Fundamentals in Roofing Ventilation and Ventilation Applications

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INTRODUCTION

"A vented attic, where insulation is placed on an air-sealed attic floor, is one of the most underappreciated building assemblies that we have in the history of building science…A vented attic works in hot climates, mixed climates, and cold climates. It works in the Arctic and in the Amazon. It works absolutely everywhere – when executed properly"[1]
—Joe Lstiburek, Ph.D., P.Eng.

Builders, contractors, and homeowners may relate to parts of this statement. Once construction is completed and the homeowner moves into their new home, we tend not to be concerned or give much thought to the unoccupied and unfinished attic space at the top of the house. However, what happens to your attic and specifically how well the attic is ventilated is important to the performance and the durability of the roof system. For architects, builders, and contractors, a properly designed and constructed home with a well functioning attic ventilation has a proven track record. For homeowners, it offers peace of mind that their investment is protected.

A proper roof ventilation system is important to the longevity of the roof structure as well as the asphalt shingles. The three **"ABCs"** of a well performing roof system are (Figure 1):

"A" – Ample amount of ventilation (at least code required minimum ventilation)

"B" – Balance ventilation between intake and exhaust

"C" – Control heat, moisture and air flow between the attic and the occupied space

This document outlines reasons for ventilating roofs, provides design guidelines, discusses regulatory requirements, and identifies roof ventilation products offered by Owens Corning Roofing. Whether you are a contractor, builder, distributor or installer you can have the knowledge and the confidence that Owens Corning Roofing has the right products for the job and your success.

Figure 1 - Vented attic with balanced intake & exhaust ventilation

1 WHY ROOF VENTILATION IS REQUIRED

The benefits of roof ventilation must be presented in the context of climatic conditions (Figure 2). In cold climate regions of the United States, proper ventilation can help prevent wintertime condensation on the underside of the roof deck and truss cords as well as ice damming, which could lead to the degradation of the roof deck and mold growth. As you move from the colder parts of the United States to warmer southern regions, the chance of condensation and ice damming is less prevalent and the excess heat in the attic is a greater concern.

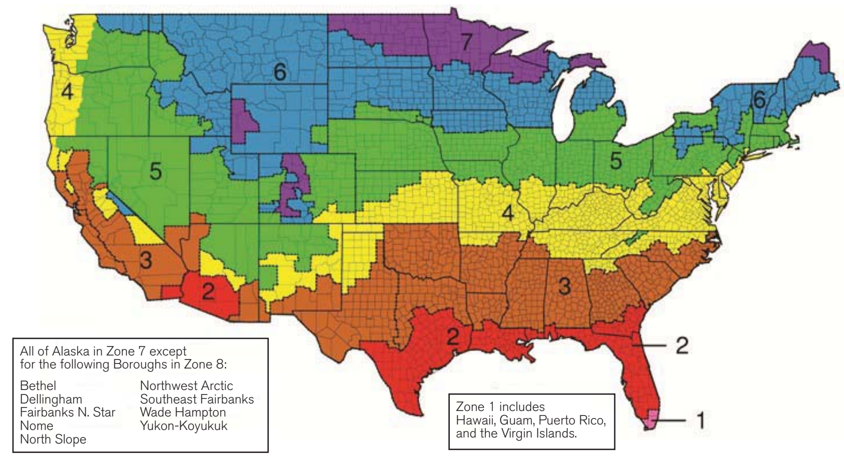


Figure 2 - The eight climate zones within the United States as designated by the International Energy Conservation Code

Wintertime Condensation Control

In cold weather, providing ventilation helps:

- Remove moist air flowing from the conditioned space, before it can condense on cold surfaces.
- Minimize the effects of ice damming by maintaining temperatures below the roof deck and in the attic at or near the outdoor temperatures.

Effective ventilation plays an important role in controlling condensation in the attic. Although these problems can surface anywhere, regions with long and cold winters pose unique challenges. For instance, in northern regions of the country where the wintertime temperatures dip below freezing for extended periods, warm/moist air from the occupied space below can migrate to the attic through penetrations in the ceiling. These penetrations can be intentional, such as light fixtures, pipe chases, or unintentional such as cracks, etc. When the temperatures of the roof deck or truss cords are at or below the temperature at which condensation will begin, water droplets may form in a way similar to water droplets forming on a soda can removed from a refrigerator or glass filled with ice water (Figure 3). You may not be able to observe these droplets on the underside of the roof deck because wood sheathing has the ability to absorb moisture in a similar way that a paper

Figure 3 - Water vapor condensing on a glass filled with ice water

towel absorbs water (Figure 4). However, what you will be able to detect is a surface that may feel moist or damp to the touch. A darker surface or spots may signify a prior occurrence of condensation (Figure 5). Further investigation may be necessary to determine both the cause and the source of this moisture.

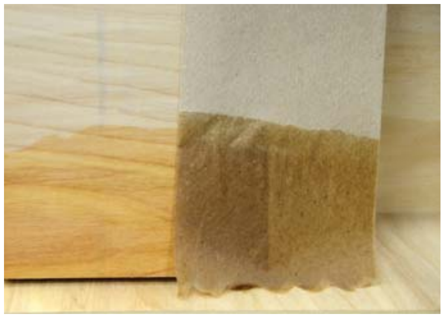


Figure 4 - Water being absorbed by paper towel & plywood sheathing

Figure 5 - Condensation on the underside of a roof deck

In the presence of freezing conditions, moisture condensed on the surface of the roof deck may turn into ice/frost. When temperatures are low enough, moisture may not condense into water droplets and may instantly change from water vapor to ice crystals. If conditions leading to condensation in the attic persist, the repeated wetting and moisture accumulation in the roof assembly may lead to deterioration and rotting. Degradation of the roof deck (Figure 6), corrosion of nails (Figure 7), and mold growth (Figure 8) are just a few consequences of moisture accumulation, and inability of the roof deck to dry. If the wetting of the roof deck exceeds the drying ability, moisture in the roof deck will accumulate.

Figure 6 - Staining & damaged roof sheathing caused by water leaks

Figure 7 - Corroded roofing nails

Figure 8 - Mold growing on the underside of the roof deck & supporting roof structures

Ice Dam Control

Another consequence and indication of improper attic ventilation is the formation of ice dams. Ice dams may be a result of a poorly designed roof, a defective attic ventilation system, inadequate insulation levels, improperly installed insulation, or air leaks through the ceiling plane. An ice dam is a ridge of ice that forms at or along the edge of a roof and prevents the melted snow from draining off of the roof (Figure 9).

Snow on the roof melts due to the heat transferred from the conditioned space as well as warm air exfiltrating through penetrations, gaps, and cracks in the ceiling. Coupled with inadequate ventilation, or insufficient or poorly installed attic insulation, the temperature on the underside of the deck may be higher than the outdoor temperature. These conditions may allow the snow to melt, run down and refreeze, forming an ice dam and typically accompanying icicles (Figure 10). The water that cannot drain backs up behind the dam and may work its way up the roof and under the shingles. This may result in leaks causing damage to walls, ceilings, insulation, and framing members. If ice dams are frequent, gutters, flashings and the leading edge of shingles may be damaged. One of the most effective ways to minimize the effects of ice damming is to design a proper ventilation system. In a well ventilated roof the outdoor air enters the attic at the lower part of the roof and exits at the upper part to help maintain the deck at or near the outdoor temperatures. The 2012 International Residential Code

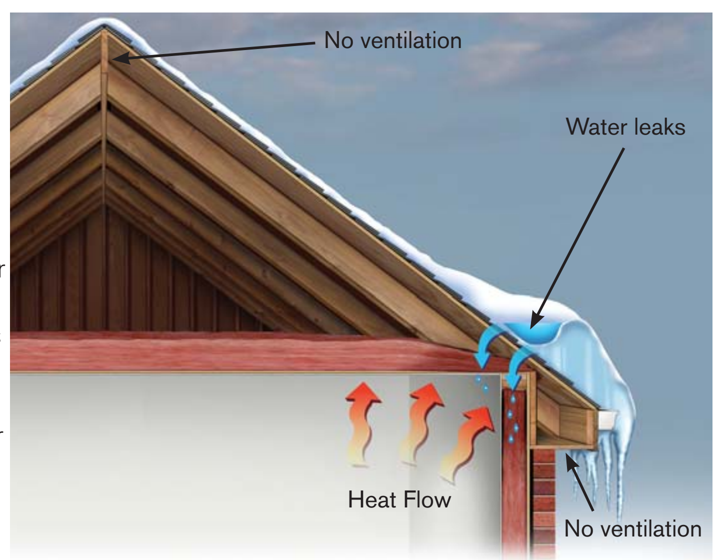


Figure 9 - Formation of ice dams

Figure 10 - Icicles on gutters may indicate ice dams

(IRC) requires the installation of self-adhering ice and water membranes along the eaves of the roof system in locations with a history of ice damming[2]. The code requires the membrane to extend at least 24 inches past the interior surface of the exterior wall line of a building[3].

Summertime Temperature Control

In warm climates or summertime weather, the air in the attic may be warmer than the outdoor air because the solar energy heats the surface of the roof and this heat is transferred into the attic. In these conditions providing ventilation helps promote air exchange between the cooler outdoor air and the hotter air in the attic.

The elevated temperature in the attic is a result of solar energy heating the surface of a roof. As the surface of asphalt shingles heats up, a temperature gradient develops, and heat is transferred through the roof assembly through conduction (Figure 11). From the underside of the roof deck the heat is transferred to the air in the attic through convection and between surfaces through thermal radiation. If the temperature of the air in the attic is higher than the temperature in the occupied space, heat will be transferred through the ceiling assembly. The color of asphalt shingles, roof pitch, building orientation in relation to the sun, shading offered by surrounding buildings and trees, as well as wind speed and direction influence the surface temperature of the roof and the amount of heat transferred into the attic. Even on a cloudy day, a significant amount of solar energy may be transmitted through the roof and the temperature of the air in the attic may be much higher than that of the outdoor air.

The elevated temperatures in the attic may have a number of consequences including:

- Thermal discomfort of the occupants,
- Penalty for cooling energy of the occupied space below the attic, and
- Potential for a reduced service life of asphalt shingles.

Balanced ventilation (between intake and exhaust) promotes the exchange of hot air in the attic with cooler outdoor air and helps reduce the chance for the above mentioned consequences. The next chapter provides an overview of fundamental concepts important to the broader understanding of how ventilation works and why it is required.

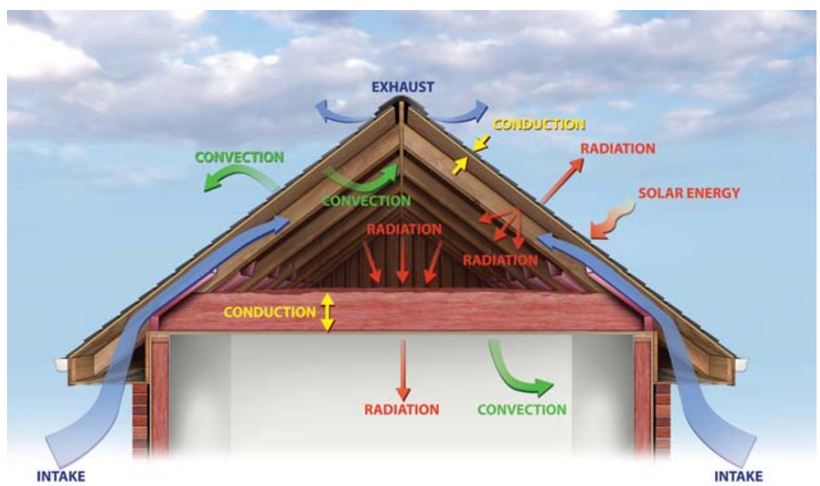


Figure 11 - Heat transfer in a traditional attic

2 FUNDAMENTAL CONCEPTS IN ROOF VENTILATION

FORCES DRIVING VENTILATION

Ventilation allows an air exchange to take place between the outdoor environment and the attic. The forces that drive ventilation are:

- Wind induced pressure
- Buoyancy forces (also referred to as stack effect)

Ventilation can also be generated using mechanical or forced means such as powered vents that draw the air out of the attic.

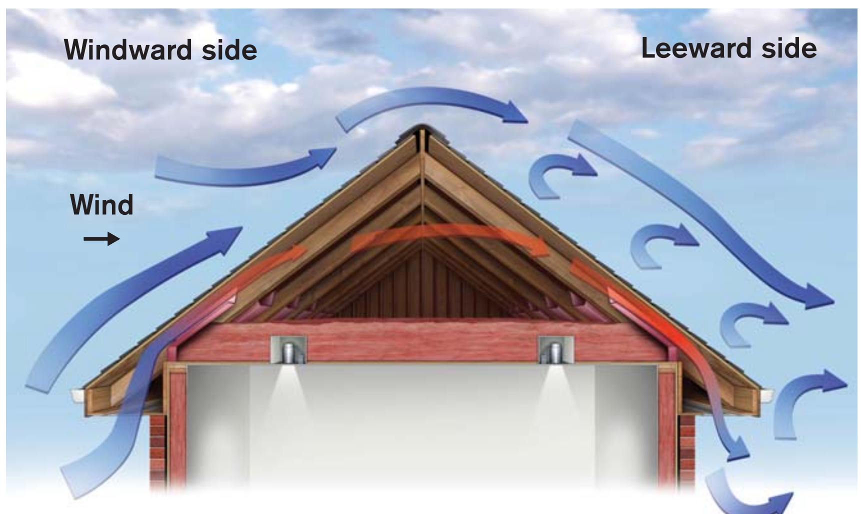


Figure 12 - Typical Wind pattern above roof

Wind Induced Pressure

Wind generates positive pressure on the windward side and a negative pressure on the leeward side of the building as well as the roof. Air will enter openings on the windward side and be exhausted through the openings on the leeward side (Figure 12)[4]. Many factors affect this process. The natural variation in wind speed, wind direction, and the surrounding topography considerably impact ventilation rates. Although higher wind speeds tend to increase attic ventilation, ventilation rates at a given wind speed may vary by a factor of 10[5]. Data in Figure 13 show a positive correlation between ventilation rates and increasing wind speed. Consequently, as the wind speed increases, predicting the ventilation rate is more of a challenge. Similar to wind speed, wind direction may also change frequently and will influence how much air flows in and out of the attic. The highest rates will occur when the wind direction is perpendicular to the intake openings and decrease as the wind direction becomes parallel to the opening.

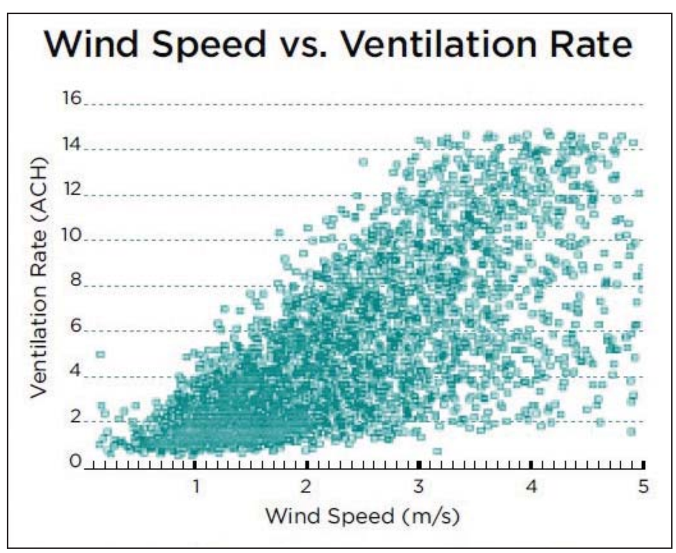


Figure 13 - Shows windspeed versus ventilation rate[5]

Note: Refer to Appendix E for definition of air changes per hour (ACH).

Local topography including the number of surrounding structures, heights of buildings, orientation and distance from the building in question will influence wind speed and direction. Lower attic ventilation rates are expected in a building sheltered by surrounding structures than in an exposed building.

Buoyancy

Air flow induced by buoyancy relies on the temperature difference between the outdoors and the lower and upper section of the attic. The greater the temperature difference between the outdoors and the attic, and the greater the height difference between the intake and exhaust openings (with steeper pitched roofs), the greater the buoyancy force, also referred to as "stack effect"[6]. Pressure difference is the driving force for buoyancy induced ventilation. However, buoyancy-driven ventilation is lower in magnitude compared to wind induced ventilation. In addition, vent design considerations such as the size, configuration, pressure drop, and location will also impact the effectiveness of buoyancy.

Mechanically Powered Ventilation

Active vents with a motorized fan may be used in lieu of static vents to provide exhaust along the upper part of the roof. As the fan pulls the air out of the attic, it generates a negative pressure on the attic side of the vent (Figure 14). The air being exhausted is replaced with the outdoor air. Care must be taken when determining ventilation requirements to ensure the fan capacity does not exceed the net free ventilating area (NFVA) of the intake openings. This may depressurize the attic and draw the air from the occupied space. Whenever power vents are considered, ensure the fan selected is properly sized to minimize the depressurization of the attic and provide adequate intake ventilation.

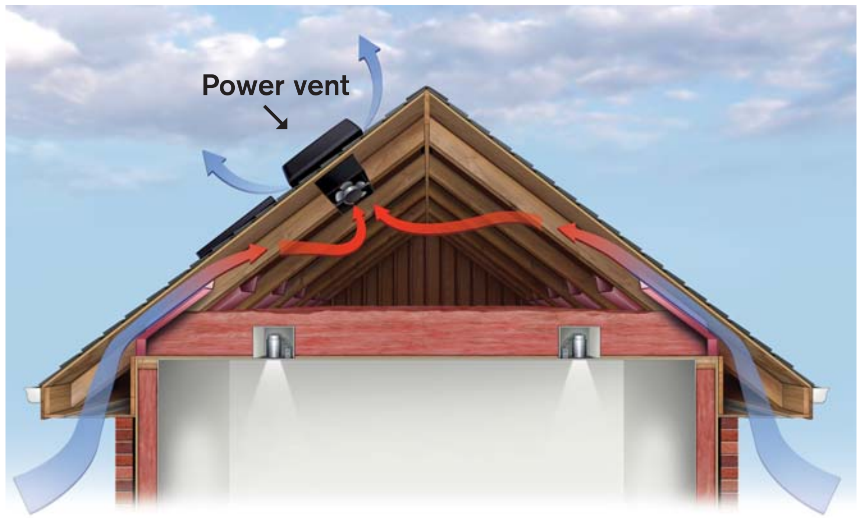


Figure 14 - Air flow in a vented attic with a powered roof vent

MOISTURE IN BUILDINGS AND HOW IT IS TRANSFERRED

What Is Water Vapor?

Water vapor is water in the form of an invisible gas. Whether during winter or summertime, air contains some amount of this invisible gas. The maximum amount of moisture that may be stored in a volume of air is referred to as saturation moisture content.

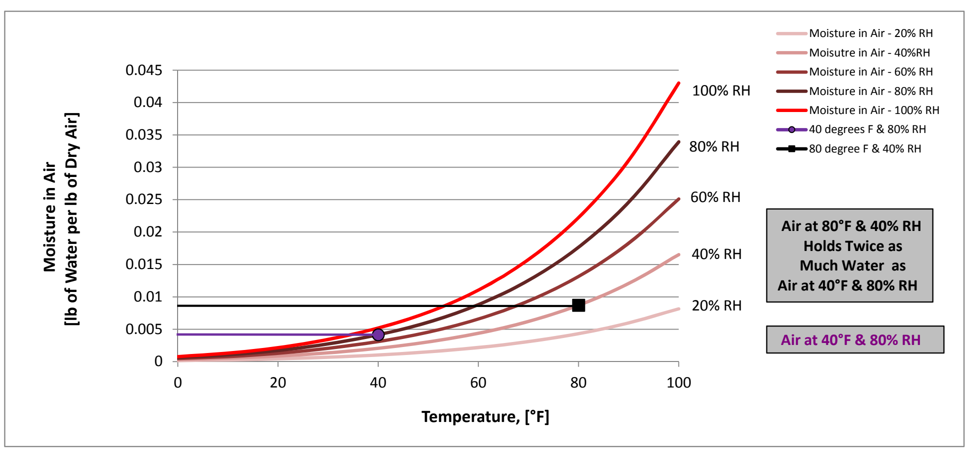


Figure 15 - Saturation moisture content of air at various temperatures

Relative Humidity

At the saturation moisture content a defined volume of air is at 100% relative humidity (Figure 15). When the temperature of the air is raised without additional moisture, the relative humidity of the air will decrease below 100%.

So, what does relative humidity represent? Relative humidity is expressed as a percentage and it is the ratio of the actual amount of water vapor in the air divided by the total possible amount of water vapor that the air can hold at that temperature. Warm air can contain more water vapor than cold air. For example, air at a temperature of 80°F can hold 5.9 times more water vapor compared to air at 40°F at saturation.

Another question that may be asked: Which air contains more moisture, the 40°F air with 80% relative humidity or the 80°F air with 40% relative humidity? A natural inclination may be to ignore the temperature and only consider the relative humidity and respond that 40°F air with 80% relative humidity contains more moisture. However, hold that thought and again consider the information in Figure 15 and 16 which shows the amount of water vapor contained in air at the two respective temperatures. The air at 80°F and 40% relative humidity holds twice the water vapor of the air at 40°F and 80% relative humidity.

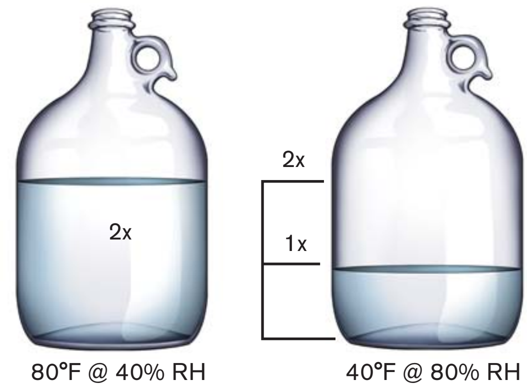


Figure 16 - Amount of water vapor contained in air at the respective temperatures

What is the relevance of moisture contained in the air and its temperature dependence on the attic ventilation? In cold climates, warm air can migrate from the occupied space into the attic. The indoor air may contain substantially more moisture than the outdoor air. In traditionally vented attics the temperature of the air may only be several degrees above the outdoor temperature. If not properly vented, the moisture migrating from the occupied space may condense on the underside the roof deck and other surfaces. Water vapor will condense into a visible water film, or water droplets, and when the temperature drops below freezing, frost and ice may form.

How is Moisture Transferred?

In the attic, moisture can come from two sources: the outdoor environment or the occupied space. If rainwater is able to penetrate the shingles, the underlayment, joints in the roof deck, or fasteners, it may appear in the form of water droplets and/or darker spots as it becomes absorbed into the roof decking. Liquid water takes the path of least resistance and is driven by gravity unless affected by other forces such as wind or capillary action. This means that water flows between materials, cracks, and gaps.

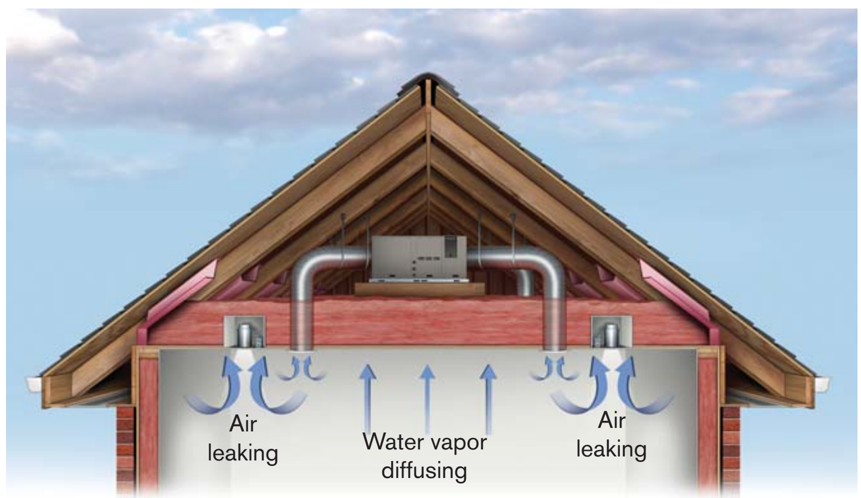


Figure 17 - Moisture migrating from the occupied space through diffusion and air leakage

Because of the porous nature of construction materials such as wood, a fraction of the moisture will wet the material surface and will be absorbed into the material. If no additional moisture is added, the moisture in the material will evaporate from the surface and diffuse into the attic air, potentially raising the relative humidity of the air. In cold weather, water that penetrates the roof system during warmer conditions may freeze and remain frozen until temperatures increase again.

From the occupied space, water vapor can migrate into the attic in two ways: through air leakage, and water vapor diffusion (Figure 17). Air leaks are more significant because they can deliver more water vapor into the attic space and typically occur through penetrations, gaps, and cracks in the ceiling. Penetrations around recessed light fixtures, diffusers, and bathroom exhaust vents provide a path for air to migrate into the attic. In the presence of entry and exit points, and pressure difference, air will be transferred either from the occupied space into the attic or from the attic into the occupied space. Typical air leaks in the ceiling of a home are shown in Figure 18.

The diffusion of water vapor is a secondary mechanism by which moisture can migrate from the occupied space, if the force that drives water vapor, the partial pressure of water vapor, is greater in the occupied space than in the attic. This mechanism delivers less moisture because water vapor diffusion is driven by a slower process than movement of moisture in a free flowing air stream.

Consequences of Moisture Migrating into Attics?

Moisture intrusion into the attic can lead to consequences that range from aesthetics to durability as well as structural integrity of the home.

Depending on the extent, this may lead to staining of the sheathing, corrosion of fasteners and mold growth or a more extensive problem such as damage and degradation affecting the structural capacity of the roof deck and the supporting structure.

In cold climates, condensation is a concern because it causes repeated wetting. If wetting exceeds the drying capacity moisture will accumulate and may result in the above mentioned problems.

What Can Be Done to Prevent Moisture Problems?

Finding and mitigating rainwater leaks is a first priority in preventing moisture problems. Providing proper intake and exhaust ventilation with an unobstructed path for outdoor air to flow into the attic is a second priority. Ensuring that penetrations around openings in the ceiling below the attic are airtight is a necessary step to prevent indoor air from migrating into the attic. Reducing moisture generated and the relative humidity in the occupied space will be helpful. Finally, if the air handler and ductwork are located in the attic, reducing air leaks in the system may help decrease cooling/heating loads and energy use. Improving ventilation and providing air and vapor flow control are important approaches in preventing moisture problems in attics.

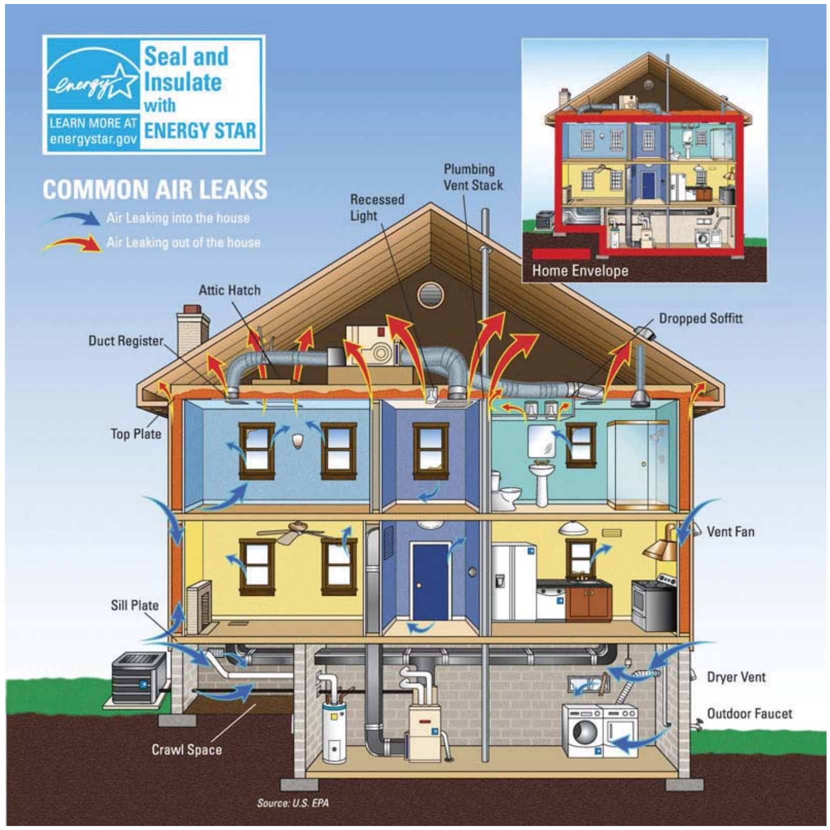


Figure 18 - Typical sources of air leaks in a home[7]

SOURCES OF MOISTURE

Moisture sources can be grouped into three categories: outdoor, indoor and construction moisture.

Indoor Sources

Building occupants, bathrooms, kitchens, laundry rooms, humidifiers, combustion appliances, and plants are just a few indoor moisture sources. People generate moisture by respiration (breathing) and perspiration (sweating)[8]. One study found that the amount of water vapor produced by a family of four averaged 1.3 gallons/day[9]. These moisture sources and the corresponding loads are typically generated year round.

Natural gas and kerosene are sources of fuel that may be used in homes for cooking, heating or other applications. Water vapor is one of the by-products of combustion. Unvented kerosene space heater may contribute 0.3 gallons/hour[10]. Similarly, burning of natural gas for cooking, heating or any other application in an open and unvented mode generates moisture.

Two sources that can potentially create substantial amounts of moisture are bathrooms and clothes driers. Bathrooms are equipped with exhaust fans to extract moisture to the exterior. Similarly, clothes dryers remove moisture from laundry to the outdoors through ducts. All too often, this may not be the case and the ducts may terminate in the attic and introduce a significant moisture load. Even with proper attic ventilation, the moisture load from dryer ducts terminating in the attic may be too large to dilute and exhaust; resulting in condensation on the underside of the roof deck and truss cords. If prolonged conditions persist, they may negatively impact the longevity and durability of the attic and the roof system. A quick inspection of the attic can ensure that moisture from bathrooms and clothes dryers is not exhausted into your attic and does not compromise the longevity of your roof.

Outdoor Sources

Moisture in the atmosphere in the form of rain or humid air as well as moisture in the soil contributes to external, or outdoor, moisture sources. Rain may enter the building structure through penetrations, gaps, or cracks in the building component details and transitions and will be absorbed by roof decking and the supporting roof structure.

In hot and humid weather, the outdoor air can be a major source of moisture. The greater the air exchange between the outdoors and the attic, the greater the amount of moist air introduced into the attic[11]. In cases when the air handler and/or ducts are located in the vented attic and are not insulated and air sealed moisture may condense on the ducts, hot and humid air will be drawn into the system on the return side adding to the latent load. Similarly, on the supply side of the air handler, the already conditioned air (typically cooler and dryer) will leak into the attic contributing to efficiency losses.

Moisture from soil/ground water may not directly impact the attic space and the roof system. However, moisture migrating from surrounding soil into foundations, basements, and crawl spaces may increase the relative humidity in the occupied space[12]. This air may migrate into the attic through pipe and duct chases and may increase moisture content of the air.

Construction Moisture

Construction moisture (in a form of liquid or water vapor) relates to moisture contained in building materials such as wood and concrete and is present in newly constructed homes. Unlike the outdoor and the indoor moisture sources which typically occur year after year, construction moisture may have a significant impact during the first two to three years of a new building's life[13]. Concrete provides one of the most significant sources of moisture. For example foundation walls and a basement floor containing 34 cubic yards of concrete will release 618 gallons of water during the first year[14].

3

ROOF VENTILATION REQUIREMENTS IN BUILDING CODES AND INDUSTRY GUIDELINES

Historic Developments in Ventilation Requirements

During the last several decades, considerable efforts have been made to better understand the contribution of ventilation on the performance of attics. While all of the questions have not been answered, the research completed to date reflects the commitment of the industry and research institutes to better understand the importance of attic ventilation. Discussion on the historic perspective of attic ventilation is presented in Appendix D.

CODE REQUIREMENTS FOR ATTIC VENTILATION

Historically, ventilation requirements in the International Residential Code (IRC) are applicable to one and two family homes, and have been based on the ratio of "net free ventilating area" (NFVA) that is the area of the ventilation openings in the attic to the area of attic space. The NFVA is the total unobstructed area through which the air can pass and it is calculated at the most restricted location through the vent's cross section.

The code development process follows a triennial cycle, and new editions of the IRC are developed every three years. Each state or local jurisdiction may or may not elect to adopt a newer version of building codes. The 2012, 2009 and 2006 editions of the IRC are the three most recent and have been adopted in the majority of the states in the continental U.S. This fact is emphasized because code requirements may vary between editions. The 2015 edition of international building codes is published and states may elect to adopt those codes as early as January 1, 2015. Table B1 and Table B2 in Appendix B lists attic ventilation requirements in the 2015, 2012, 2009 and 2006 editions of IRC, International Building Code (IBC), the 2010 editions of the Florida Building Code and Florida Building Code Residential and the 2013 editions of the California Building Code and California Residential Code. Check your local jurisdiction for the applicable building code edition.

Ventilation requirements listed in Section R806 in the 2012 edition of the IRC are listed in the excerpts below[15]:

- **R806.1 Ventilation Required.** Enclosed attic and enclosed rafter spaces formed where ceilings are applied directly to the underside of the roof rafters shall have cross ventilation for each separate space by ventilating openings protected against the entrance of rain or snow. Ventilation openings shall have a least dimension of 1/16 inch minimum and ¼ inch maximum. Ventilation openings having a least dimension larger than ¼ inch shall be provided with corrosion-resistant wire cloth screening, hardware cloth, or similar material with openings having a least dimension of 1/16 inch minimum and ¼ inch maximum.

- **R806.2 Minimum Vent Area.** The minimum net free ventilating area shall be 1/150 of the area of the vented space.
    - **Exception:** The minimum net free ventilating area shall be 1/300 of the vented space provided one or more of the following conditions are met:

1. In climate zones 6, 7 and 8, a Class 1 or 2 vapor retarder is installed on the warm-in-winter side of the ceiling.
2. At least 40 percent and not more than 50 percent of the required ventilating area is provided by the ventilators located in the upper portion of the attic or rafter space. Upper ventilators shall be located no more than 3 feet below the ridge or highest point of the space, measured vertically, with the balance of the required ventilation provided by the eave or cornice vents. Where the location of wall or roof framing members conflicts with the installation of upper ventilators, installation more than 3 feet below the ridge or highest point of the space shall be permitted.

- **R806.3 Vent and Insulation Clearance.** Where eave or cornice vents are installed, insulation shall not block the free flow of air. A minimum of a 1 inch space shall be provided between the insulation and the roof sheathing and at the location of the vent.

- **R806.4 Installation and Weather Protection.** Ventilators shall be installed in accordance with manufacturer's installation instructions. Installation of ventilators in roof systems shall be in accordance with the requirements of Section R903…

In summary, the ventilation requirements in the 2012 edition of the IRC are:

- **Provision of 1 square foot of NFVA for each 150 square feet of attic floor. One important note – the attic floor area is just that – area – not volume. This is the minimum requirement and does not stipulate that the required ventilation openings provide intake (low), exhaust (high), or both.**

- **Provision of 1 square foot of NFVA for each 300 square feet of attic floor if both or either of the following conditions are applicable:**
  - **A Class 1 (≤ 0.1 Perm) or 2 (> 0.1 to ≤ 1.0 Perm) vapor retarder is installed on the warm-in-winter side of the ceiling when the structure is located in climate zone 6, 7, or 8.**
  - **At least 40%, but not more than 50% of the NFVA is provided by vents located not more than 3 feet below the highest point of the roof.**
- **Provision for a minimum 1 inch air space between the roof sheathing and insulation in the attic at the location of the vent.**

In addition to the requirements found in codes, both Asphalt Roofing Manufacturers Association (ARMA) and National Roofing Contractors Association (NRCA) have developed industry guidelines for attic ventilation.

INDUSTRY GUIDELINES

ARMA Recommendations for Roof Ventilation

ARMA's Technical Bulletin titled "Ventilation and Moisture Control for Residential Roofing", explains why ventilation should be incorporated into the roof design. The recommended minimum roof ventilation reflects the requirements of the International Residential Code[16]:

> "In most cases, a minimum free-flow ventilation area equal to one square foot per 150 square feet of attic floor must be designed and properly installed to provide proper ventilation. Where a properly designed and installed eave and ridge ventilation system is employed, a free-flow ventilation area equal to at least 1 square foot per 300 square feet of attic floor is often sufficient. Combination eave and ridge venting is generally recognized as a superior venting technique."

NRCA Recommendations for Roof Ventilation

NRCA's Technical Bulletin titled "Ventilation for Steep-Slope Roof Assemblies", emphasizes that proper ventilation of attic space is a necessary component of quality steep-slope roof assemblies." The recommended minimum roof ventilation reflects the requirements of the International Residential Code as well as ARMA[17]:

> "NRCA recommends attic ventilation in the minimum amount of 1 square foot of net free ventilation area for every 150 square feet of attic space (1:150) measured at the attic floor level (e.g., ceiling)…NRCA suggest the amount of attic ventilation be balanced between the eave and ridge. The intent of a balanced ventilation system is to provide nearly equivalent amounts of ventilation area at the eave/soffit and at or near the ridge. For a balanced ventilation system to function properly, approximately one-half of the ventilation area must be at the eave/soft and approximately one-half of the ventilation area must be at or near the ridge (e.g., ridge vents, static vents)…"

4 DESIGNING A PROPERLY VENTILATED ROOF SYSTEM

What Is a Balanced Ventilation System and Why Is It Needed?

A balanced roof ventilation system is an effective design from a standpoint of air exchange. In this configuration vents located in the lower portion of the roof provide air intake while those located in the upper portion of the roof provide exhaust. The proper balance (Figure 19) is achieved when exhaust and intake are split evenly (50%/50%):

Figure 19 - A properly ventilated roof system has balanced intake and exhaust

If proper balance cannot be achieved ensure that:

- The NFVA at the exhaust is not less than 40% but not more than 50%, and
- The NFVA at the intake is not more than 60% but not less than 50%.

When ventilation is balanced between the intake and exhaust, the benefit of wind induced and buoyancy induced ventilation combine to help increase air exchanges and reduce temperature in the attic.

Balanced ventilation between intake (soffit) and exhaust (ridge) is more effective in reducing temperature in the attic when compared to ventilation at the soffits only or attic without any ventilation (Figure 20).[18] A computer simulation shows 40°F higher peak air temperatures in the attic without ventilation (green plot) when compared to the ventilation approach with balanced intake and exhaust (blue plot). The soffit only ventilation approach (red plot) is

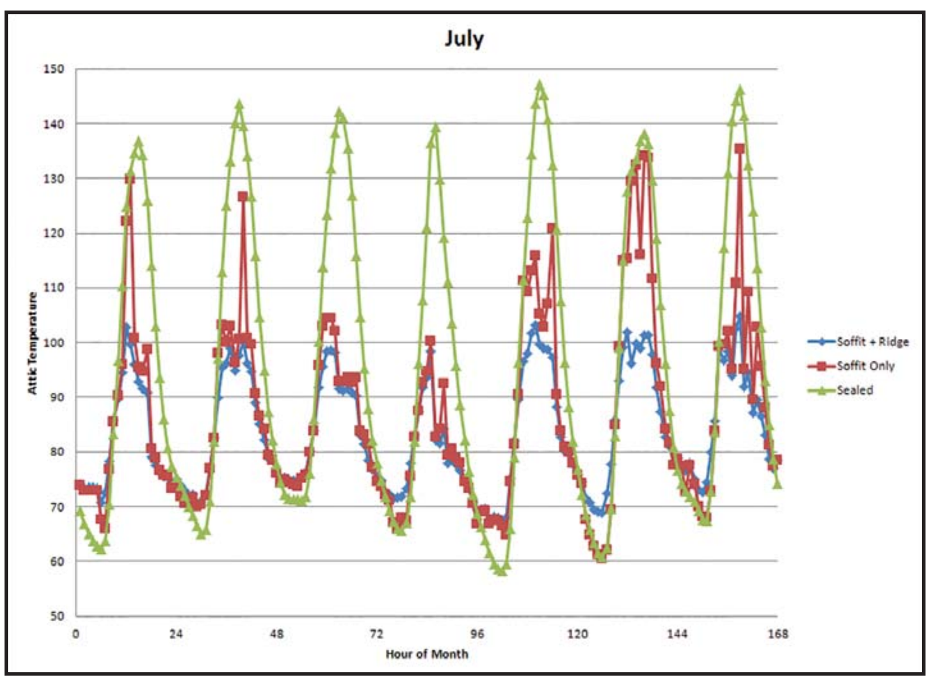


Figure 20 - Simulated temperatures in the attics during one week in July in Tampa, FL[18]

more variable and does not lead to the same air temperature reduction as the balanced approach. The soffit only ventilation is not as effective as the balance approach and appears to be affected by changes in wind speed and direction in the weather data used in the simulation. The weather data file was based on wind speed and direction measured in the field.

Note: A computer simulation with AtticSim was performed with a 50ft by 27ft attic having 1:150 ventilation ratio, 4:12 in roof pitch and R-30 insulation in the ceiling (attic floor). Simulation performed for 1 week in July with weather data for Tampa, Florida with three ventilation schemes:

- Balanced ventilation (soffit-to-ridge)
- Unbalanced (soffit-to-soffit only)
- Attic without any ventilation

Additional Requirements

In addition to providing balanced ventilation, the following measures should also be followed for ventilation to work effectively:

- Provide an unobstructed path for air to flow between the underside of the roof sheathing and the top of the insulation.
- Maintain the recommended insulation R-values in the ceiling and ensure that proper installation practices are followed.
- Air seal penetrations in the ceiling to reduce the flow of conditioned air from the occupied space below the attic, especially around recessed light fixtures, air diffusers, access openings and other penetrations.
- Ensure exhaust ducts from bathrooms and kitchens are properly vented to the exterior and not into the attic.
- In regions with a history of ice damming, minimize its effects by installing self-adhered ice and water membranes at eaves and valleys. These products adhere directly to the roof deck and help prevent water leaks in areas susceptible to ice damming. It is important to note that self-adhered ice and water membranes do not prevent ice dams from forming but help prevent water intrusion in the event that ice dams occur.
- Air handler and ducts located in the attic are air sealed and insulated to code required levels as a minimum.

Calculating Required NFVA

A sample of NFVA calculation is shown in Table 1 below, and Appendix A provides a list of ventilation requirements for several different sized attics. Additionally, an online NFVA calculator is available from Owens Corning Roofing under the following link: http://www.owenscorning.com/roofing/accessories/ventilation/determine-your-requirements/

Table 1. Sample NFVA calculation for 2000 square foot attic.

	Description	Example 1 of NFVA	Example 2 of NFVA
Step 1	Indentify the ventilation ratio (1 sq ft of NFVA per every 150 or 300 sq ft of attic floor[1])	1:150 Rule	1:300 Rule
Step 2	Determine the area to be ventilated (in square feet) * Multiply attic length and width (in feet[2])	[Length = 40 ft] x [Width = 50 ft] Total Attic Area = 2,000 sq ft	[Length = 40 ft] x [Width = 50 ft] Total Area = 2,000 sq ft
Step 3	Determine total NFVA required * Divide Total Attic Area calculated in Step 2 by the ventilation ratio	2,000 sq ft /150 = 13.33 sq ft	2,000 ft / 300 = 6.67 sq ft
Step 4	Convert NFVA into Square Inches (how products are rated) * Multiply NFVA calculated in Step 3 by 144 (1 sq ft = 144 sq in)	13.33 x 144 = 1,920 sq in	6.67 x 144 = 960 sq in
Step 5 OR	Determine the NFVA required as intake and as exhaust * 50% of total NFVA to be exhaust and 50% intake	1,920 x 0.5 = 960 sq in Exhaust; 1,920 x 0.5 = 960 sq in Intake	960 x 0.5 = 480 sq in Exhaust; 960 x 0.5 = 480 sq in Intake
Step 5a	* If cannot balance, maximum 60% intake and 40% exhaust	1,920 x 0.4 = 768 sq in Exhaust; 1,920 x 0.6 = 1,152 sq in Intake	960 x 0.4 = 384 sq in Exhaust; 960 x 0.6 = 576 sq in Intake

Notes:
(1) sq ft = square foot, sq in = square inch
(2) For complex attic configurations, the attic may have to be subdivided into several smaller areas and totaled

5 TYPES OF ROOF VENTS

In the most basic sense, ventilation products can be classified as either intake vents or exhaust vents (Figure 21). Intake vents allow air to enter the attic, while exhaust vents allow air to exit the attic. Proper ventilation requires a combination of both intake and exhaust vents. Ventilation products can be further defined as static (passive) or powered (solar or electric), and exhaust vents can further be classified by their location on the roof. Exhaust ridge vents are installed directly on the ridge of the roof, while exhaust off-ridge vents are installed in the upper portion of the roof, but not directly over the ridge.

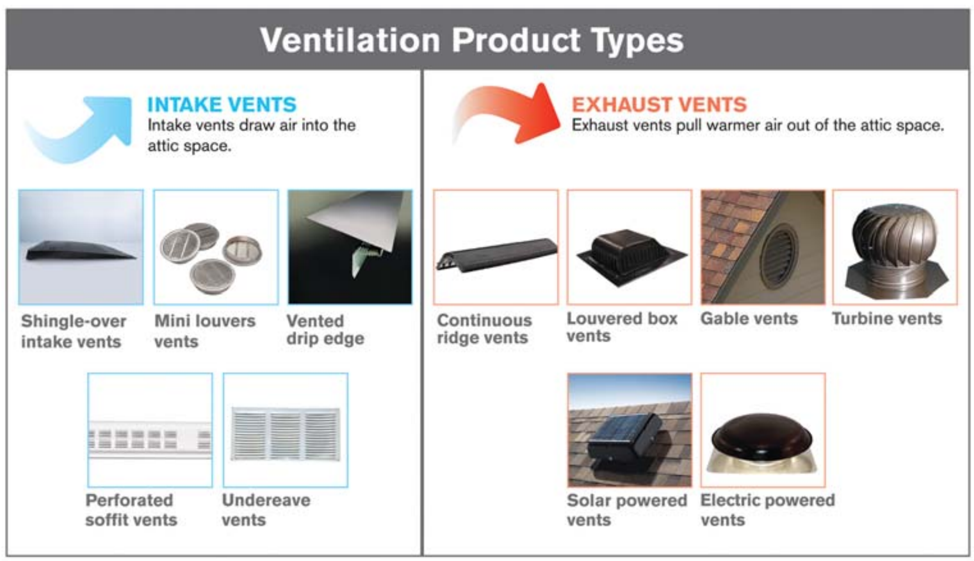


Figure 21 - Types of ventilation products

It is important to ensure the ventilation system is comprised of both intake and exhaust vents. The most effective system should have an equal amount of intake and exhaust ventilation.

Note: if a perfectly-balanced system of intake and exhaust ventilation is not feasible, always ensure there is more intake than exhaust ventilation. Owens Corning Roofing offers several types of intake and exhaust roof ventilation products to help meet the needs of nearly any application.

INTAKE VENTS

Intake vents allow outside air into the home's attic. Intake vent products are generally classified as Undereave Vents, Soffit Vents or Shingle-Over Intake Vents (Figure 22). Products in these categories may provide varying amounts of intake ventilation and should be balanced with exhaust vents for the most effective ventilation system.

Figure 22 - Types of intake ventilation

Owens Corning Roofing recommends continuous intake ventilation at or above the soffit, which can be achieved using our shingle-over solution, the Ventsure® InFlow® Intake Vent. Table 2 lists Owens Corning® intake ventilation products offering from highest to least recommended solution.

Table 2. Owens Corning® Roofing Intake Ventilation Products.

Owens Corning® VentSure® Product	Type of Exhaust	Description
VentSure® InFlow® Intake Vent	Shingle-Over Intake Vent	▪ Polypropylene shingle-over intake installed at or above the eave ▪ Available in 4 ft sectional sticks providing NFVA=10 sq in/lf
VentSure® Undereave Vent	Undereave Vent	▪ Aluminum-screened vents installed under the eave ▪ Available in 3 sizes: 4 in x 16 in (NFVA = 16.3 sq in) 6 in x 16 in (NFVA = 27.2 sq in) 8 in x 16 in (NFVA = 38.1 sq in)
VentSure® Continuous Soffit Vent	Perforated Soffit Vent	▪ 8 ft aluminum vent installed in the soffit NFVA=37.4 sq in
VentSure® Round Mini Soffit Vents	Mini Louver Vent	▪ Aluminum vents installed at the soffit ▪ Available in 3 diameter sizes: 2 in (NFVA = 0.6 sq in) 3 in (NFVA = 1.3 sq in) 4 in (NFVA = 2.4 sq in)

EXHAUST VENTS

Exhaust vents help expel warmer air and moisture from the attic by providing an escape path to the outdoors. Exhaust vents are typically located within 2-3 feet of the roof's ridge line (roof peak) or directly on top of the ridge line.

Several types of exhaust ventilation products are available in the marketplace today, offering varying sizes, styles, and ventilation capacities. Table 3 lists Owens Corning® Roofing exhaust ventilation products offering from highest to least recommended solution.

Table 3. Owens Corning® Roofing Exhaust Ventilation Offerings.

Owens Corning® VentSure® Product	Type of Exhaust	Description
4-foot Strip	Static Ridge Vent	▪ Polypropylene vent with external baffle ▪ Provided in 4 ft interlocking sectional pieces with an optional Weather PROtector® Moisture Barrier ▪ Available regionally in the following shingle-over widths: 8 in (NFVA = 18 sq in/lf) 10 in (NFVA = 18 sq in/lf) 12 in (NFVA = 20 sq in/lf)
RidgeCat™ Rolled Ridge Vent	Static Ridge Vent	▪ Nylon entangled-net structure available in 20 ft rolls ▪ 11 in width (NFVA = 15 sq in/lf)
Rigid Roll	Static Ridge Vent	▪ High-density polypropylene vent available in 20 ft rolls with Weather PROtector® Moisture barrier ▪ Available regionally in shingle-over widths of 11.5 in (NFVA = 12.5 sq in/lf) 9 in (NFVA = 12.5 sq in/lf) 7 in (NFVA = 12.5 sq in/lf)
Low Profile Metal Slant Back	Static Off-Ridge Vent	▪ Galvanized steel construction ▪ 32 in x 23 in base with 11 in x 11 in opening ▪ Available in multiple colors NFVA = 72 sq in

Table 3. Owens Corning® Roofing Exhaust Ventilation Offerings. (continued)

Metal Dome	Static Off-Ridge Vent	▪ Galvanized steel dome with screen ▪ 25 in x 25 in base with 15 in diameter opening ▪ Available in multiple colors NFVA = 144 sq in
Plastic Slant Back	Static Off-Ridge Vent	▪ Polypropylene construction ▪ 17 in x 18 in base with 9 in x 9 in opening ▪ Available in multiple colors NFVA = 55 sq in
Metal Slant Back (standard profile)	Static Off-Ridge Vent	▪ Aluminum or Galvanized Steel ▪ 16 in x 20 in base with 8 in diameter opening ▪ Available in multiple colors NFVA = 51 sq in
Metal Square Top	Static Off-Ridge Vent	▪ Aluminum or Galvanized Steel ▪ 16.5 in x 17.5 in base with 8 in x 8 in opening ▪ Available in multiple colors NFVA = 51 sq in
Solar Powered Attic Fan	Solar Powered Off-Ridge Vent	▪ 25W Solar panel and ventilates up to 3,200 sq ft ▪ Thermostat AND Humidistat ▪ Equipped for optional electric backup ▪ Roof Mount and Gable Mount options ▪ Portable Remote Attic Monitor displays attic humidity and temperature (optional)

Ridge Vents

- Ridge vents are installed directly on the roof's ridge and provide continuous exhaust ventilation at the highest possible location on the roof. Provided ample ridge length is available, Owens Corning Roofing recommends using ridge vents when possible.
- Blend nicely with the roofline for an aesthetically pleasing look.
- Available in rolls and strips (sectional vent pieces) with or without an external baffle which helps divert weather elements away from the vent opening.

Louvered/Boxed/Square Hood Vents

- The off-ridge vents are installed in various locations below the ridge line but in the upper portion of the roof (typically within 2-3 feet of the ridge). Multiple units are often required.
- Recommended for situations where ridge length is insufficient to properly ventilate with ridge vents.
- Available in plastic or metal, standard or low profile, and a variety of colors and finishes.

Turbine Vents

- Typically characterized by a dome or crown-like appearance with built-in weather vanes and moving parts.
- The wind above the roof rotates the turbine, an area of low pressure is generated below the fan, pulling the air out of the attic.
- Performance is dependent on wind speed, orientation, exposure, and the amount of intake ventilation. As wind speeds increase the rotation also increases and more air will be exhausted from the attic.

Note: Turbine vents may not be as effective in densely populated areas due to surrounding structures and terrain limiting the vent's exposure to wind conditions.

Powered Vents

- Powered vents are characterized by having a motor which is typically powered by electricity or solar energy.
- These vents are often equipped with thermostats and/or humidistats which drive operation within desired temperature and relative humidity settings.
- When using powered vents in place of static exhaust vents, it is critical to provide sufficient air intake to offset the air being exhausted. A powered exhaust vent installed without adequate air intake may create negative pressure in the attic

Note: The Home Ventilating Institute recommends 0.7 cubic feet per minute (CFM) of air flow per 1.0 square foot of attic area with a 15% increase for dark roofs[19].

and pull air from the conditioned living space. This may have unintended consequences on the energy efficiency of the home, moisture control, and the performance and durability of the roof system.

- Powered vents should never be used in conjunction with other types of exhaust vents, since the non-powered vents could function as intake vents.

Gable Vents

- Static, louvered vents installed directly in the gable-end of the home rather than the roof deck.
- It is important to install gable vents on the opposing gable ends of a home to promote cross ventilation.
- Because of their size, configuration, and location, these vents serve as intake and exhaust.

Note: In order to help prevent short-circuiting of the ventilation system, gable vents should be covered from the attic interior when other exhaust vents are present. If left uncovered, the gable vents could act as an intake vent, thus leaving the lower portions of the roof and attic space unventilated.

6 ENERGY EFFICIENCY AND ATTICS

Vented Attics in the Context of Energy Efficiency

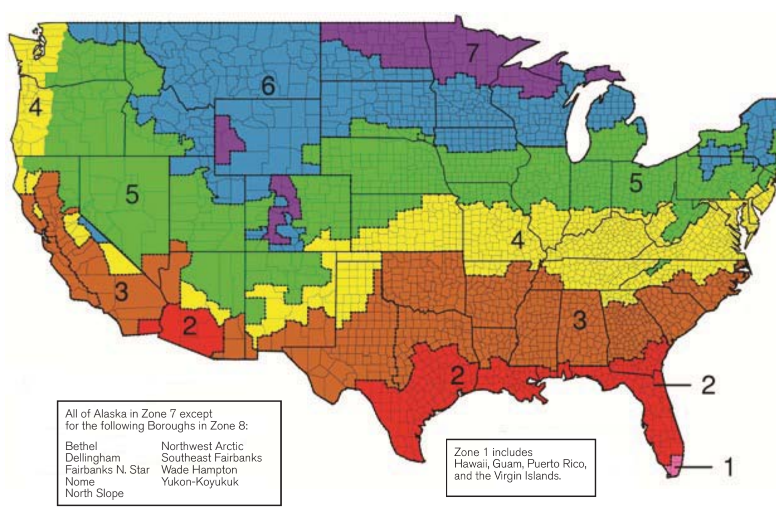
We may think a vented attic is not important to the overall energy performance of a home because it is located outside of the home's thermal envelope, or heated/cooled living space. However, the attic plays an important part when considering energy efficiency because the air in this space may either be at:

- The same temperature as the outdoors, such as during cold winter conditions, or;
- Higher temperature than the outdoors, such as during hot summer conditions.

From the energy performance standpoint, temperature of the air in the attic affects the heat gain and losses in the occupied space. While ventilation can help remove a portion of the summertime heat, it alone cannot expel all of it. Providing an adequate amount of insulation and minimizing air leaks through the penetrations in the ceiling (such as light fixtures) are critical design/retrofit strategies when improving the energy efficiency of a home.

Insulation

In accordance with the International Energy Conservation Code (IECC), regions of the United States are separated into 8 climate zones (Figure 23)[20]. The zones are further divided according to moisture regions; A-moist, B-Dry, and C-Marine. The East half of the country is considered moist and as you move west, the regions transition to dry climates. The exception to this rule in coastal areas, which typically are considered marine. Furthermore, the thickness of the insulation required in the attic increases as you move from the southern to the northern regions of the country.



U.S. Department of Energy Attic Insulation Recommended R-Value
Existing Wood Framed Home

Zone	Uninsulated Attic
1	R-30 TO R-49
2	R-30 TO R-60
3	R-30 TO R-60
4	R-38 TO R-60
5	R-49 TO R-60
6	R-49 TO R-60
7	R-49 TO R-60
8	R-49 TO R-60

Figure 23 - The eight climate zones within the United States as designated in the International Energy Conservation Code and Insulation R-Values in each zone recommended flow by the Department of Energy

The ENERGY STAR® website lists the recommended levels of insulation to be added to insulated or under insulated attics. The levels of insulation in Table 4 are cost effective for different climate zones[21].

ENERGY STAR® also has helpful hints on attic insulation projects and can guide the homeowner in installing attic insulation[22]. In addition, homeowners and professionals can visit the Owens Corning website (http://insulation.owenscorning.com/professionals/insulation/) for information on how to improve the thermal efficiency of the attic.

Table 4. Levels of insulation that may be added to the attic that is currently not insulated or under insulated.

Zone	Add Insulation to Attic: Uninsulated Attic	Add Insulation to Attic: Existing 3-4" of Insulation	Floor
1	R-30 to R-49	R-25 to R-30	R-13
2	R-30 to R-60	R-25 to R-38	R-13 to R-19
3	R-30 to R-60	R-25 to R-38	R-19 to R-25
4	R-38 to R-60	R-38	R-25 to R-30
5 to 8	R-49 to R-60	R-38 to R-49	R-25 to R-30

Air Leakage

Air leakage is a major cause of energy loss. Figure 24 illustrates typical air leak sources in the attic. Air migrating from the occupied space into the attic may contain large amounts of moisture which will condense if the temperature is at or below the dew-point.

Installing a vapor barrier in the ceiling on the warm-in-winter side of the insulation will help control the transmission of water vapor. However, it will do little to help control air leaks through penetrations in the ceiling, unless it is installed as an air barrier. In homes with vented attics, ceilings (the gypsum board in combination with proper detailing that includes sealing penetrations with sealant or mastic) may be part of the air barrier system. This link: (http://www.ocenergycomplete.com/) provides additional information on air leakage and Owens Corning® Energy Complete air sealing system as well as practices. Additional information relevant to air leaks can also be found on the ENERGY STAR® website: (http://www.energystar.gov/ia/partners/publications/pubdocs/DIY_Guide_May_2008.pdf)[23].

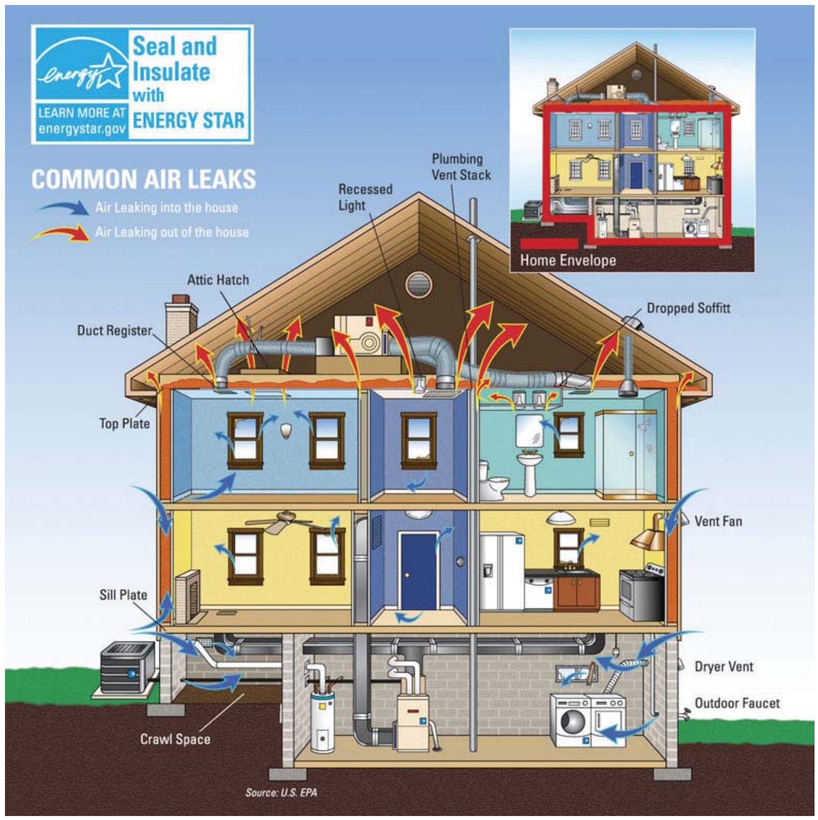


Figure 24 - Typical sources of air leaks in home.[7]

Radiant Barriers in Vented Attic

During past decades, the use of radiant barriers in attics has increased, primarily in warm regions within the continental United States, as a measure of reducing summer heat gain. A radiant barrier is a material with a thermal emittance of 0.05 or lower and reduces the radiant energy emitted from its surface[24, 25]. Two physical properties characterize radiant barriers; high reflectance of thermal radiation and low thermal emittance. Today, radiant barriers are installed in various climate zones in new construction as well as retrofit applications to help mitigate the excess heat in the attic. Since a non-insulated roof assembly offers little resistance to heat transfer, the temperature on the underside of the deck may only be several degrees lower than the temperature of the shingles. The color of the shingles, roof pitch, and building orientation affect the surface temperature of the roof. A portion of the solar energy reaching the surface of the roof is absorbed and a portion is reflected. The absorbed energy heats the asphalt shingles and causes a temperature difference between the top surface and the underside of the roof deck. Heat is transmitted through the solid materials in the roof assembly (the shingles, the underlayment and the sheathing) through conduction. Heat is transmitted from the underside of the roof deck through convection and radiation. As a consequence, the temperature of the air in the attic increases and the upper surface of the insulation in the attic floor is also warmer[26, 27]. Owens Corning Roofing does not recommend but will accept installation of asphalt shingles over roof assemblies with radiant barriers in single and two-family homes (residential applications) with less than 100 squares of roof covering.

Note: The radiant barrier and any other components of the system must be installed in accordance with radiant barrier manufacturer's installation instructions. Contact Owens Corning® GETTECH at gettech@owenscorning.com for guidelines that must be followed when installing shingles over unvented roof decks and roofs/attics with radiant barriers.

How Does A Radiant Barrier Work?

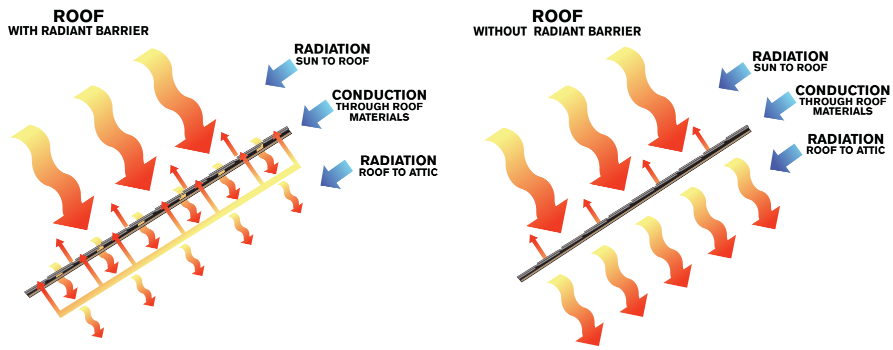


Figure 25 - Heat flow in roofs with and without radiant barrier

Radiant barriers may have one or two low emissive surfaces and function to reflect thermal radiation, thus reducing the heat released into the surrounding attic surfaces (Figure 25). In new construction, which is the most common application, the radiant barrier may be part of the roof decking with the shiny surface facing the interior of the attic. It may also be draped over the roof trusses. In some retrofit applications, the radiant barrier may be stapled to the trusses and separated from the underside of the deck with an air gap. In other applications it may be laid on top of the attic floor. This application may not be as effective because over time dust may accumulate on the surface of the radiant barrier and reduce its effectiveness.

Effect of Radiant Barriers on Asphalt Shingle Temperatures

Radiant barriers installed below the roof deck reduce the radiant energy emitted into the attic and reflect it back toward the deck. This results in higher temperatures of the roof deck and asphalt shingles. However, the location of the radiant barrier in the attic will influence these temperatures. Radiant barriers installed close to the roof deck may increase the shingle temperature between 2°F to 10°F, and those installed on top of the attic floor may only result in a 2°F temperature rise[28].

Moisture Considerations

Moisture migrating from the occupied space may potentially condense on the underside of a radiant barrier installed on top of the attic insulation[29]. A typical radiant barrier is faced with metal foil, a surface that creates a barrier to the transfer of water vapor. This may become an issue in cold climates or conditions where a vented attic is at or near the dew-point temperature. Providing a vapor permeable or perforated radiant barrier may allow moisture to migrate through the material to be exhausted out of the attic.

Air Handler and Ducts in Vented Attics

The location of the heating and cooling system may vary, and while in some homes the mechanical equipment is located in dedicated closets within the occupied space, in others these units are installed in the attic. Typically, vented attics remain at, or near, outdoor temperatures during wintertime. During summertime the attic may be at a much higher temperature than outdoor air because solar energy is transferred through the roof. Higher heating and cooling loads are expected for a home with an air handler and ductwork located outside of the thermal enclosure; such is the case with a vented attic (Figure 26).

Air leaks in the air handlers and the ducts have a major impact on the cooling and heating loads for a home. It is not uncommon for older mechanical systems to exceed the 20% air leakage rates.

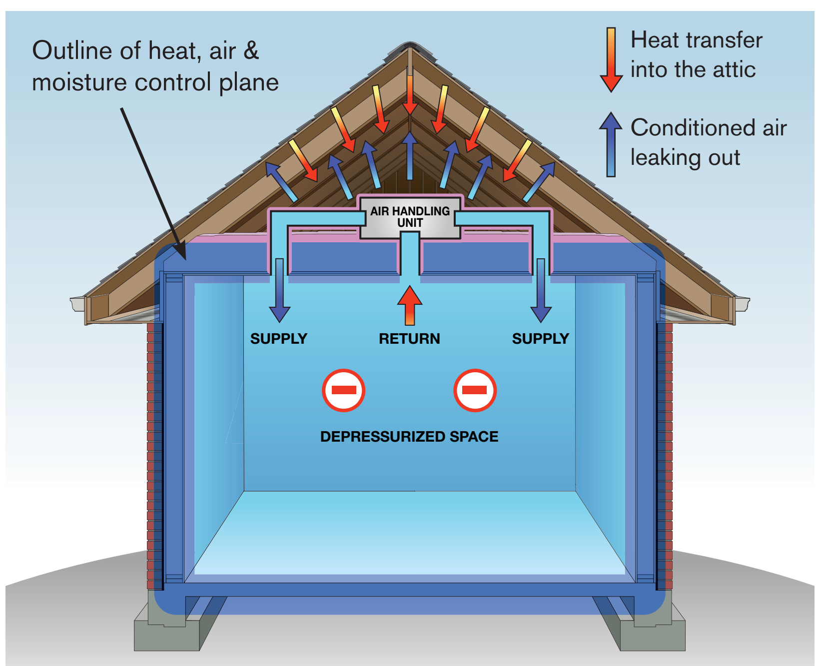


Figure 26 - Heat, air and moisture control plane in a vented attic

Rudd & Lstiburek, noted that:

> "Leakage out of the supply system into the vented attic results in an equal quantity of infiltration through the enclosure. In cold climates the heat loss can lead to ice dam creation, in hot climates the infiltration leads to high latent loads due to infiltration into the conditioned space and condensation on ductwork and air handler. In all climates this leads to thermal penalties – increased energy consumption in the order of 20% of the total space conditioning load."[30]

New homes are typically constructed to more stringent code requirements than buildings built a decade or two ago. Today's homes may have lower air leakage rate across the building envelope, higher insulation levels and less leaky air handlers and ducts.

From the energy efficiency and moisture performance standpoint, it is best to locate the ductwork and the air handler within the thermal envelope rather than in the vented attic for reasons mentioned above. If the air handler is installed in a vented attic in an existing home, the following measures should be taken to help reduce operating loads and provide adequate moisture performance of the attic and the roof assembly:

- **Provide code required ventilation as a minimum and ensure that intake and exhaust are as close to being balanced (50% to 50%) as possible. Provide a minimum of 40% NFVA at the exhaust but never exceeds 50% NFVA.**
- **Provide a free path for air flow from the intake into the attic.**
- **Ensure the air handler and the distribution ducts are sealed well and are insulated to meet the minimum code required airtightness and R-value. This will reduce attic air from being drawn in on the return side and expelled on the supply side of the air handler and will help reduce heating and cooling loads.**
- **Ensure all penetrations in the ceiling below the attic including recessed light fixtures, diffusers, and vent stacks are sealed to eliminate airflow between the attic and the occupied space.**

7 NON-TRADITIONAL ATTICS

In recent years, non-traditional attics such as unvented attics (either semi-conditioned or conditioned) have become more popular among contractors and home builders. In this approach, the thermal, air, and moisture control plane(s) are shifted from the attic floor (in a traditionally vented attic) to the roof such that the building thermal envelope includes the attic (Figure 27).

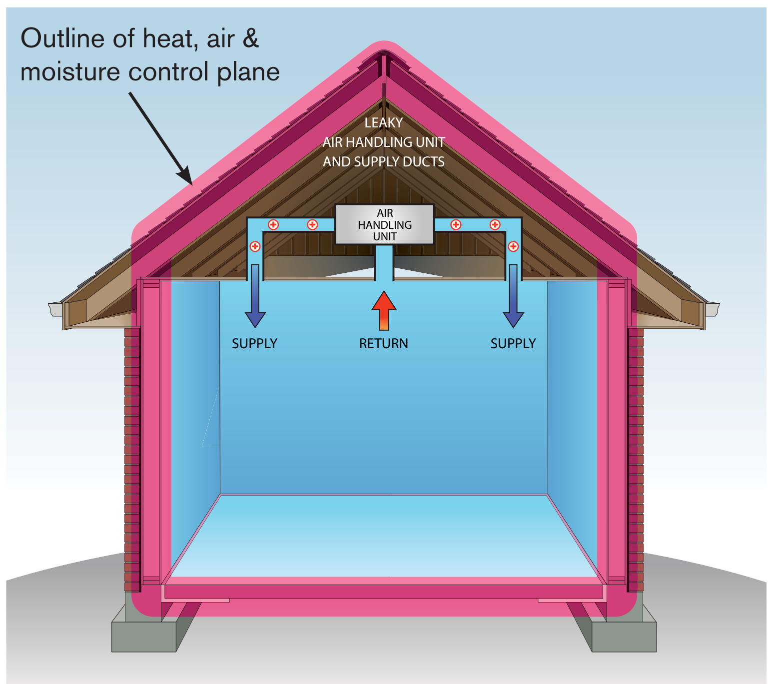


Figure 27 - Heat, air and moisture control plane in an unvented attic

Most recently the California Energy Commission added to the complexity of attics and roof assemblies by introducing into the “2016 Building Energy Efficiency Standard”, prescriptive requirements for supplemental insulation and an air space at the roof deck in traditionally vented attics. These provisions are being introduced to reduce heat gain through the home’s roof, and thus decrease the temperature in the attic, and are part of a broader state wide energy efficiency strategy to reach Zero Net Energy in the new residential construction market by 2020.

The following sections discuss thermal, air and moisture performance for two main categories of non-traditional attics;

1. Unvented attics with two-part spray polyurethane foam (SPF) or fibrous type insulation such as fiberglass or cellulose, and
2. Ventilated attics with additional insulation below/above the roof deck and an optional air space between the roof deck and the roof covering

UNVENTED ATTICS

Unvented attics may be constructed using different materials to provide heat, air and moisture control, and may be insulated with SPF, or fibrous type insulation such as blown-in fiberglass. Lately, the debate has intensified amid evidence from the field that unvented attics with SPF insulation in certain regions of the country are not performing as well as initially thought[31]. In Southern regions of the United States, where hot and humid conditions prevail throughout the year, unvented attics insulated with SPF may not be the right solution to deliver adequate performance and durability. We encourage you to visit www.insulatewithintegrity.com to become familiar with some of the issues that are surfacing related to the use of SPF even if you have not experienced these issues first hand as yet.

Moisture and Air Flow Control

An unvented attic eliminates ventilation and the benefit of removing moisture. The unvented attic is located within the home's thermal envelope and becomes part of the conditioned or semi-conditioned space. Unvented attics that incorporate SPF insulation in controlling heat, moisture and air flow in a single layer may offer limited redundancy relative to moisture performance. Moisture management is an emerging problem tied to the use of SPF in unvented attics and has been known to contribute to structural damage of roof decks[32]. Guidance for proper use of spray polyurethane foam is not available for all climate zones[33]. OSB and plywood manufacturers, as well as the Engineered Wood Association, are beginning to provide recommendations to avoid the use of spray polyurethane foam under roof decks or adopt moisture management construction methods that are challenging[34]. While SPF is often marketed as a dual solution that can provide air sealing and insulation, it leaves many sources of air leaks unsealed and therefore is not a complete solution[35].

Ice Dam Concerns

Similarly, to traditionally vented attics, placement of ice and water barriers along the eave is necessary in minimizing effects of ice dams in regions prone to ice dam formation. Today, building codes require the use of ice dam control in regions with a history of ice dams. Owens Corning Roofing continues to recommend the use of WeatherLock® Self-Sealing Ice & Water Barrier at the eaves to provide excellent roof deck protection against water infiltration resulting from ice dams, wind-driven rain and normal water flow around eaves. We recommend this in all markets today.

Heat Buildup

Research on unvented attics shows higher peak temperatures for both the asphalt shingle and the roof deck. Asphalt shingles over unvented attics stay hotter because the insulation resists the flow of heat through the roof assembly. This is similar to the impact radiant barriers have on temperatures of asphalt shingles and roof decks. With insulation below the roof deck, the average shingle and roof deck temperatures are not expected to increase by more than 10°F as noted by several studies [36,37]. Owens Corning Roofing does not believe that unvented attic assemblies are a significant driver in accelerating aging of shingle products or accessories. Contact Owens Corning® GETTECH at gettech@owenscorning.com for guidelines that must be followed when installing shingles over unvented attics and roofs/attics with radiant barriers.

VENTED ATTICS WITH SUPPLEMENTAL INSULATION AND AIR SPACE AT THE ROOF DECK

Alternative to the traditionally vented attics or unvented attics, roofs can also be constructed to include additional insulation and air space between the deck and roof covering. In 2017 California will become the first state requiring additional insulation at the roof deck and an optional air space in all newly constructed residential dwellings with traditionally vented attics containing air handler or air distribution ducts. This means that in addition to providing roof intake and exhaust vents, additional insulation at the roof deck and optional air space between the roof deck and the roof covering will be required in newly constructed homes.

Moisture Control

From a moisture performance standpoint, these types of roofs/attics are expected to perform similar to traditionally vented roofs because intake/exhaust will be provided to remove moisture from the attic that may have migrated from the occupied space. The inclusion of an optional air space between the deck and the roof covering provides additional means of removing moisture from the roof assembly.

Ice Dam Concerns

Proper ventilation design has a proven track record as means of minimizing the effects of ice dams. However, placement of ice and water barriers along the eave is necessary in minimizing effects of ice dams in regions prone to ice dam formation. Today, building codes require the use of ice dam control in regions with a history of ice dams. Owens Corning Roofing continues to recommend the use of WeatherLock® Self-Sealing Ice & Water Barrier at the eaves to provide excellent roof deck protection against water infiltration resulting from ice dams, wind-driven rain and normal water flow around eaves. We recommend this in all markets today.

Heat Buildup

The inclusion of vented air space between the deck and roof covering is expected to reduce the asphalt shingle temperature. Owens Corning Roofing does not believe that roof/attic assemblies in this category are a significant driver in accelerating aging of shingle products or accessories.

APPENDICES

Appendix A: Reference NFVA for Various Attic Sizes

The table below contains a reference NFVA calculated on the basis of 1:150 and 1:300 ratio. The values have been converted to square inches.

Size of Attic (square feet)	Required Net Free Vent Area (NFVA) (square inches)							
	NVFA 1:150 Ratio				NVFA 1:300 Ratio			
	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust	Intake	Exhaust
	50%	50%	60%	40%	50%	50%	60%	40%
500	240	240	288	192	120	120	144	96
600	288	288	346	230	144	144	172	115
700	336	336	404	269	168	168	202	134
800	384	384	460	307	192	192	230	154
900	432	432	518	346	216	216	260	173
1000	480	480	576	384	240	240	288	192
1100	528	528	634	422	264	264	316	211
1200	576	576	692	461	288	288	346	230
1300	604	624	748	499	312	312	374	250
1400	672	672	806	538	336	336	404	269
1500	720	720	864	576	360	360	432	288
1600	768	768	922	614	384	384	460	307
1700	816	816	980	653	408	408	490	326
1800	864	864	1036	691	432	432	518	346
1900	912	912	1094	730	456	456	548	365
2000	960	960	1152	768	480	480	576	384
2100	1008	1008	1210	806	504	504	604	403
2200	1056	1056	1268	845	528	528	634	422
2300	1104	1104	1324	883	552	552	662	442
2400	1152	1152	1382	922	576	576	692	461
2500	1200	1200	1440	960	600	600	720	480
2600	1248	1248	1498	998	624	624	748	499
2700	1296	1296	1556	1037	648	648	778	518
2800	1344	1344	1612	1075	672	672	806	538
2900	1392	1392	1670	1114	696	696	836	557
3000	1440	1440	1728	1152	720	720	864	576

Appendix B: Roof Ventilation Requirements in Residential Building Codes (Table B1)

	Building Code		Minimum Net Free Ventilating Area (NFVA)			Vent Insulation Clearance	Vent Location	Mechanical Ventilation
			1/150①	1/300②				
				Exception 1	Exception 2			
RESIDENTIAL BUILDING CODES	IRC[38]	2015	Yes	In climate zones 6, 7 & 8, Class 1 or 2 vapor retarder on the warm-in-winter side of the ceiling③	At least 40% not more than 50% NFVA at the upper part of roof not more than 3 feet below the ridge or highest point of the space	Minimum 1-inch		
	IRC[38]	2012	Yes	In climate zones 6, 7 & 8, Class 1 or 2 vapor retarder on the warm-in-winter side of the ceiling③	At least 40% not more than 50% NFVA at the upper part of roof not more than 3 feet below the ridge or highest point of the space	Minimum 1-inch	-	-
	IRC[38]	2009	Yes	In climate zones 6, 7 & 8, Class 1 or 2 vapor retarder on the warm-in-winter side of the ceiling③	At least 50% not more than 80% NFVA at the upper part of roof at least 3 feet above eave vents; with the balance of required ventilation provided by eave/cornice vents	Minimum 1-inch	-	-
	IRC[38]	2006	Yes	Vapor retarder with transmission rate of 1 Perm③ on the warm-in-winter side of the ceiling	At least 50% not more than 80% NFVA at the upper part of roof at least 3 feet above eave vent; with the balance of required ventilation provided by the eave/cornice vents	Minimum 1-inch	-	-
	Florida[39]	2010	Yes	In climate zones 6, 7 & 8, Class 1 or 2 vapor retarder on the warm-in-winter side of the ceiling③	At least 50% not more than 80% NFVA at the upper part of roof at least 3 feet above eave vent; with the balance of required ventilation provided by the eave/cornice vents	Minimum 1-inch	-	-
	Florida[39]	HVHZ④	Yes	-	At least 50% NFVA at the upper part of roof within 18 inches of roof ridge; with the balance of required ventilation provided by the eave/cornice vents	Minimum 1-inch	Where practical, ventilation openings arranged on 3 sides	Where mechanical vents are used, the ventilation rate shall be at least 6 times
	California[40]	2013	Yes	In climate zones 6, 7 & 8, Class 1 or 2 vapor retarder on the warm-in-winter side of the ceiling	At least 40% not more than 50% NFVA at the upper part of roof not more than 3 feet below the ridge or highest point of the space	Minimum 1-inch	-	-

Notes:

① At 1/150 NFVA building codes do not require balancing the ventilation between intake and exhaust. Building codes specify the **minimum standards** for constructed objects to protect public health, safety and general welfare. **Owens Corning Roofing always recommends providing a balanced ventilation system between exhaust and intake.**

② Reduction in NFVA from 1/150 to 1/300 is allowed if one or more exceptions are met.

③ Vapor retarder classification is based on water vapor transmission.
1 Perm is a typical unit and it is equivalent to 5.7x10-11 [kg/sm²Pa]:
Class 1: ≤ 0.1 Perm
Class 2: > 0.1 to < 1 Perm

④ HVHZ - High Velocity Hurricane Zone applicable to Miami-Dade and Broward Counties.

Roof Ventilation Requirements in Commercial Building Codes (Table B2)

	Building Code		Minimum Net Free Ventilating Area (NFVA)			Vent Insulation Clearance	Vent Location	Mechanical Ventilation
			1/150①	1/300②				
				Exception 1	Exception 2			
COMMERCIAL BUILDING CODES		2015	Yes	In climate zones 6, 7 & 8, Class 1 or 2 vapor retarder on the warm-in-winter side of the ceiling③	At least 40% not more than 50% NFVA at the upper part of roof not more than 3 feet below the ridge or highest point of the space	Minimum 1-inch		
	IRC[41]	2012	Yes	In climate zones 6, 7 & 8, Class 1 or 2 vapor retarder on the warm-in-winter side of the ceiling③	At least 50% not more than 80% NFVA at the upper part of roof at least 3 feet above eave vent; with the balance of required ventilation provided by the eave/cornice vents	Minimum 1-inch	-	-
		2009	Yes	In climate zones 6, 7 & 8, Class 1 or 2 vapor retarder on the warm-in-winter side of the ceiling③	At least 50% not more than 80% NFVA at the upper part of roof at least 3 feet above eave vents; with the balance of required ventilation provided by eave/cornice vents	Minimum 1-inch	-	-
		2006	Yes	Vapor retarder with transmission rate of 1 Perm④ on the warm-in-winter side of the ceiling③	At least 50% not more than 80% NFVA at the upper part of roof at least 3 feet above eave vent; with the balance of required ventilation provided by the eave/cornice vents	Minimum 1-inch	-	-
	Florida[42]	2010	Yes	Class 1 or 2 vapor retarder on the warm-in-winter side of the ceiling③	At least 50% not more than 80% NFVA at the upper part of roof at least 3 feet above eave vent; with the balance of required ventilation provided by the eave/cornice vents	Minimum 1-inch	-	-
	California[43]	2013	Yes	Class 1 or 2 vapor retarder on the warm-in-winter side of the ceiling③	At least 50% not more than 80% NFVA at the upper part of roof at least 3 feet above eave vent; with the balance of required ventilation provided by the eave/cornice vents	Minimum 1-inch	-	-

Notes:

① At 1/150 NFVA building codes do not require balancing the ventilation between intake and exhaust. Building codes specify the **minimum standards** for constructed objects to protect public health, safety and general welfare. **Owens Corning Roofing always recommends providing a balanced ventilation system between exhaust and intake.**

② Reduction in NFVA from 1/150 to 1/300 is allowed if one or more exceptions are met.

③ Vapor retarder classification is based on water vapor transmission.
1 Perm is a typical unit and it is equivalent to 5.7x10-11 [kg/sm^{2}Pa]:
Class 1: ≤ 0.1 Perm
Class 2: > 0.1 to < 1 Perm

Appendix C: Roof Inspection Checklist

ROOF INSPECTION CHECKLIST

Proper roof ventilation system is important to the performance and durability of the attic. Improper ventilation can lead to:

- Ice Damming leading to Water Leakage
- Buckling of Roof Sheathing
- Mold Growth in the Attic
- Premature Shingle Aging
- Condensation on the Underside of Roof Deck
- Reduced Thermal Comfort in Occupied Space

The following checklist will help identify potential problems with a roof ventilation system. Please note it is extremely important to inspect the attic interior as well as the roof exterior.

ROOF/ATTIC INFORMATION

Attic Floor Area ________________ ft^2

Length of Ridge ________________lf

Length of Eaves ________________lf

Intake Ventilation Req'd ___ ft^2 x 144 = _____ in^2/lf

Exhaust Ventilation Req'd ___ ft^2 x 144 = _____ in^2/lf

# Intake Vents Present / NFVA		**#Exhaust Vents Present/NFVA**	
Undereave/soffit	___/___	Ridge Vents	___/___
Shingle-over intake	___/___	Static Off-Ridge	___/___
Other Intake	___/___	Power Off-Ridge	___/___
		Turbines	___/___
		Gable Vents	___/___
		Other Exhaust	___/___

Total Intake NFVA _______ **Total Exhaust NFVA** ______

Sufficient Intake? _______ **Sufficient Exhaust?** ______

SKETCH

INSPECTION CHECKLIST

Field of Roof

Curling/Crackling of Shingles ☐ Yes ☐ No

Bucking of Roof Sheathing ☐ Yes ☐ No

Additional Comments: ______________________

____

____

Attic Interior

Presence of Mold	☐Yes	☐ No
Evidence of Excessive Moisture	☐Yes	☐ No
Moisture on Framing or Sheathing	☐Yes	☐ No
Buckling of Sheathing	☐Yes	☐ No
Wet Insulation	☐Yes	☐ No
Sufficient Attic Insulation	☐Yes	☐ No
Insulation Baffles	☐Yes	☐ No
Daylight Visible Through Soffit & Ridge	☐Yes	☐ No
Bathroom/Kitchen Vented into Attic	☐Yes	☐ No
Can Lights	☐Yes	☐ No
Other Penetrations into Attic from	☐Yes	☐ No
Living Area	☐Yes	☐ No

Appendix D: Historic Perspective and Developments in Roof Ventilation

During the last several decades, considerable efforts were made to better understand the contribution of ventilation on the performance of attics. The early research and testing focused on condensation control in cold climates. During the 70s energy crisis, the emphasis shifted toward understanding the impact that attic ventilation has on the energy performance of the building. Initially, the work focused on temperature and heat flux measurements, but with the growth of computing technology, modeling efforts have become an essential part of laboratory and field measurements.

Teesdale (1937), Rogers (1938) and Rowley (1938 & 1939) completed some of the earliest research and testing related to condensation and moisture migration into the roof assemblies[44]. In 1938, Tyler S. Rogers argued for condensation control in insulated assemblies based on work completed by the National Mineral Wool Association and a project at U.S. Forest Products Laboratory[45]. Rogers, the Director of Technical Publications for Owens Corning advocated for venting of roof areas above the insulation and application of vapor barriers as two approaches to condensation control in attics[46]. Based on the laboratory testing, Rowley et. Al., (1938) advocated ventilation of attics as a prudent approach to condensation control in cases when a vapor barrier may or may not be present in the ceiling assembly[47].

In 1938 and 1939, Rowley conducted temperature and moisture monitoring studies with three test huts in a controlled laboratory environment with low temperatures. The huts included an attic without ventilation openings, an attic with openings that could be ventilated and mechanically ventilated attic space. The results showed that[48]:

- Hut with no ventilation – Condensation appeared in test hut with no ventilation but disappeared when the temperature was increased from -10°F to 15°F.
- Hut with natural ventilation – Condensation did not appear with NFVA of 1:576. Condensation appeared when the NFVA ratio was reduced to 1:1152.
- Hut with mechanical ventilation – Condensation did not appear with ventilation at 3 cubic feet per hour for 1 square foot of ceiling area. Condensation appeared when the ventilation flow rate was reduced in half.

This early work focused on understanding the cause(s) of condensation in roof systems subject to cold climatic conditions and helped shape the fundamental knowledge on attic ventilation.

In 1942, the Federal Housing Administration (FHA) revised the Property Standards and Minimum Construction Requirements for dwellings to include provisions for a minimum net ventilation area of 1:300 of horizontally projected roof area and use of corrosion resistant screening over ventilation openings[49]. The FHA ventilation requirements were included in the first model building code in 1948[50]. In 1948, the Housing and Home Finance Agency (HHFA) published "Condensation Control in Modern Buildings" which was widely used in construction and became the base for most future standards and regulations related to condensation control and ventilation[51]. In 1951, condensation control strategies and drawings became part of the Architectural Graphic Standards[52]. That same year, the National Paint and Varnish Association launched a campaign to raise awareness and provide best moisture control practices in an effort to prevent peeling of paint on the exterior side of building enclosures including gable ends[53]. The document published as "How to Win Your War Against Water", emphasized three important factors in preventing condensation in attics, including: improving ventilation; reducing humidity in occupied space; and using barriers to prevent migration of moisture into locations where it may condense[54]. In the 1950s, Neil B. Hutcheon's research on air leakage at the Division of Building Research at the National Research Council of Canada (NRCC) was fundamental to our understanding of heat, air and moisture transfer through the building envelope including ceilings in vented attics[55]. His work highlighted that air leakage may contribute one or two orders of magnitude more moisture into the attic space than diffusion of water vapor alone[56]. In 1961, H. S. Hinrichs used smoke to help visualize the flow of air through different ventilators and showed that combining soffit and ridge vents provided more effective ventilation than gable-end vents, off-ridge vents, ridge only and soffit only vents[57]. During the 70s and onwards; research, testing and modeling work focused on evaluating impact attic ventilation may have on the overall energy savings of a home. The studies have shown that with increasing energy efficiency of building envelope the contribution of roof ventilation to the overall energy savings can be greatly reduced. Unvented attics are one of the most recent trends in roof construction. In this approach the thermal, air, and moisture control layers are shifted from the attic floor (in a traditionally vented attic) to the roof. Research encompassing laboratory and field testing as well as modeling work are ongoing to evaluate and validate performance and durability of unvented attics.

Appendix E: Glossary

Above Sheathing Ventilation - Air space above the roof sheathing which allows air flow to the roof top as a method of reducing solar heat gain.

Air Changes per Hour (ACH) - Measure of the number of times the air within a defined space such as an attic is replaced per hour.

Attic Ventilation System - The combination of intake vents installed in the lower portion of the roof and exhaust vents installed in the upper portion of the roof, working together to provide an exchange and mixing of outdoor air with air in the attic.

Balanced Attic Ventilation System - An Attic Ventilation System in which 50% of the ventilation for a contained attic space originates from the lower portion of the roof (intake vents) and 50% originates from the upper portion (exhaust vents).

Note: If balance cannot be achieved, the upper portion of the attic space should provide between 40% and 50% of the total ventilation.

Buoyancy - An upward force exerted by a fluid that opposes the weight of an immersed object[58].

California Building Code - Part 2 and Part 25 of the California Building Standards Code and Title 24 of the California Code of Regulations (it is based on International Building code). It is maintained by the California Building Standards Commission[59].

Climate Regions - The U.S. Department of Energy has separated regions of the United States into 8 climate regions, based on temperature, precipitation, and heating and cooling days[60]. The zones include: hot-humid, hot-dry, mixed-dry, mixed-humid, marine, cold, very cold, and subarctic.

Condensation - The change of water vapor (moisture in a form of a gas) into a liquid state.

Conduction or Conductive Heat Transfer - The transfer of heat from one to another object in contact as a result of one object being at a higher temperature[61]. Conductive heat transfer can also occur in a single object in presence of temperature difference (when one or more of its sides are at higher temperature). The heat transferred through the roof decking is an example of conductive heat transfer.

Construction Moisture - Moisture contained or absorbed into building materials during the construction process.

Convection or Convective Heat Transfer - Transfer of heat between an object and its environment, as a result of motion in the fluid[62]. Example: The heat transferred from the bottom surface of the roof decking to air (fluid) in the attic.

Continuous Soffit Vents - Intake vents installed directly in the soffit, often characterized by having a series of slots or holes to draw air into the attic. These are typically available in 8-foot lengths and are usually Aluminum or PVC.

Cornice - A horizontal molded projection located at or near the top of an architectural feature.

Dew-point Temperature - Temperature at which air cannot hold additional moisture because it is saturated with water vapor, resulting in the change of water from an invisible gas to a liquid water.

Diffusion - The transport of a substance from a region of high concentration to a region of low concentration[63].

Eave - The overhanging, lower portion of a roof.

Energy Star® - An international standard for energy efficient consumer products originated in the United States of America[64].

Exhaust Vent - A product installed over an opening cut into the upper portion of the roof deck providing a pathway for air to move outside from the attic. Exhaust vents can be installed directly on the ridge or close to the ridge, and are available in many different forms (e.g., static, powered, turbines, gable vents).

Florida Building Code - The Florida Building Code is developed and updated by Florida Building Commission and applies to construction, erection, alterations, modification, repair, equipment use and occupancy, location, maintenance, removal and demolition of every public and private building structure[65].

Humidistat - A component of a control system that regulates the amount of moisture (relative humidity) in the air. A humidistat often functions as an on/off switch for a powered vent, triggered by the level of humidity measured in relation to the desired level the humidistat is set to maintain[66].

Ice Dam - A ridge of ice formed at the lower edge of the roof, preventing melting snow to drain properly. An ice dam is the result of snow melting on the roof and then re-freezing at the overhang, creating a dam. Water backing up at the ice dam can get underneath shingles and leak into the home causing damage to walls, ceilings, insulation, and other interior fixtures.

Impermeable Membrane – Membrane that restricts the passage of a fluid or a gas.

Intake Vent - A product installed over an opening at the lower portion of the roof, often at the eave or in the soffit, providing a pathway for air to be drawn into the attic.

International Building Code (IBC) - Model building code developed by the International Code Council (ICC) that is not applicable to one and two family dwellings[67].

International Residential Code (IRC) - Model building code developed by the International Code Council (ICC) that is applicable to one and two family dwellings[68].

Leeward - Direction downwind from the point of reference[69].

Mechanical Vent - A vent powered by an electrical source to pull air through the system.

Net Free Ventilating Area (NFVA) - The total unobstructed opening in which air can pass through a vent, often measured in square inches per lineal foot (sqin/LF).

Partial Pressure of Water Vapor - The pressure a gas in a mixture of gases would exert if it occupied the same volume as the mixture, at the same temperature.

Perforated Soffit Panels – A continuous intake soffit vent characterized by having a series of holes used for drawing air into the attic.

Radiant Barrier - A material (often reflective) designed to reduce or stop the flow of radiant energy[70].

Relative Humidity - The amount of moisture contained in a defined volume of air relative to the maximum quantity that can be held in the same volume of air at a given temperature. Relative Humidity can be expressed in terms of a percent from 0%-100%.

Saturation Moisture Content - The maximum amount of moisture that can be stored in a volume of air.

Thermal Emittance - Ratio of the radiant emittance of heat for an object or surface in relation to a standard black body[71].

Thermal Radiation – Emission of electromagnetic waves from all matter that has a temperature greater than absolute zero[72].

Thermostat - A component of a control system that regulates the air temperature of a specific area. A thermostat often functions as an on/off switch for a powered vent, triggered by the temperature measured in relation to the desired temperature the thermostat is set to maintain[73].

Spray Polyurethane Foam Insulation (SPF) - Type of insulation used in construction of buildings that consists of two component mixture (isocyanate and polyol resin) combined using a gun applicator to form expanding foam.

Static Vents - A vent that is fixed/stationary and does not have moving parts to impart airflow.

Steep Slope Roof - Roof with a pitch of 4:12 or greater but not more than 21:12.

Under Eave Vents – An Intake vent installed in a cutout in the eave, often characterized by having a series of slots or holes to draw air into the attic. These are typically available in smaller sections than Continuous Soffit Vents, and are usually available in aluminum or steel.

Vapor Retarder - Any material which slows the transmission of water vapor.

Vent - Any device installed on the roof, gable or soffit used to ventilate the underside of the rood deck.

Water Vapor - Water in the form of a gas.

Windward - Direction upwind from the point of reference[74].

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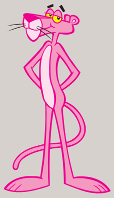

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