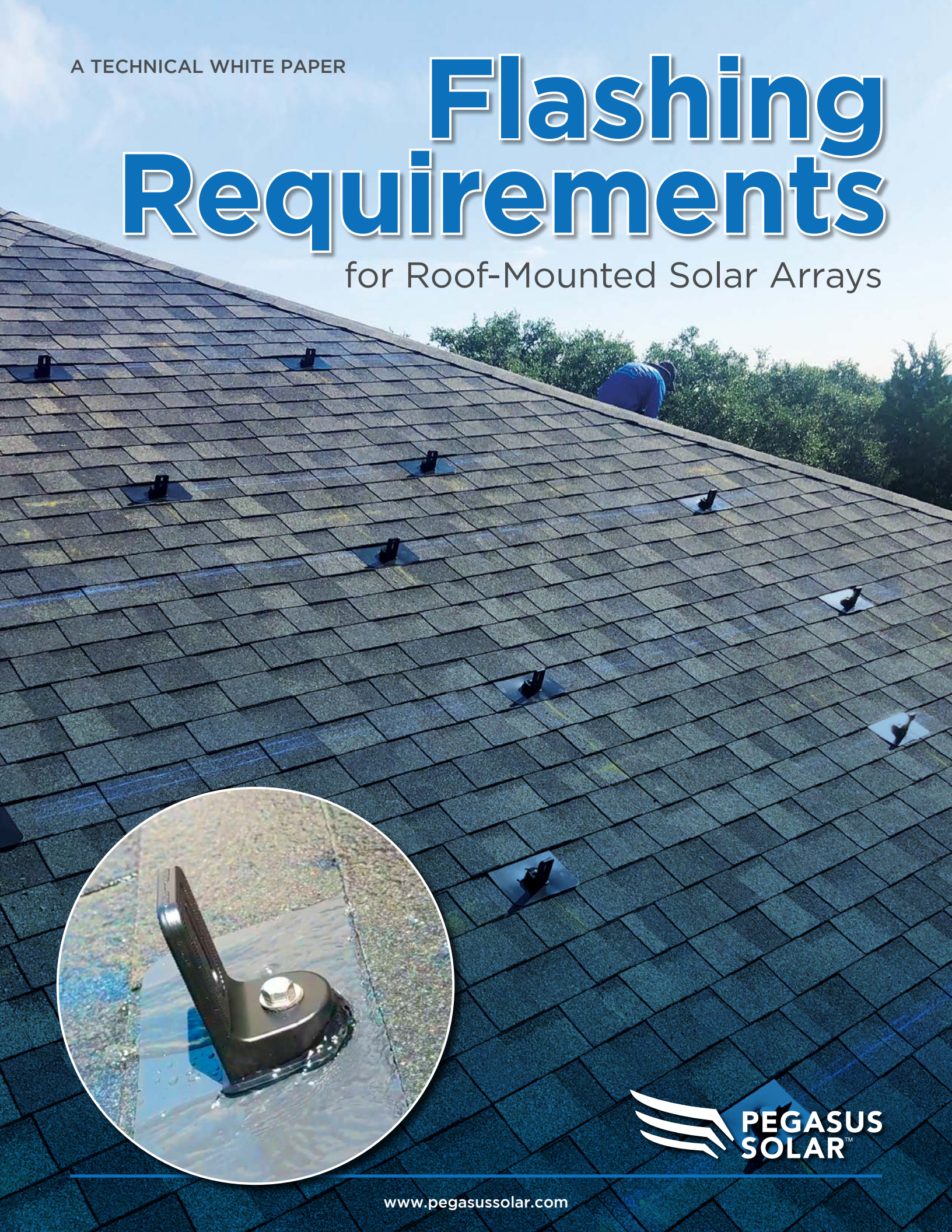
A TECHNICAL WHITE PAPER

Flashing Requirements

for Roof-Mounted Solar Arrays



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Flashing Requirements
for Roof-Mounted Solar Arrays

The potential for roof leaks is a well-known liability in the solar industry. In the early 2000s, when residential grid-tied solar PV systems entered the market, installers had few choices for roof-mounting solutions and, in many cases, had to make do with products forced into the application. These products did not use flashings and relied on single or multiple penetrations into the rafter or decking material and some form of sealant at each mount location.

Early solar contractors learned that these products failed and caused leaks within a few years. Expensive remediation required system tear offs and re-roofing, causing many contractors to go out of business. This hard-won experience led to the development of engineered systems that include flashings to protect the roof, the owner's home and match the long working life and warranty periods of the solar modules and roofing material.

Photovoltaic (PV) installations are expected to produce power for more than 25 years. Therefore, installation methods must consider industry best practices, applicable building codes, equipment, and roofing material manufacturer requirements. When penetrating a roof for solar attachments, it is important to include flashings for proper roof protection. Making the wrong choice with mounting products, or relying solely on sealants, turns every installation into a potential water leak time bomb.

No major composite shingle manufacturer, such as GAF, CertainTeed or Owens-Corning, endorses or approves non-flashing based solar mounting systems for use with their roofing materials. Practically, this transfers all warranty liability to the solar mount company and the contractor who installs the products. With the hundreds of thousands of PV installations now achieved on an annual basis, use of non-flashing product will create a tremendous liability and reputational issue for the solar industry.

Recently, some mount companies have re-introduced non-flashing roof attachments in an attempt to lower costs and speed up installation time. However, the proper installation process dictated by their instructions are so specific that it is difficult to comply with consistently for each mount—even within a single array. This means that a crew can often improperly install the non-flashing mount, placing most if not all liability on the contractor for roof leaks.

This non-flashing mount (left) had sealant—as seen coming through the roof deck—yet this was not enough to prevent a leak after only two years.

Water dripped from the roof penetration (right), causing water damage to the attic floor. Unfortunately, the solar contractor was held fully liable to pay for the repairs on this home in Sacramento, California.

Roofers like Ryan Winkle of RD Winkle Roofing and Solar see the results of poorly waterproofed solar attachment penetrations. He has repaired dozens of roofs with leaks caused by solar installations in Southern California despite several years of drought conditions. "We don't even know how many roofs are currently leaking because the solar attachments weren't correctly flashed," Winkle says. "The homeowners with visible damage are lucky to have a sign that lets them know there is a problem. Small water leaks can do damage to the home's structure for years before they get noticed. By that time, you have to replace all the damaged decking and rafters plus do mitigation for the mold problems that can occur. It can cost the homeowner or PV system installer several thousand dollars."

Construction of an Asphalt Composition Shingle Roof

Asphalt composition shingles (comp shingles for short) are used on approximately four out of five homes in the United States. Understanding the construction of these roofs helps illustrate the proper methods of protection. Roofs are built with multiple layers of materials to guard against water intrusion. The first layer of waterproofing is the underlayment installed directly on the roof deck. Each layer of underlayment overlaps the layer below it by at least 2 inches. The underlayment protects the roof decking in case the shingles fail, wind-driven rain pushes water up under the shingles, or ice dams penetrate the shingles.

The next layer of protection is the flashing installed at the edges, roof penetrations, chimneys and valleys. In locations where multiple flashings meet, they are installed with at least a 2-inch overlap, so they properly direct the water, deflecting it from the roof joints and seams, allowing it to flow harmlessly down the roof and into the rain gutters.

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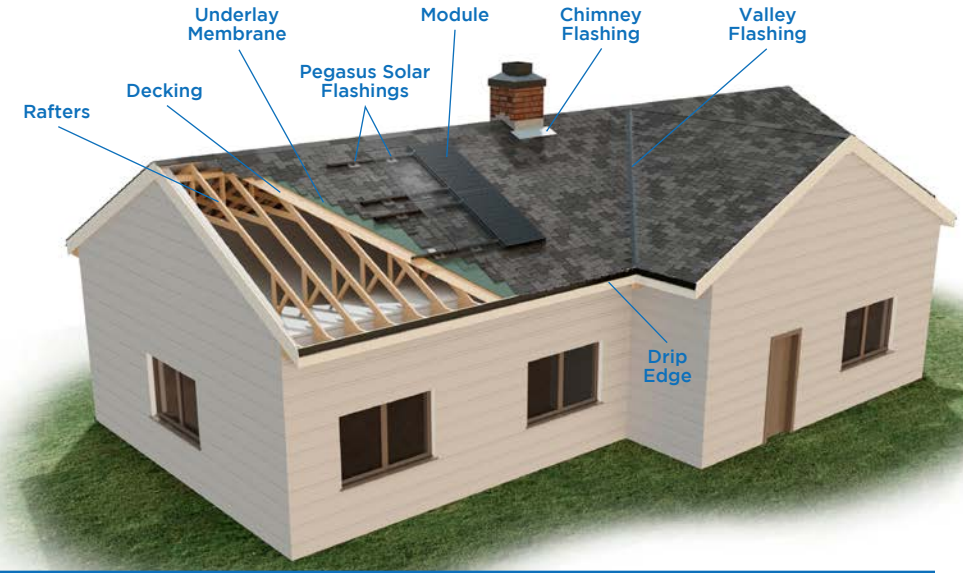
Finally, the shingles are laid on top of the underlayment and flashings. Per manufacturer's instructions, like the CertainTeed Shingle Applicator's Manual[1], the shingles are typically designed to overlap each other by 4.5 to 5 inches, with the shingle above covering the nails in the shingle below it. Ridge cap and edge shingles create the final seal of a roofing system that, if properly installed, can last 30 or more years.

The comp shingles themselves can vary in appearance and construction. The three most common types are strip (or 3-tab) shingles; dimensional (or architectural) shingles; and luxury (or presidential) shingles. Each type has unique features and benefits for price, durability and construction. Dimensional shingles currently dominate the comp shingle market, with approximately 80% of new comp shingle roofs utilizing this style. These shingles are manufactured with two or more layers of asphalt that results in a thicker material, when compared to strip shingles, to more closely match the wood shake or natural slate aesthetic. PV installers need to have appropriate flashing solutions ready to account for the various shingles they will encounter.



Composition shingle roofs have multiple layers of protection to eliminate the potential for water intrusion. Each layer of protection builds on the one below. An underlayment is applied directly over the wood decking. Metal flashings are placed over the underlayment at all points of penetrations and valleys and the shingles are finally placed over both the underlayment and flashings.

PV Systems on an Asphalt Composition Shingle Roof

Integrating a PV system on an asphalt-shingled roof can be accomplished in a manner that maintains the required protection. When installing solar on these roofs, solar racking must be secured to the roof structural members. This means penetrating through the shingles, underlayment and decking and into the structural members with lag screws. Each penetration should be treated with the same best practices as the initial roof installation. A flashing such as Pegasus' Comp Mount should be installed between the shingle and roof attachment with appropriate overlapping of the roofing materials above the penetration.

Importance of Overlapping This overlapping requires the flashing to extend up-roof from the roof penetration and underneath the two courses of shingles directly above the penetration. This allows the flashing to provide adequate protection for the roof penetration without relying on sealants as the primary weatherproofing method.

Shingle Variety & Thickness Proper roof protection can be further complicated by the staggered thick and thin tabs of the dimensional and luxury shingles. The roof framing member will not always line up with the flat sections of these shingles, causing a roof penetration where a change in shingle height occurs (see image on this page). When using a non-flashed mounting system, the mount footing will straddle this section of the shingle, resulting in a large gap that must be filled with sealant—in this case acting as the only method to prevent water intrusion. Over time, movement of the roof and solar system from daily thermal expansion, wind and snow forces can break the seal and allow water penetration.

Using a flashing system in this scenario provides protection on all sides of the roof penetration and does not rely on sealant as the only level of protection. The width of the flashing covers the staggered layers of the shingles to shield the roof penetration from water. This method greatly simplifies the installation process and does not encourage PV installers to alter the roof penetrations to accommodate the shingle locations.

Pilot Holes that Miss Rafters PV installers drill pilot holes into the roof structure as part of the mounting system installation. The goal is to place the pilot hole in the center of the rafter the mount is attached to. Often though, the rafters are not perfectly spaced and the holes can miss the rafter. The Pegasus flashing is 9" wide, allowing the installer to miss by as much as a full inch and still have the necessary 4" of flashing in the lateral dimension. Non-flashed roofing penetrations will leave the missed pilot holes reliant on sealants to protect the hole from water intrusion..

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Cyclical Loading & Thermocycling After installation, environmental effects continually stress the roof attachments. For example, in snow regions, the cyclical snow loading on the PV modules themselves can cause the up-roof edge of the roof attachments to lift. The adding and melting of snow to the top of the array effectively works the attachments back and forth, causing fatigue on any sealant used between the mounting foot and the roof surface. A mounting foot directly attached to the roof surface and reliant solely on adhesives for sealant is especially susceptible to damage. Consistent stresses on the footing and sealant will result in cracking and premature failure of the sealant, allowing ingress of water. Conversely, flashed penetrations separate the mount from the roof and allow the front lip of the footing to lift on and off the flashing without tearing of the sealant. The Pegasus Comp Mount places the footing over a raised cone in the flashing, providing even more protection for the roof penetration.

The most common composition asphalt shingles are manufactured with multiple thickness tabs. Non-flashed roof mounts cannot account for these differences and rely solely on sealants to eliminate water intrusion. Flashed roof mounts can work with these shingles and provide protection in line with roofing manufacturers' requirements.

Installers often drill pilot holes that miss the intended roof framing member. Flashed penetrations add protection in all directions, reducing the risk of water intrusion.

Difficulty of Installation Requirements PV installations generally are not installed on brand-new roofs. Relying on sealants on roofs that have aged, have any moisture present during application, and have varying levels of dirt build-up and degradation is a risky proposition at best. In addition, an installer's ability to follow the sealant manufacturer's installation instructions can be difficult. For example, a common sealant, ChemLink DuraLink 50, requires the installation to occur on a clean, dry- and contamination-free surface; and to maintain sealant at room temperature to ensure adequate adhesion. Maintaining such strict temperature ranges for the storing and application of their product will be nearly impossible during the installation of a PV system on a rooftop.

Manufacturers of non-flashed products often point to standard testing protocols, such as AC286, as proof of longevity. These protocols, discussed in detail later, cannot account for the various real-world situations installers will encounter. Therefore, the validity of these testing standards must be evaluated for not only the product used, but also for the specifics of the roof the products are installed on.

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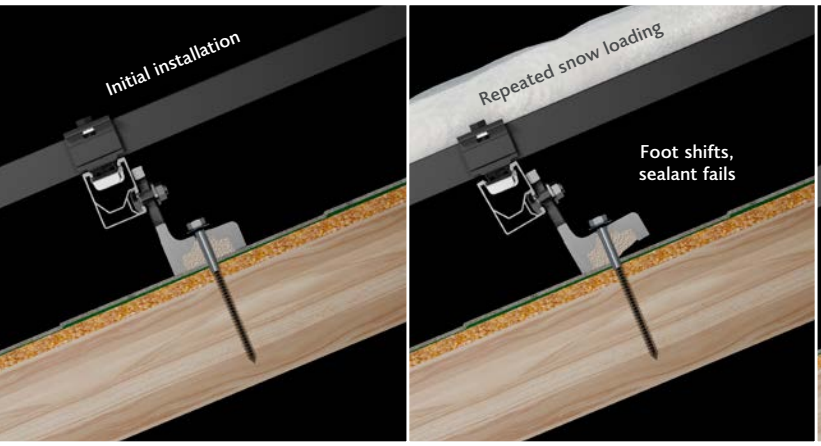
IBC & IRC Codes Regarding Roof Flashing

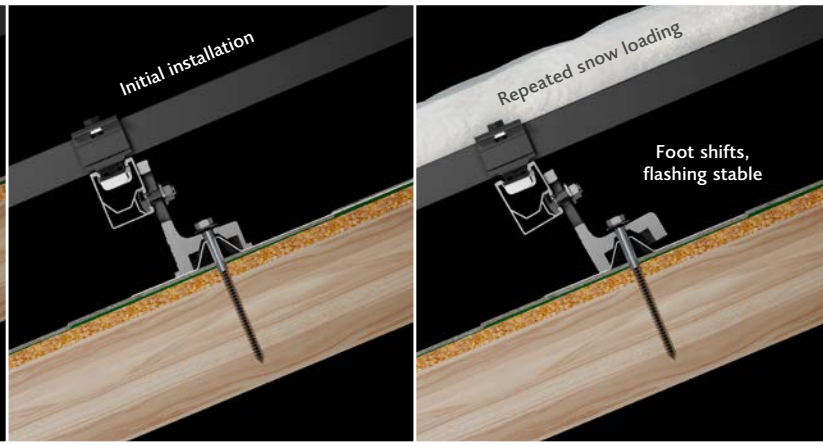
The *International Building Code (IBC)*[6] and *International Residential Code (IRC)*[7] are developed by the International Code Council to establish the minimum requirements for building officials and contractors. These codes have been adopted by most jurisdictions in the United States. These codes aim to protect the structure and the inhabitants as stated in IBC section 101.3. Code-making panels consider the building practices to establish the minimum requirements. These standards should be considered as the minimum line of requirements, but not necessarily the best practices, when installing an array on a rooftop.

The 2018 IBC includes direct references to flashing requirements for proper roof protection. Section 1503.2 requires flashing to be installed to prevent moisture intrusion in several situations, including penetrations through the roof plane. The most common flashing material is metal, allowing installation of the flashing in many locations for a long-term solution. IBC sections 1503.2 and 1507.2.8 dictate metal flashings be corrosion-resistant and a minimum of 0.019" thickness.

Caulked Penetration



Flashed Penetration



The Pegasus Comp Mount places the footing over a raised cone at the roof penetration. This patented design feature provides additional protection from water intrusion, even in climates where freezing conditions may lift the front edge of the footing.

IBC section 1507 states that flashings for asphalt shingles must be applied in accordance with the printed instructions from the shingle manufacturer. Asphalt roofing manufacturers' instructions[1] typically detail that metal flashings be installed on top of the underlayment and under the shingles with everything having at least a 2" overlap.

The 2018 IRC also addresses the need for flashings as well as requirements for proper flashing installation in Chapter 9. IRC sections R903.1 and R903.2 state that flashings must be installed such that the roofing assembly protects the building and in a manner that prevents moisture from entering at any penetrations of the roof plane. R903.2.1 echoes the requirement in the IBC that metal flashings be corrosion-resistant and a minimum thickness of 0.019". The IRC also concurs with the IBC in that flashings must be installed in compliance with the roofing manufacturer's instructions.

Building departments follow these code requirements when reviewing permit applications but the volume of permit applications makes it impossible for them to review the details of the original roofing manufacturer instructions for every application. They also may not have the expertise to individually evaluate every solar roof attachment product available and whether the manufacturers of those products are using loose definitions of the word "flashing" in order to skirt around the codes. This leaves the building departments relying on the contractors performing the installation to adhere to the details of the code. In a competitive market like PV installation, contractors will often cut corners to save a few dollars on an easy-to-install product without regard for potential future issues.

Flashing Warranties, Requirements, and Best Practices

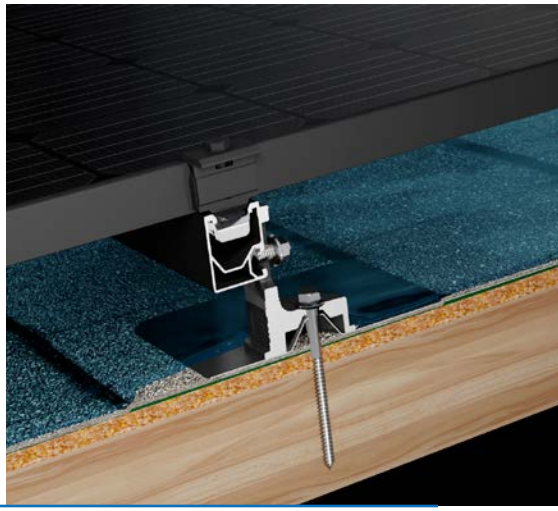
One of the top questions for many homeowners as well as PV installers should be: how does this affect the warranty of my roof? Considering that replacing or dealing with a leaky roof is likely one of the most expensive home repairs to make, it is a valid question. Ultimately, the continuation of the roof warranty will be decided by the roofing manufacturer. Major roofing manufacturers recognize the addition of PV systems as a growing occurrence and have addressed this in their documentation.

Maintaining Warranties Roofing manufacturers commonly include language in their warranty about not covering damage caused by solar panel installation. To properly maintain a roof's warranty, the installation must follow the manufacturer's guidelines. GAF, the largest roofing manufacturer in North America, has a technical bulletin[2] titled "Solar Installations & GAF Guaranteed Roofing Systems Guidelines for Maintaining/Obtaining Guarantee Coverage" available on their website. GAF requires drawings showing the specific installation details "including all flashing details that will be used to install the PV system."

Owens Corning, another leading roofing manufacturer, has issued a technical bulletin noting "the Owens Corning roof system is fully compatible with properly installed [PV] systems." The installation of a PV system can be done in a way to maintain warranties, provided the PV installation doesn't comprise the existing roofing system. Therefore, PV installers need to refer to original installation instructions to meet the manufacturer's requirements.

Roof penetrations that rely solely on caulking for waterproofing (left) are at much higher risk of infiltration over time.

Fully flashed roof penetrations (right) provide roofing industry accepted protection for the life of the roof.



Even when not specifically addressing solar installations, roofing warranties refer to following the installation instructions which require flashing at every juncture and penetration of the roof plane. The instructions also detail the installation of flashings between the underlayment and shingles which would exclude any solar roof attachments that sit on top of the shingles.

Testing Standards Most building departments follow less strict guidelines than the Energy Trust of Oregon or the roofing manufacturers association's recommendations. As plan reviewers are inundated with PV projects, their main focus on PV systems is electrical safety and if they do have time to evaluate and approve roof penetration flashings for solar on a case-by-case basis, they often rely on testing reports for the flashing products based on tests like the AC286 rain test and the TAS100 wind-driven rain test.

The effectiveness of these testing methods to determine if the roof attachment method will not leak for the 25-year life of the PV system is questionable. The roof attachment is installed on new roofing materials, in a lab environment, according to the manufacturer's instructions and the test begins as soon as the sealant has had time to cure. Some tests, including AC286, are only required to be conducted for one hour while other tests can go on for several hours or sometimes a few days. But even days of testing cannot prove the roof attachment will remain leak-free for 25 years, especially when the real-world installation is on aged roof with 10-year-old underlayment and shingles. The characteristics of the sealant will also change over time and as it becomes more brittle, small cracks can form that will allow water penetration at roof attachments that rely solely on sealant to prevent leaks.

The testing protocols do not even attempt to mimic thermo-cycling of cool or snowy nights followed by hot days, which can substantially accelerate the sealant's degradation compared to a lab environment. This trust in short-duration, perfect-condition testing of freshly installed equipment instead of adhering to industry-advised best practices leaves the consumer at risk to potentially expensive repairs.

Best Practice Guidelines Roofing associations like the National Roofing Contractors Association (NRCA) and the Asphalt Roofing Manufacturers Association (ARMA) created roofing guidelines that have been adopted by many in the solar industry. Membership-based organizations like these have a vested interest in the proper installation and care of the products they represent. When solar installations started to proliferate, these organizations wisely addressed the concerns of installing solar modules on new and existing roofs.

A Pegasus Comp Mount integrates into the roofing system. The flashing extends under the second course of shingles above the penetration and on top of the underlayment. The flashing extends below the penetration to protect against ice damming and wind-blown rain.

The NRCA[3] "Quality Control Guidelines for the Application of Asphalt Shingle Roofing Systems" lists criteria for penetration flashings including "Upslope end of the flashing flange extends a minimum of 2 inches under double shingle coverage." This would indicate that a metal flashing must not only be under the shingles above the penetration but that the upslope end must be long enough to reach the area where the next course of shingles is overlapped. This is consistent with solar industry best practices and manufacturers of flashed roof mounts within the solar industry.

The ARMA[4] "Asphalt Roofing Residential Manual Design and Application Methods" specifically addresses rooftop solar mounts saying they "should not be dependent on caulks and sealants to prevent water infiltration into the building" and "have flanges incorporated such that they can be shingled into the roof system in flashing procedures so that they properly shed water and wind driven rain events." These recommendations help roofers and solar installers identify best practices for long-term effectiveness for the installation of solar arrays.

The Energy Trust of Oregon (ETO) is another organization with a vested interest in the installation of PV systems. The ETO is an independent customer-focused nonprofit organization that helps businesses and homeowners convert to renewable energy. Funded by rate payers, the ETO acts as the guardians of spending money on renewable energy installations wisely so an emphasis is placed on system longevity and consumer protection. As part of this effort, they have weighed in on the best practices for making penetrations on shingled roofs for solar installations by strictly prohibiting roof attachments that do not include a metal flashing that slides under the shingles above the penetration to the point where the shingles overlap, as documented in the ETO's[5] "Solar Electric Installation Requirements." Roof attachments that are set on top of the shingles and rely heavily on sealants may hold up for the first few years, but they are a weak point in the roof's weatherproofing that will not likely last the full 25- to 30-year life of the PV modules.

Risks & Costs

PPV installations, like all construction trades, look for improving efficiencies and cutting costs wherever possible. Flashed roof attachments have comparable costs to their non-flashed counterparts. The idea that non-flashed footings save significant material costs does not add up. In fact, when considering the added cost of sealants, non-flashed solutions may have a higher material cost. Flashed penetrations will require additional installation time, so the "savings" for non-flashed roof attachments will be measured in minutes of installation time.

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The non-flashed products may be considered less difficult, so many installers use this as the justification for using these products. However, installing flashed roof attachments is not an overly complex process and can be incorporated with minimal training. The risks associated with using the non-flashed "easy" products should be a cause of concern for all involved in the installation process: homeowners, installers and financiers. The long-term effects from poorly installed PV systems can put the homeowner and any individual company at significant financial risk. Flashed roof penetrations are known as the standard practice in the roofing industry; bypassing that only exposes the installation companies and financiers to unnecessarily shoulder the heavy costs incurred by a roof leak and the potential water, rot and mold damage to the home.

References

1 CertainTeed Shingle Applicator's Manual: https://www.certainteed.com/resources/

2 Solar Installations & GAF Roofing Systems Guidelines for Maintaining/Obtaining Guarantee Coverage, https://www.gaf.com/

3 Quality Control Guidelines for the Application of Asphalt Shingle Roofing Systems, https://www.nrca.net/

4 Asphalt Roofing Residential Manual Design and Application Methods, https://www.asphaltroofing.org/

5 Solar Electric Installation Requirements, https://insider.energytrust.org/

6 *International Building Code (IBC)*, https://codes.iccsafe.org/content/IBC2021P1

7 *International Fire Code (IFC)*, https://codes.iccsafe.org/content/IRC2018P3