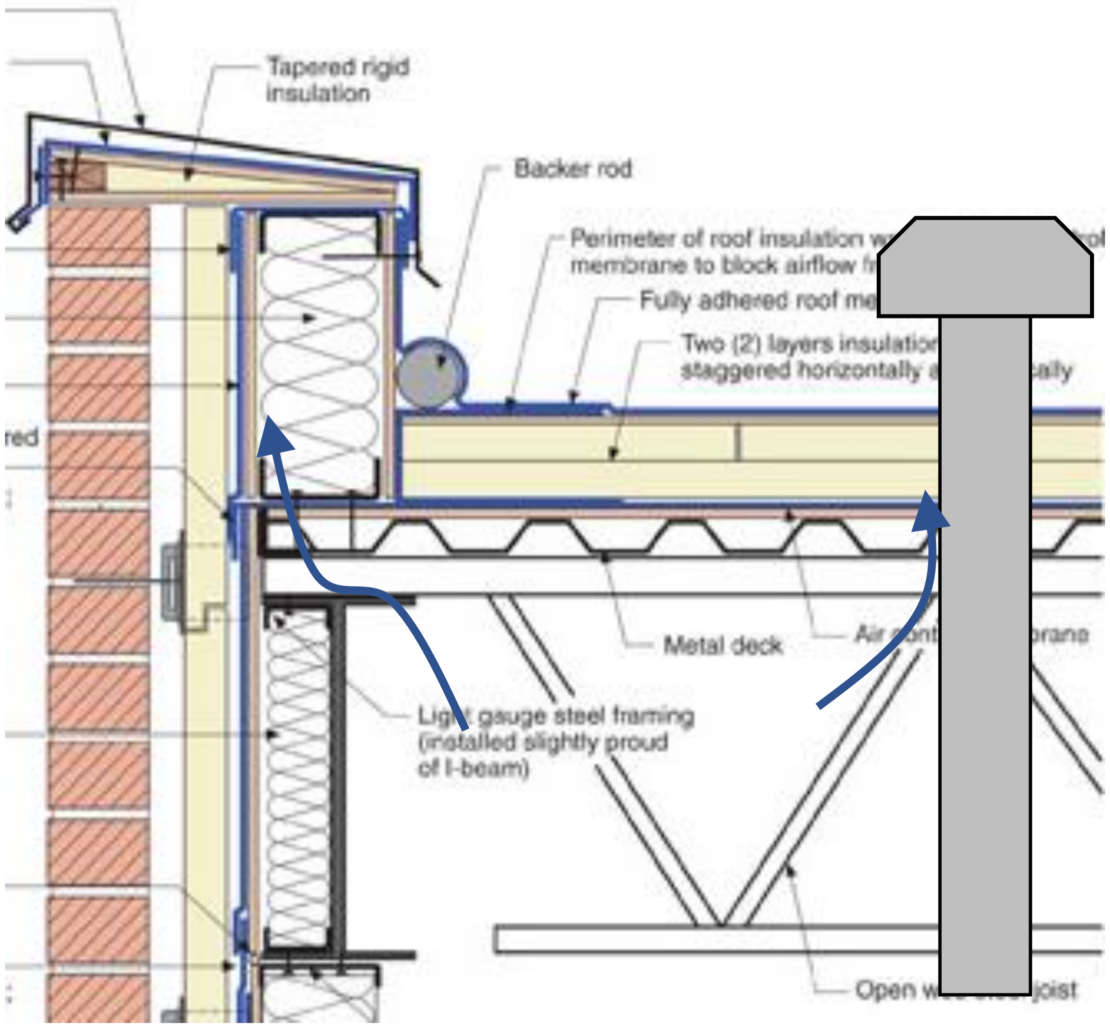
Commercial Unvented Roofs:

Why it works (usually)

→ Beware penetrations and transitions



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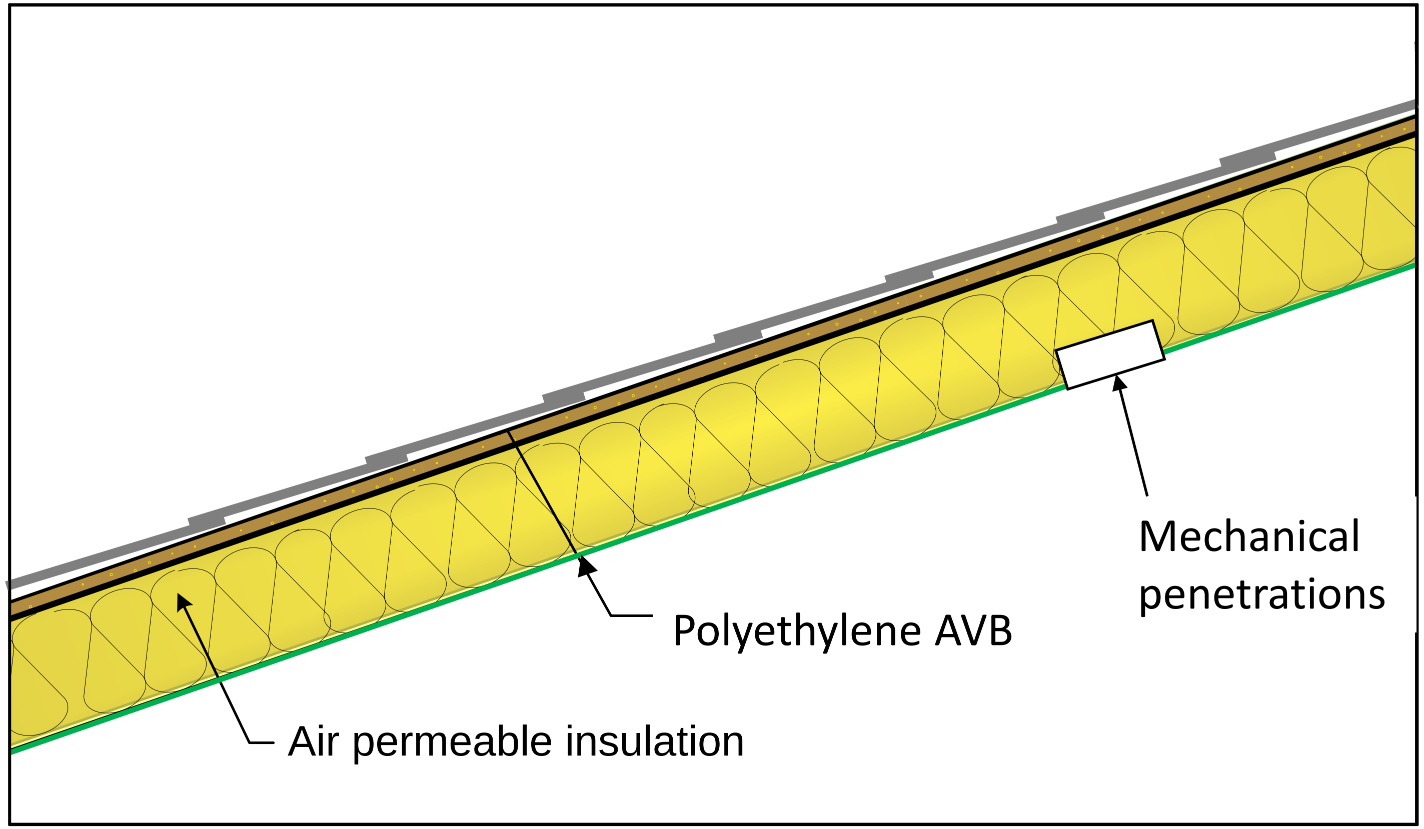
Sloped Unvented Roofs:

Batt Insulated

- → Interior polyethylene AVB
- → Difficult to make air barrier continuous
- → Insulation interior to structure
- → Insulation permeable to air
- → Beware penetrations and transitions



NOT RECOMMENDED

Image credit: Building Science Corporation

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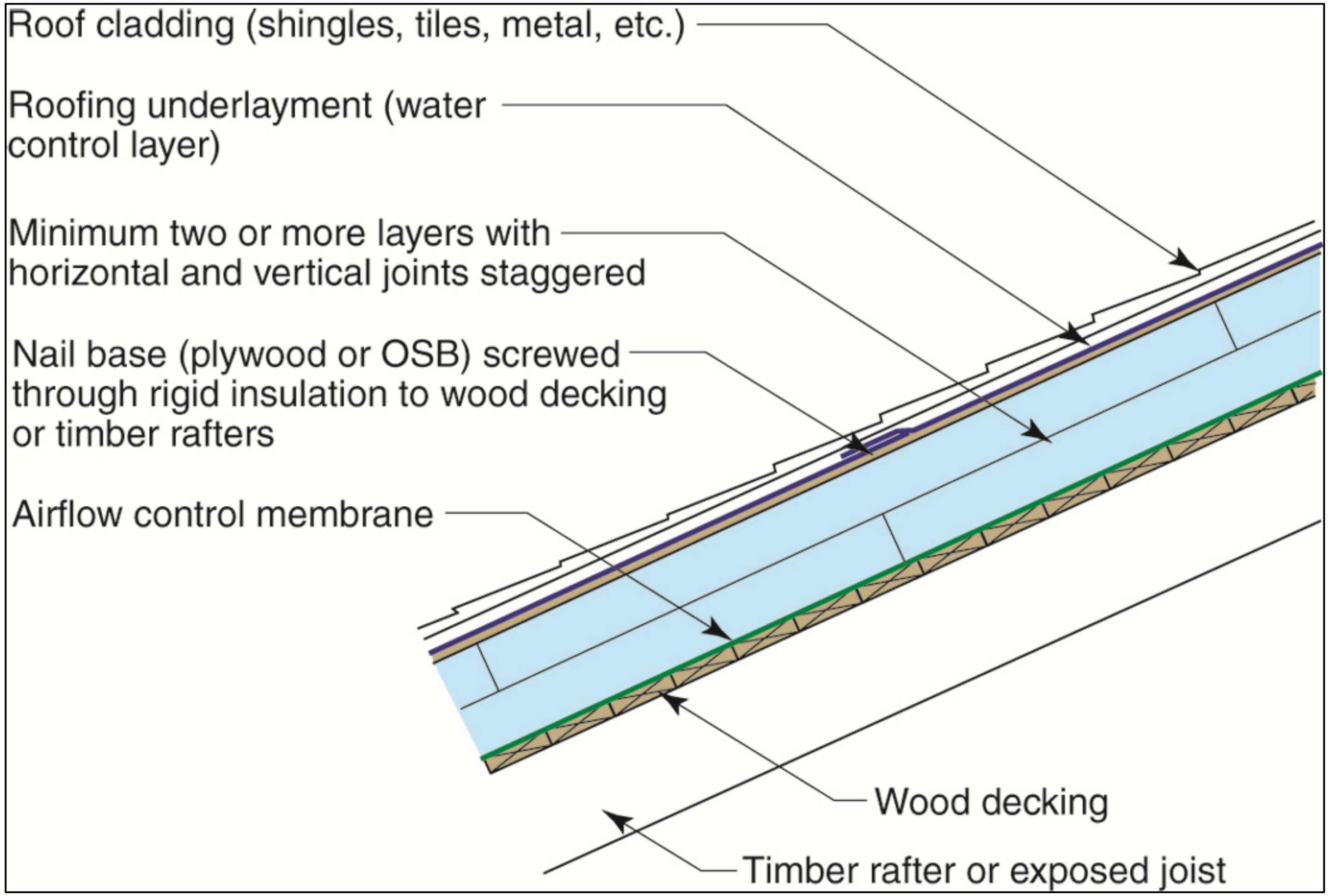
Sloped Unvented Roofs:

Exterior Insulated

- → Multiple layers acting as air barrier
- → Easy to make air barrier continuous
- → Insulation exterior to structure
- → Beware penetrations and transitions



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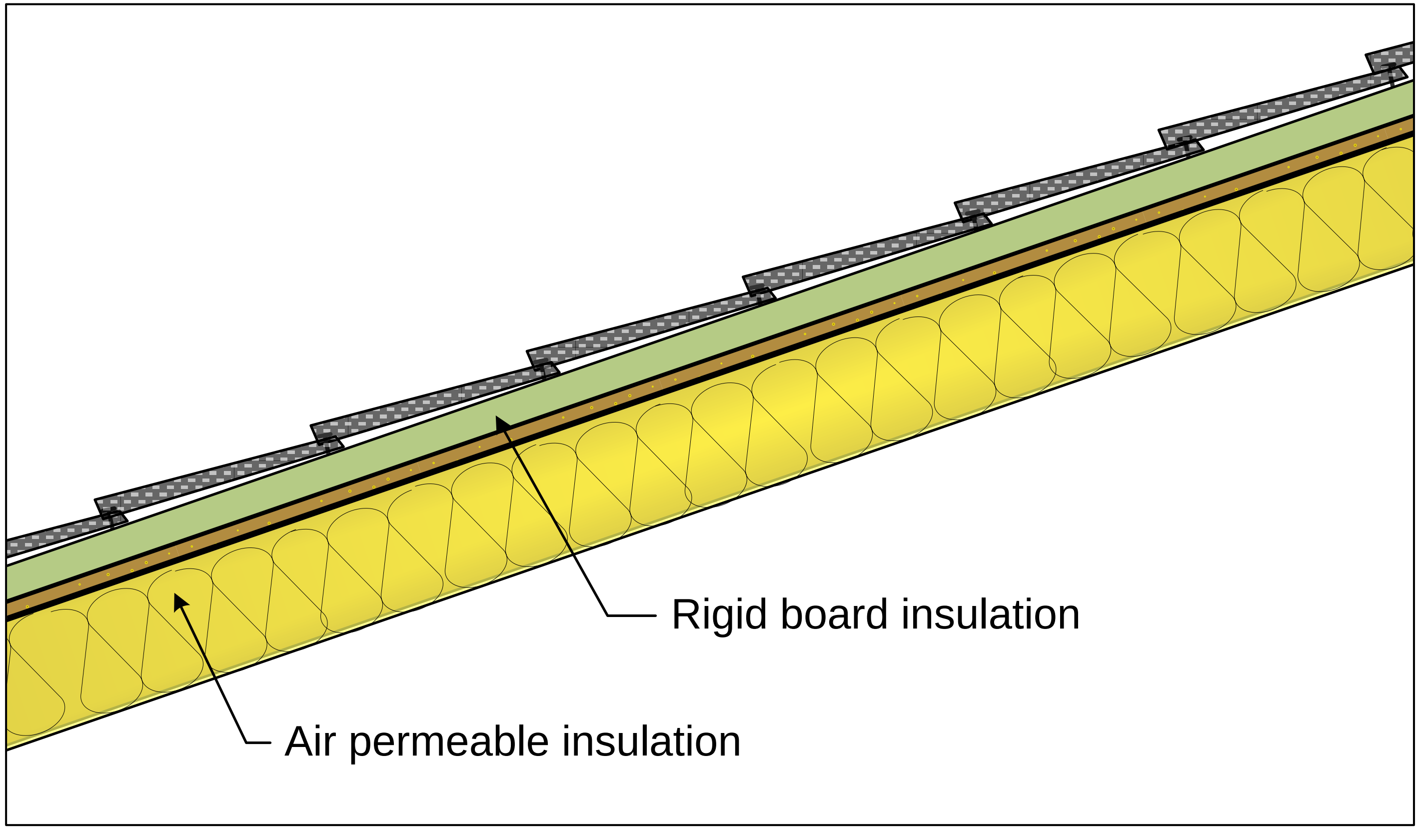
Sloped Unvented Roofs:
Split Insulated

- Multiple layers acting as air barrier
- Easy to make air barrier continuous
- Insulation exterior and interior to structure
- Insulation types and ratios matter
- Beware penetrations and transitions



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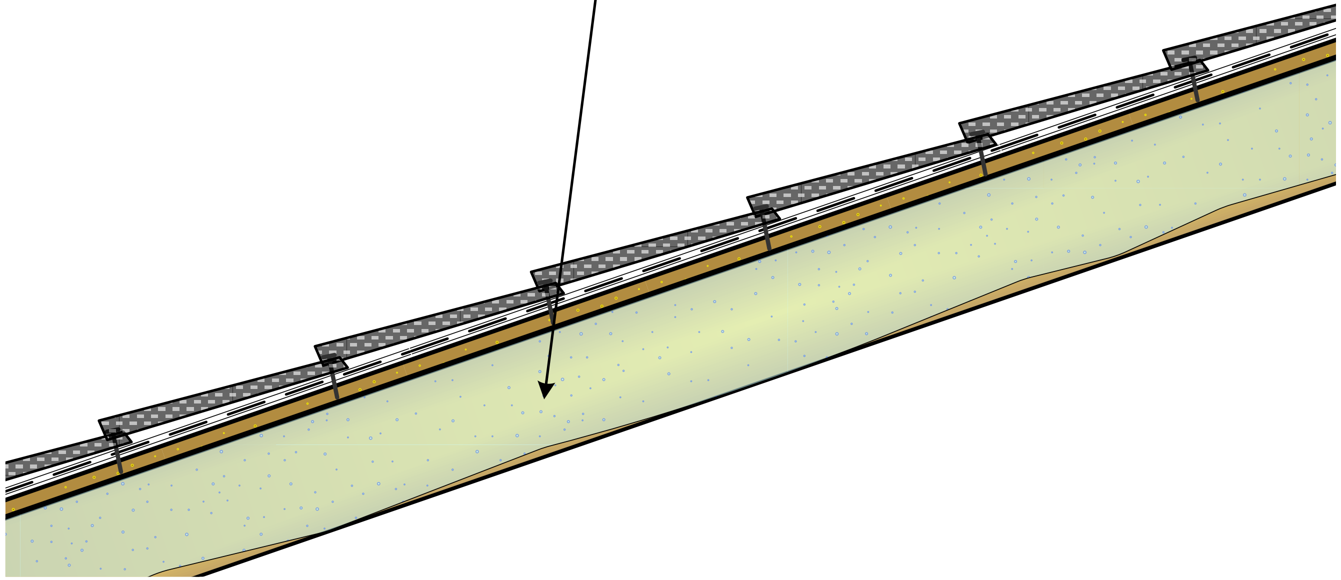
Sloped Unvented Roofs:

Spray Foam

- Spray foam acting as air barrier
- Spray foam air barrier continuity is critical
- Areas not covered with spray foam must be sealed
- Insulation interior to structure
- Beware penetrations and transitions



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Sloped Unvented Roofs:

Flash and Batt

- → Spray foam acting as air barrier
- → Spray foam air barrier continuity is critical
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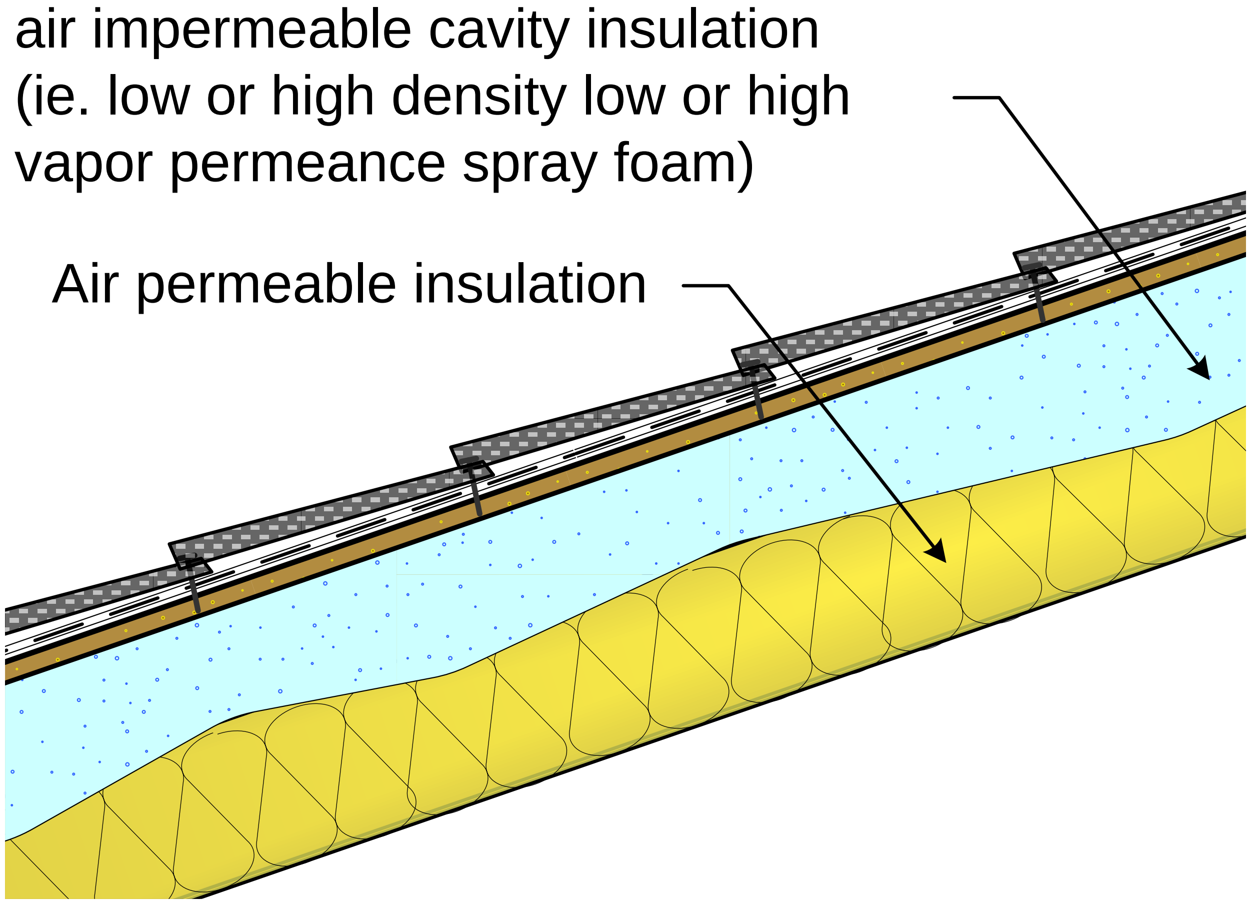
- → Insulation interior to structure
- → Insulation ratios matter
- → Beware penetrations and transitions



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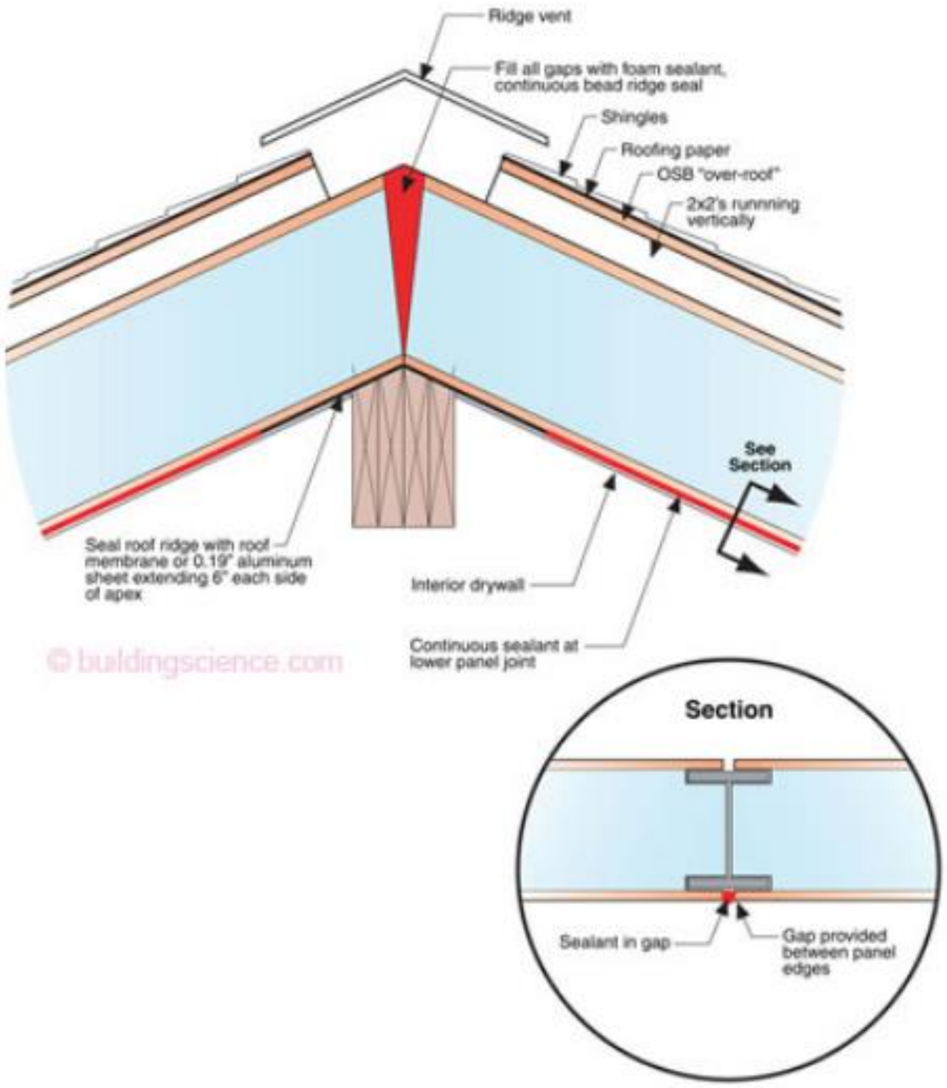
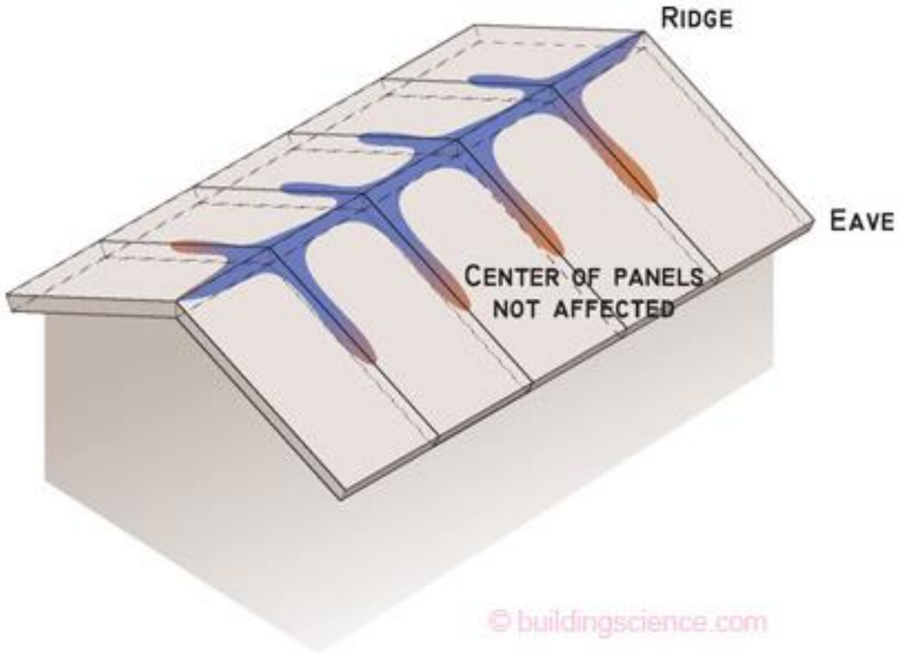
Sloped Unvented Roofs:

SIPs Panels





- Beware of air leakage at the many joints
- Beware of 3-D air leakage pathways
- Special air sealing details required
- OSB Structure is vulnerable to moisture

Image credit: Building Science Corporation

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Sloped Unvented Roofs:

The Best Approach – Exterior Insulation

- → Pairs well with exterior insulated wall systems
- → Easy to create air barrier continuity
- → Easy to create thermal continuity
- → Structure remains warm and dry
- → Beware penetrations and transitions
- → Window/door penetrations require more effort

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Sloped Unvented Roofs:

The Best Approach – Exterior Insulation

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Sloped Unvented Roofs:

The Most Common Approach: Spray Foam

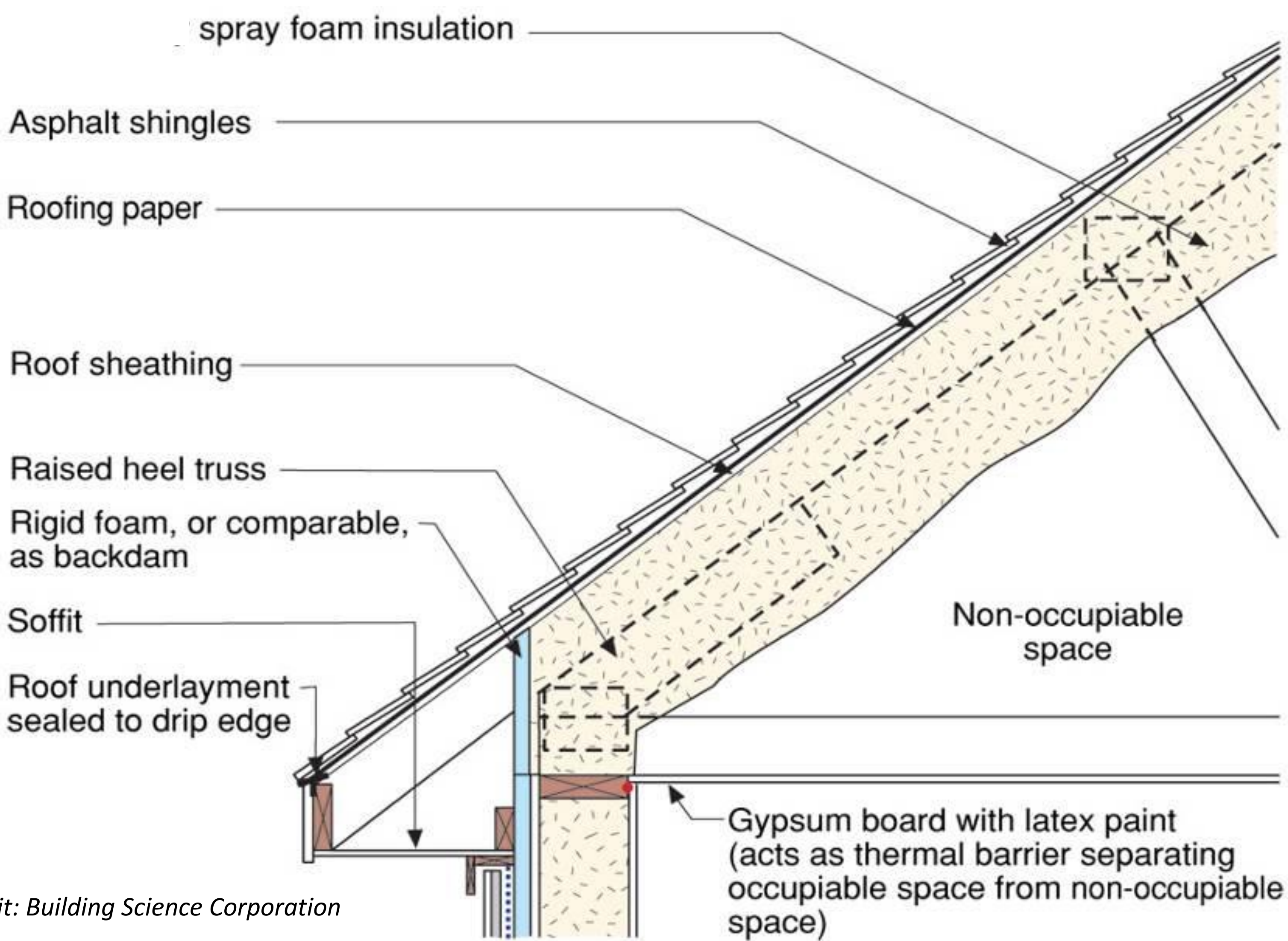

Image credit: Building Science Corporation

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Sloped Unvented Roofs:

The Most Common Approach – Spray Foam

- → Performance highly dependant on:
  -Detail design
  -Installation quality
- → Roofing must be installed and sheathing must be dry
- → Transition from roof to wall critical
- → Beware wood-wood joints
- → How to treat the non-occupiable space?

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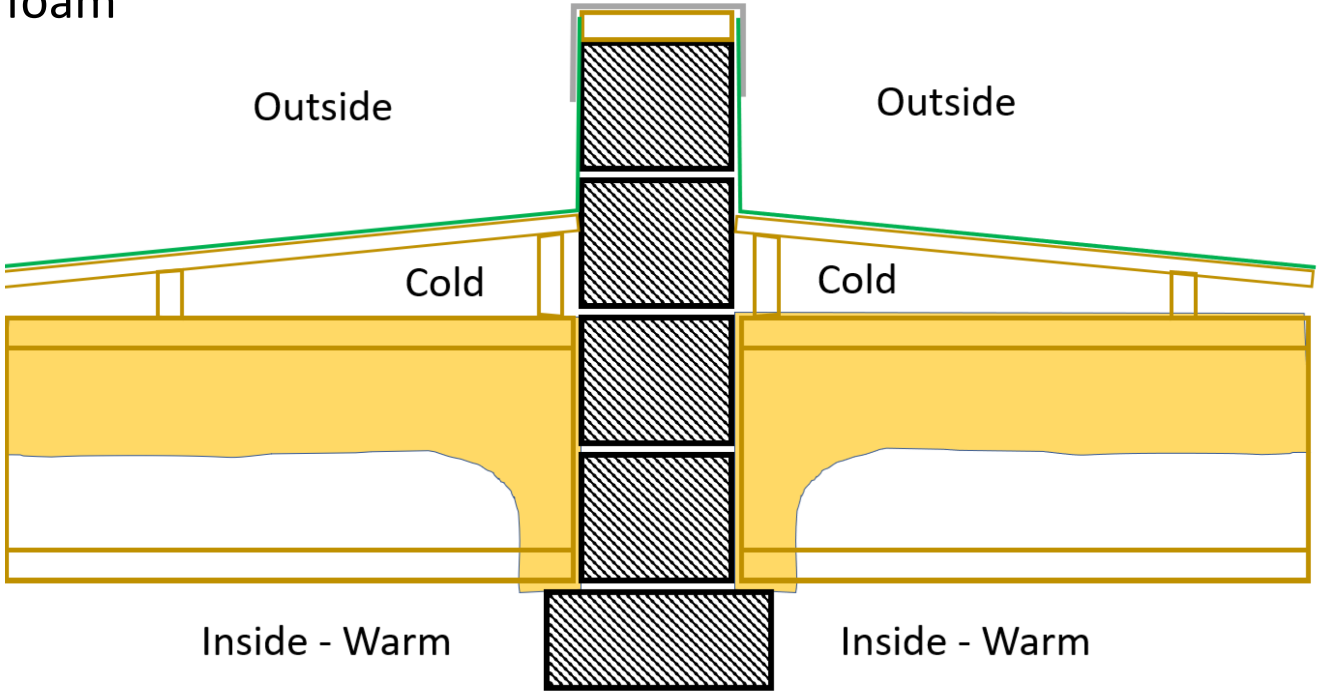
Case Studies

When unvented roofs don’t work

Case Study 3

- Flat Roof Townhouse with Patio

As designed with closed cell spray foam



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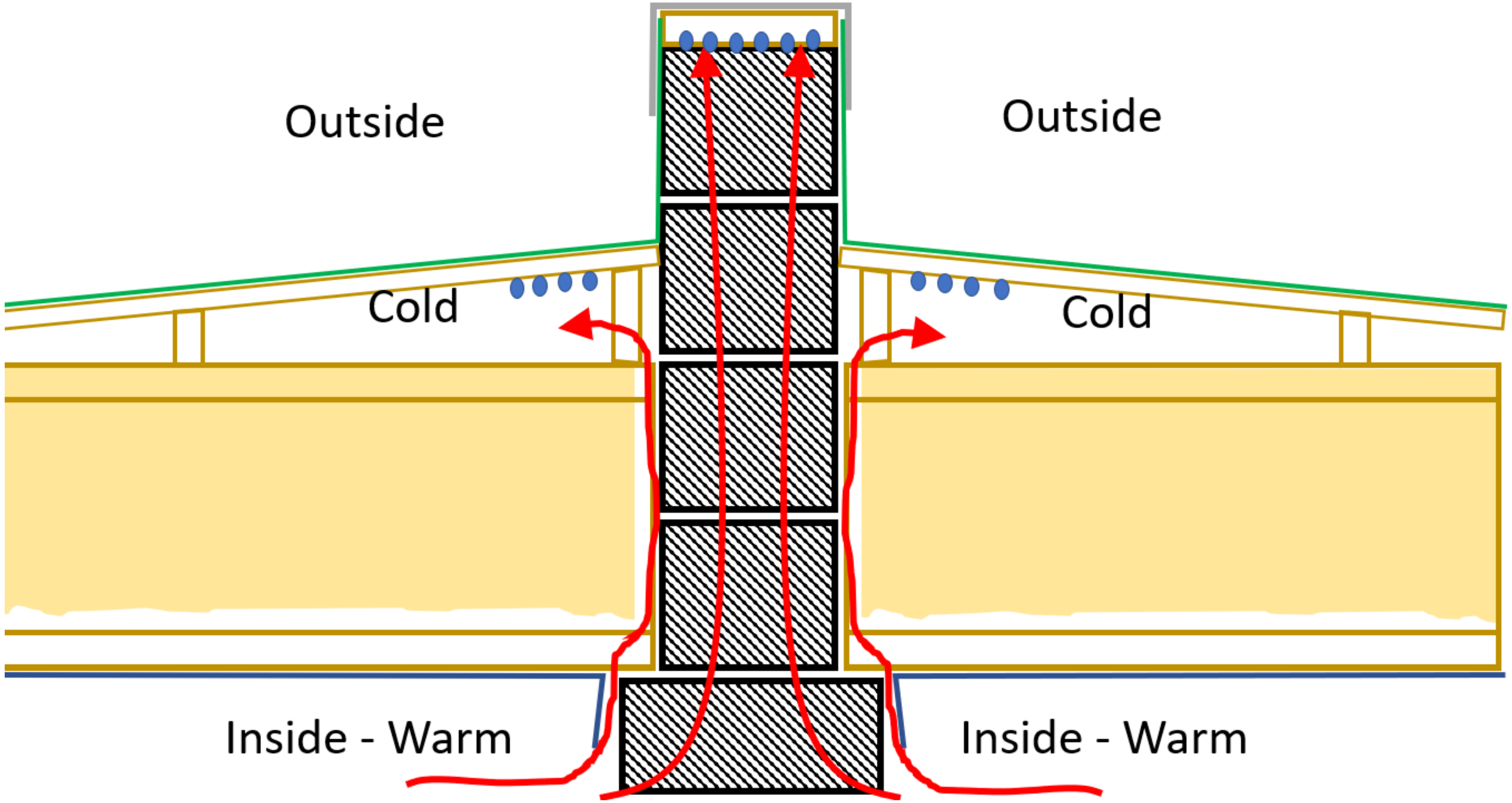
Case Study 3

As built, with open cell spray foam and poly air/vapour barrier



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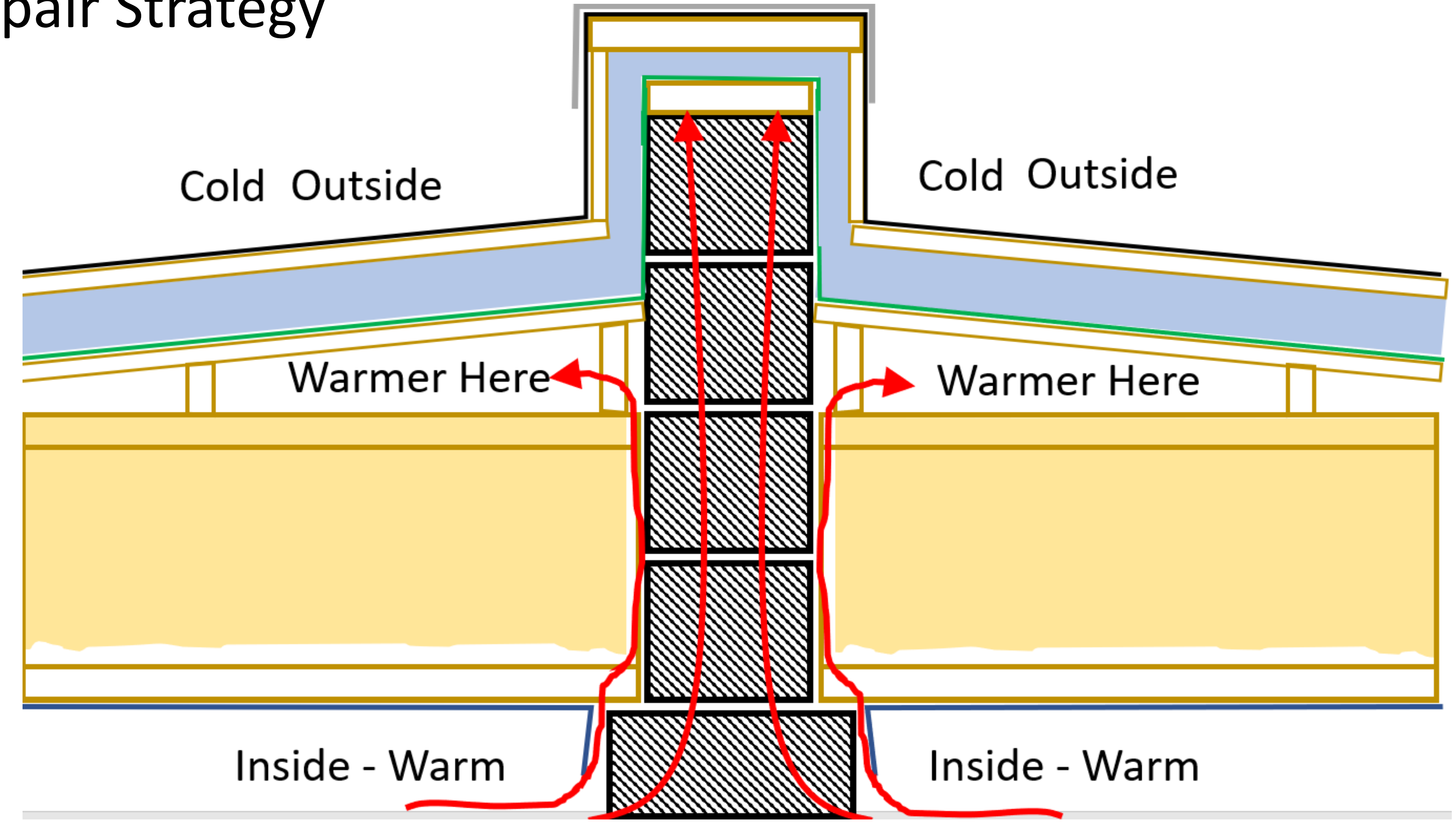
Case Study 3

Case Study 3

- Repair Strategy



Case Study 4

- Flat Roof Townhouses

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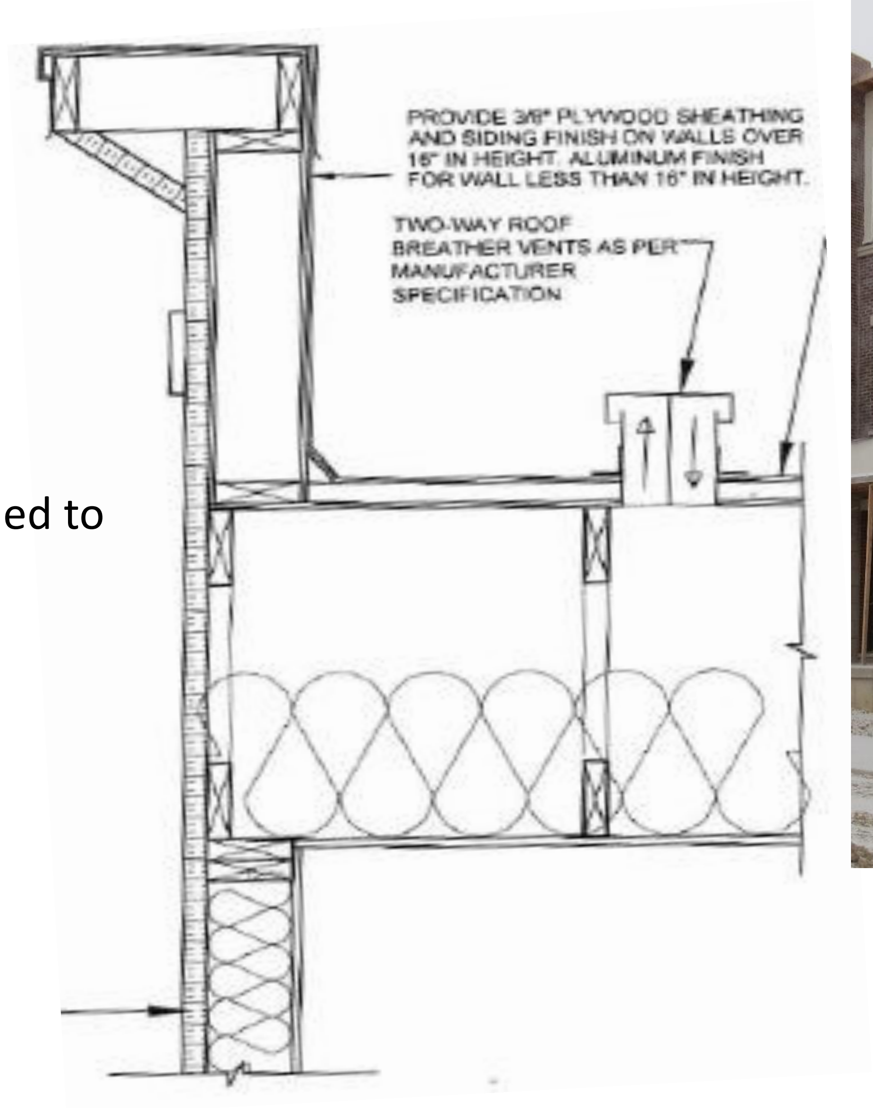
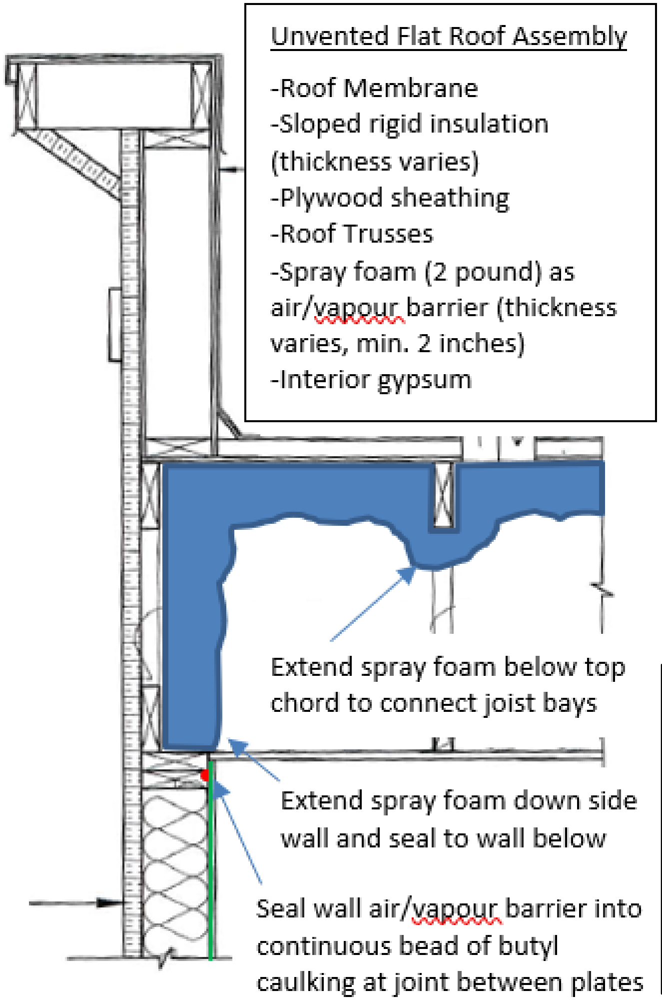
Case Study 4

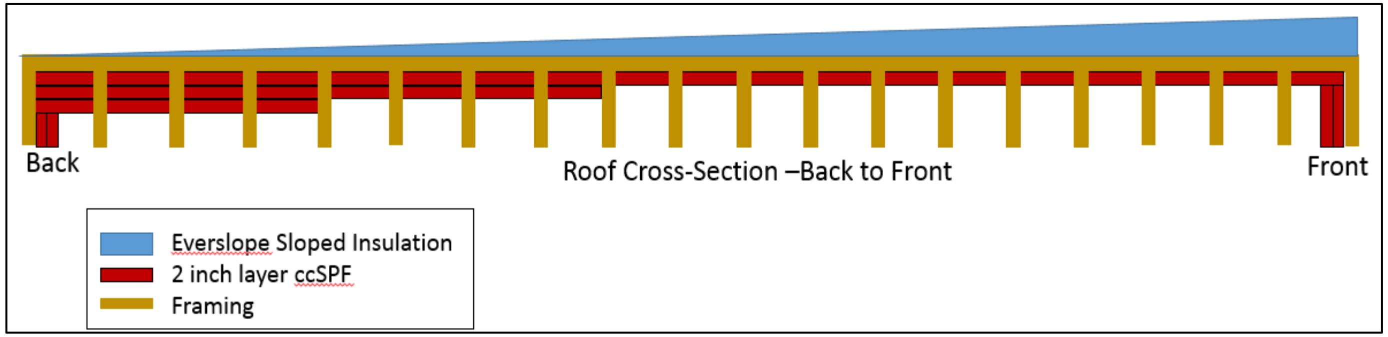
- Originally designed to be vented



Case Study 4

- Design Changed to unvented





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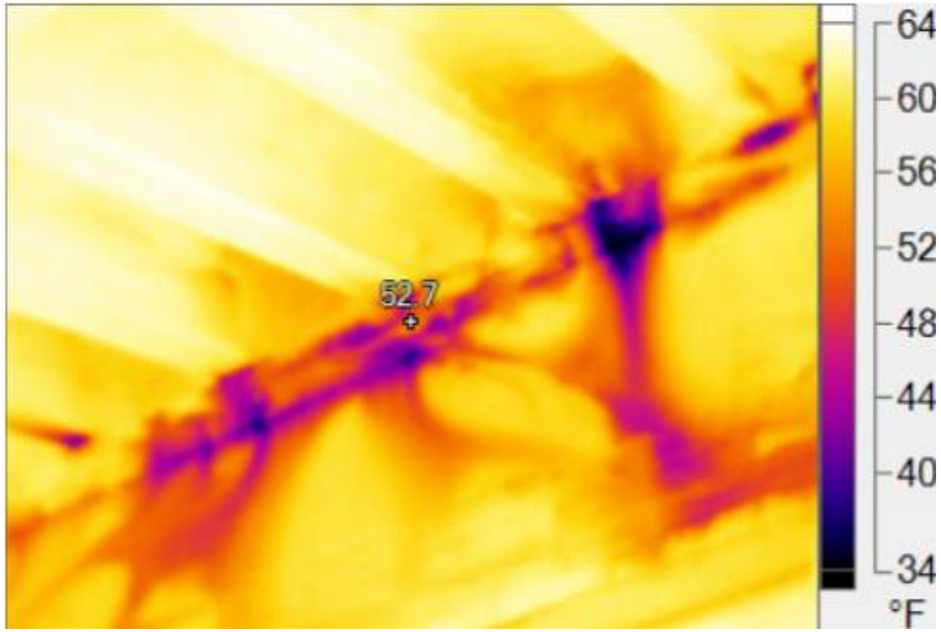
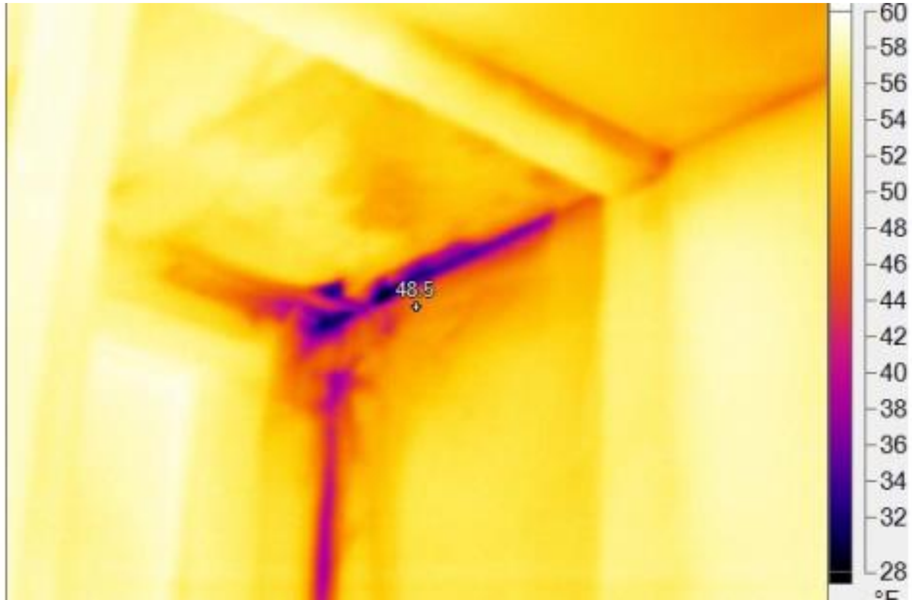
Case Study 4





- Thorough quality control/ inspection required

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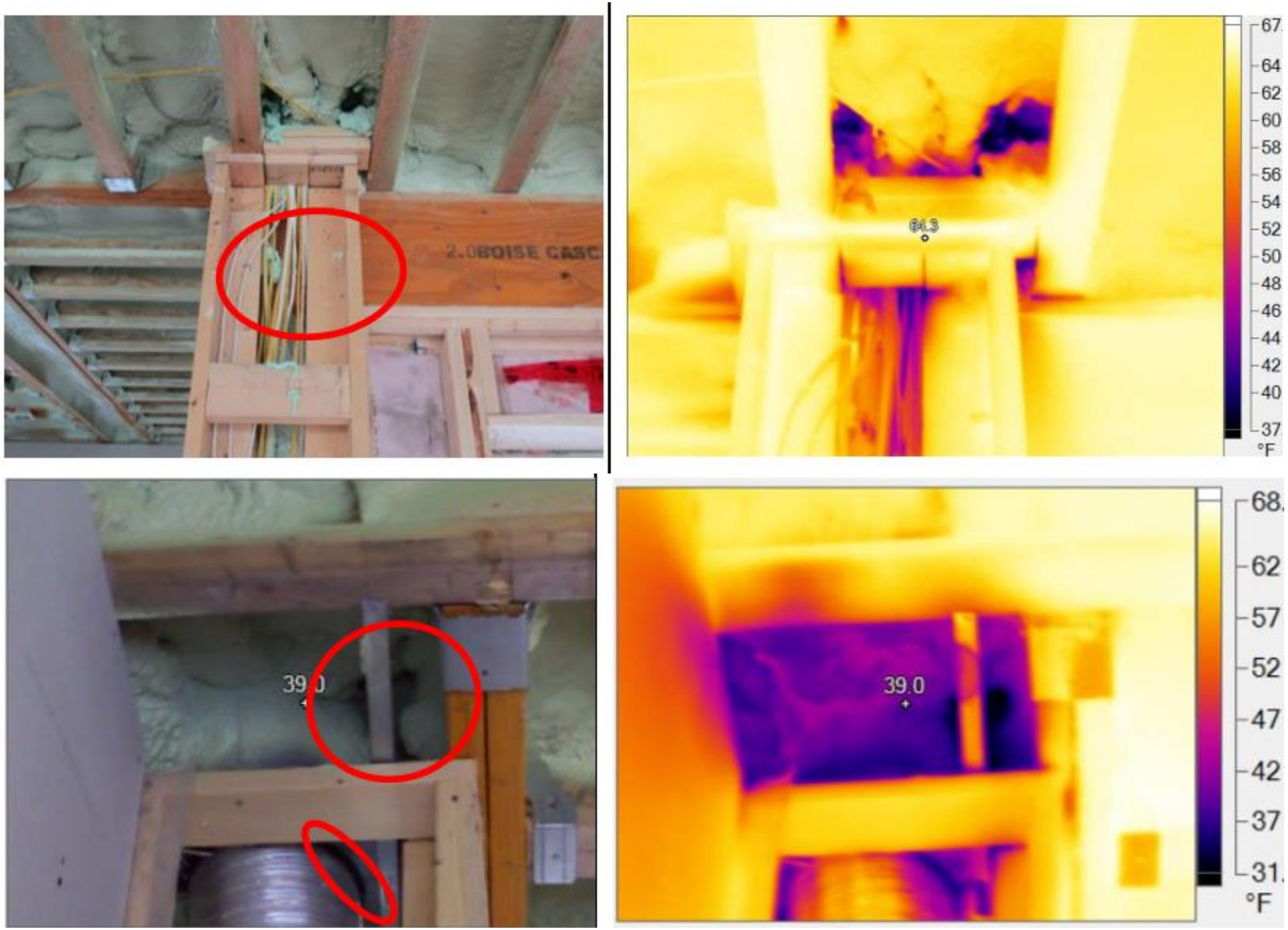
Case Study 4



- Thorough quality control/ inspection required

Residential Un-vented Roofs:

Benefits

1) Ideal for low slope and complex roof systems where venting is difficult/ineffective

2) Easier to accomplish good airtightness

3) Not relying on questionable amounts of venting for performance

3) Proven track record commercially

Residential Un-vented Roofs:

What can go wrong?

1) Spray foam as an air barrier
   - Must be installed with great care
   - Third party inspection recommended

2) Insufficient exterior insulation
   - For split insulated roof systems

3) Detailing penetrations
   - For water and air control