

Installation of Residential Corrugated Metal Roof Systems



FEMA

HURRICANES IRMA AND MARIA IN THE U.S. VIRGIN ISLANDS

Recovery Advisory 3, March 2018

Purpose and Intended Audience

The purpose of this Recovery Advisory is to recommend practices for installing corrugated metal roof systems that will enhance their wind and water leakage resistance in the U.S. Virgin Islands (USVI). This guidance is primarily intended for contractors; however, it provides helpful information for architects, engineers, homeowners, and building owners.

Key Issues

1. Prior to installation of a new roof system over an existing wood roof support structure, a wind vulnerability assessment should be performed to verify that the existing beams, joists, or trusses and their connections have adequate wind resistance. If the existing roof structure is not capable of resisting at least 75 percent of the wind loads derived from American Society of Civil Engineers Standard 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE 7-16, 2017) it is recommended that the deficient structural members and connections be replaced or strengthened to meet the ASCE 7-16 wind loads.¹
2. If existing wood sheathing occurs over the roof support structure, verify that the sheathing material, thickness, and attachment complies with the recommendations in this Recovery Advisory. If the attachment does not comply with the provided recommendations, additional fasteners should be installed as specified in this Recovery Advisory. If the sheathing material does not comply with these recommendations, it is recommended that the sheathing be removed and replaced with new plywood.
3. During construction, contractors should implement quality control and quality assurance procedures to ensure that the recommended installation criteria are met.

Repairing Wind Damaged Roofs on Public Facilities Using the FEMA Public Assistance (PA) Program

According to the *Public Assistance Program and Policy Guide* (FEMA PAPPG, 2018), additional grant funding may be available on eligible repairs to provide hazard mitigation against future events. For more information see PAPPG Appendix J, VIII. Buildings and Structures, H. Roofs.

Significant structural damage to the vertical load capacity or lateral force-resisting system may trigger Substantial Structural Damage (SSD) and would require building code upgrades.

For more information on SSD, visit <https://www.fema.gov/media-library/assets/documents/130384>.

The following recommendations are based on lessons learned from Hurricanes Marilyn (1995), Irma (2017), and Maria (2017), and on professional judgment. All photographs are from observations in the U.S. Virgin Islands following Hurricanes Irma and Maria.

This Recovery Advisory Addresses

- Existing roofs that were damaged by the 2017 hurricanes.
- Future reroofing.
- Roofs that will be installed on new buildings.

This Recovery Advisory addresses roof system components that are installed above a wood roof support structure (i.e., beams, joists, or trusses). It does not address the design or installation of the roof support structure. For information about attaching equipment to a roof, see U.S. Virgin Islands Recovery Advisory 2, *Attachment of Rooftop Equipment in High-Wind Regions* (FEMA, 2018).

¹ The 75 percent value is based on criteria in the 2018 *International Existing Building Code*.

Construction Mitigation Guidance

This section provides the following:

- Examples of corrugated metal roof assembly problems that were observed after the 2017 hurricanes
- Wind design criteria for roof systems
- Roof system installation details
- Criteria for outlet tubes and downspouts

Figure 1 illustrates a house where all or most of the roof support structure is still in place. For such conditions, prior to installation of a new roof system over the roof structure, a wind vulnerability assessment should be performed. If the support structure does not meet the conditions specified in Key Issue 1, deficient structural members and connections should be replaced or strengthened.



Figure 1. View of a temporary roof covering on a house that was damaged during the 2017 hurricanes.

Most of the roof structure blew off the house shown in Figure 2. The corrugated metal roof panels were screwed to 2 inch x 4 inch nailers. The nailers were placed over plywood sheathing. The nailers and plywood were attached with nails, which provide inadequate uplift resistance. Because so little of the roof structure is still in place (red oval at Figure 2), it is generally more economical to demolish the remaining roof structure rather than strengthen it. If the new roof system were to be placed over such a roof structure without strengthening it, the new roof system would be susceptible to future damage.



Figure 2. The roof structure was blown off most of this house during Hurricanes Irma and Maria.

Figure 3 shows an example where most of the roof structure blew off the house. The corrugated metal roof panels were screwed to 2 inch x 4 inch nailers. The nailers were placed over plywood sheathing. The nailers were attached to the beams with screws. However, the beams were inadequately connected to their supports. The blown-off roof structure traveled a substantial distance. Wind-borne debris such as this can injure people or damage other buildings or vehicles.



Figure 3. The roof structure was blown off most of this house during the 2017 hurricanes.

Several gutter blow-offs were also observed. All the damaged gutters were metal or plastic that were surface-mounted to the fascia (Figure 4). Blown-off gutters, like other wind-borne debris, can damage buildings and vehicles and injure people. Uncontrolled rain runoff from the eave exacerbates the potential for water entry at doors and windows. Also, when gutters blow off, cistern recharging is impaired or interrupted.

Numerous integral gutters that were constructed with 2 inch wood framing (similar to the recommended eave detail below) were observed; these appeared to have performed well.

At the house shown in Figure 4, the electrical service mast was mounted to a concrete pylon. The service was run underground from the pylon to the house. As discussed in Recovery Advisory 2, a detail such as this, versus extending the service mast through the roof, eliminates potential roof damage if the overhead power line collapses and pulls down the service mast.

Wind Design Criteria

Attachment of the plywood roof sheathing, nailers, and metal roof panels is based on the following wind load calculation criteria:

- ASCE 7-16, using a basic wind speed of 165 miles per hour (mph), a mean roof height of 30 feet, a roof slope between 2:12 and 12:12 for hip or gable roofs and a partially open internal pressure coefficient of 0.18 with a building width of 24 feet to 40 feet, and building length of 40 feet to 52 feet using a maximum overhang of 2 feet. Outlookers at gable end overhangs shall be positioned to be centered under nailers.²
- Attachment criteria are given for buildings located in exposures B and D that are not subjected to wind speed-up effects caused by abrupt changes in the general topography (as defined in ASCE 7).
- Attachment criteria are also given for buildings located in exposure B that are subjected to wind speed-up effects caused by abrupt changes in the general topography. A hill, ridge, or escarpment with less than 60 feet in elevation change for exposure B is not considered an abrupt change in topography and would not need to consider topographic effects. Given the variety of topography within the U.S. Virgin Island, an estimated topographic factor, K_{zt} , of 2 was utilized in determining the wind pressures for buildings built on the upper one-half of a hill, ridge, or escarpment or the crest of an escarpment.³
- If the exposure is D with topographic effects, calculations will need to be performed and appropriate attachment criteria determined. A hill, ridge, or escarpment with less than 15 feet in elevation change for exposure D is not considered an abrupt change in topography and would not need to consider topographic effects.



Figure 4. A portion of the surface-mounted gutter at this house blew off during the 2017 hurricanes (red arrow). The blue arrows indicate an electrical service mast mounted to a concrete pylon. The metal panel fastener heads were corroded.

Roof System Materials

The following materials are recommended. The attachment criteria below are based on these materials:

- Exposed fastener corrugated metal roof panel: ASTM A 792 Grade 50-B (aluminum zinc alloy), 24-gauge minimum. $\frac{7}{8}$ inch ribs at $2\frac{2}{3}$ inches on center (o.c.). Continuous length from eave to ridge/hip. Factory-applied coating is optional.
- Pre-fabricated foam closures and sealant tape at panel eaves and ridge/hips. Sealant tape at overlaps.
- Hip, ridge and rake flashings: Same material type and gauge as the roof panels.
- Metal panel and flashing fasteners: #14 x $2\frac{1}{2}$ inches Long Stainless Steel Self-Drilling Roofing Screw and minimum $\frac{1}{2}$ inch diameter gasketed washer for attaching to nailers, (see metal roof panel fastener spacing listed in Table 1). Metal roof panel fasteners to be 1 inch long for stitching panel side laps and attaching hip and ridge flashings.
- All pressure treated wood used under the metal roofing to have Use Category of UC3A for aboveground installation shall be manufactured in accordance with the American Wood Protection Association (AWPA) requirement (AWPA U1-17, 2017).
- Pressure treated 2 inch x 4 inch wood nailers of the following species: #1 Southern Pine, #2 Southern Pine, #1 Douglas Fir, or #2 Douglas Fir.

² Houses which fall outside of these plan dimensions must have the roof plywood checked by a design professional because the diaphragm forces may alter the design.

³ Special attention should be paid to homes located near the crest of an escarpment at plateau-like areas where the home is located within two times the height of an escarpment.

- Spacers between nailers and underlayment: Preservative treated wood, approximately 3 1/2 inches x 3 1/2 inches x 1/4 inch thick positioned at each 2 inch x 4 inch fastener location.
- Wood nailer fasteners: See nailer fasteners listed in Table 1.
- Insulation between nailers is optional. If installed, 1 1/2 inch thick expanded molded polystyrene or extruded polystyrene, loose-laid.
- Underlayment: The recommended option is self-adhering modified bitumen, complying with ASTM D 1970, that is intended for use underneath metal roof panels.
A more economical but less reliable underlayment material is ASTM D 226 Type II (#30) or ASTM D 4869 Type IV felt. A two-layer application is recommended where the roof slope is less than 4:12. Prior to installation of the felt, it is recommended that the plywood sheathing joints be taped with self-adhering modified bitumen tape (4 inches wide, minimum). Roll tape with a roller. Do not install tape where the liquid-applied membrane will be installed.
- Plywood: See sheathing listed in Table 1 for size, textured side down. Plywood strength axis applied perpendicular to rafters/roof joists which are at 2 feet maximum on center. For existing conditions in which rafters/roof joists are spaced more than 2 feet on center, consult a registered professional structural engineer or licensed architect for a specific design. It is likely that additional rafters/roof joists will need to be added.
- Plywood fasteners: See sheathing fasteners listed in Table 1.

Roof System Installation Details

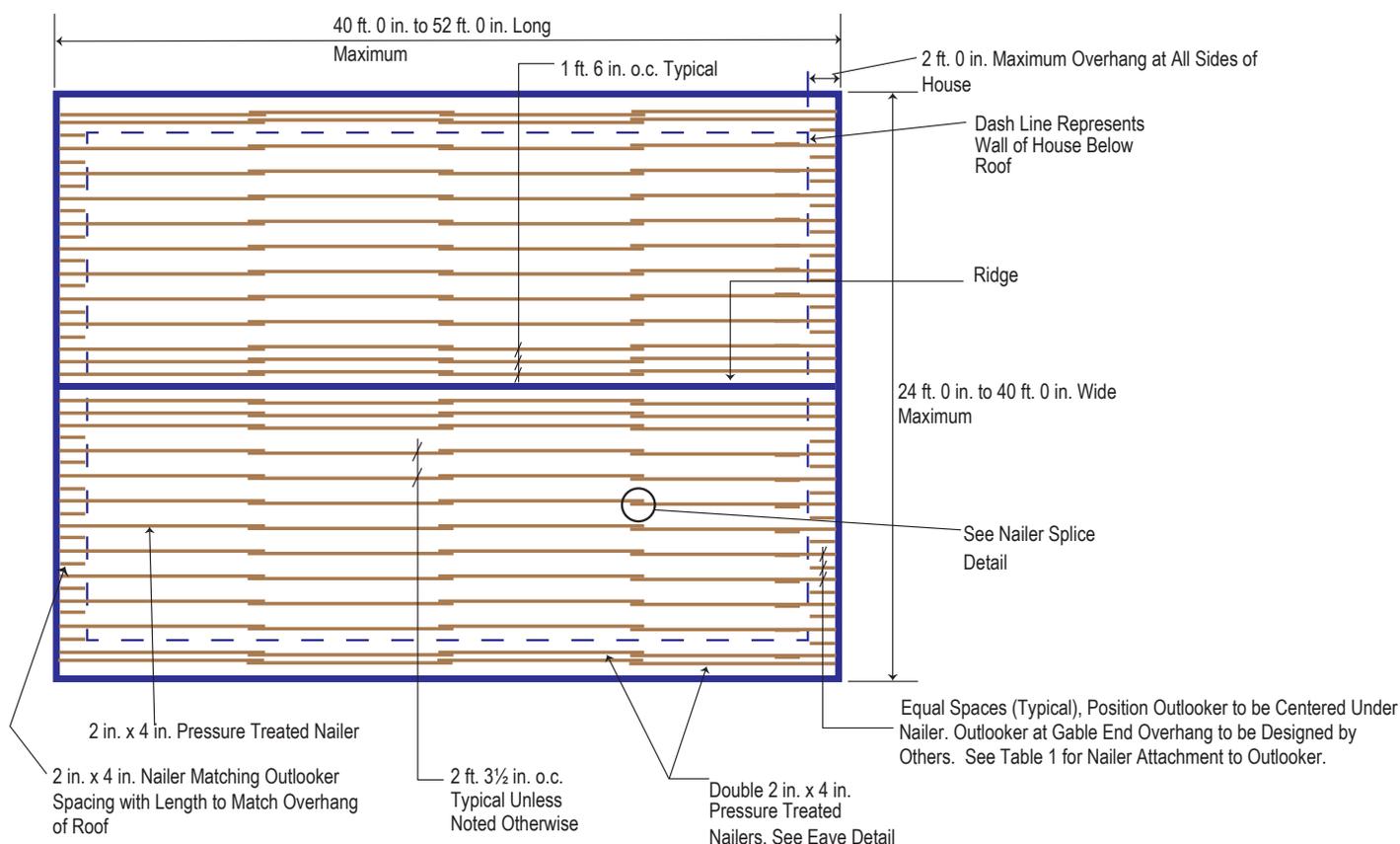


Figure 5. Roof Nailer Installation: Gable Roof Plan. Note, roof nailer splices are to be offset from each other in a staggered pattern to allow the nailer to span over the supporting roof beam by 3 inches minimum.

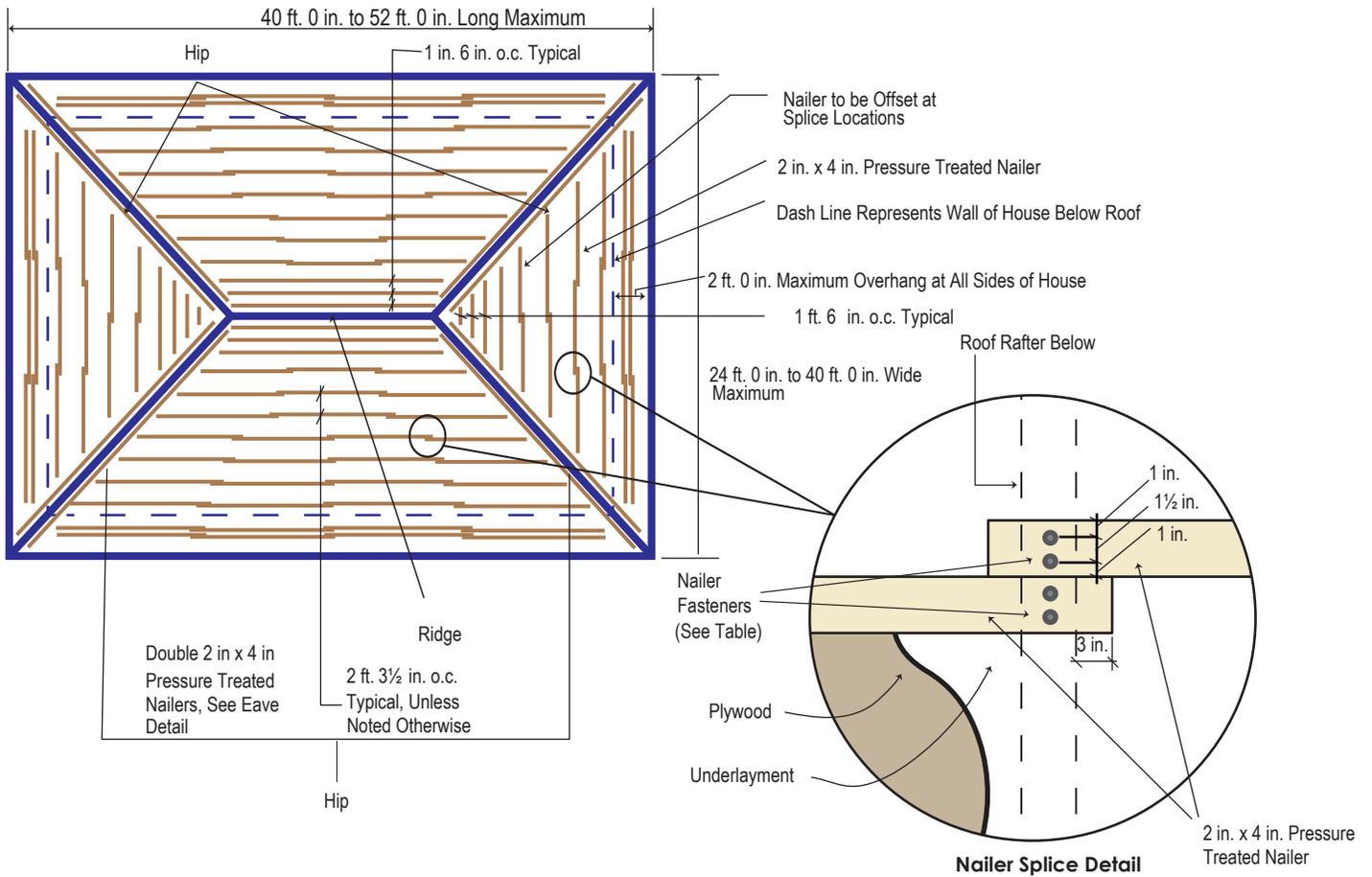


Figure 6. Roof Nailer Installation: Hip Roof Plan. Note, roof nailer splices to be offset from each other in a staggered pattern to allow nailer to span over supporting roof beam by 3 inches minimum.



View of Staggered Metal Panel Fasteners at Eave.

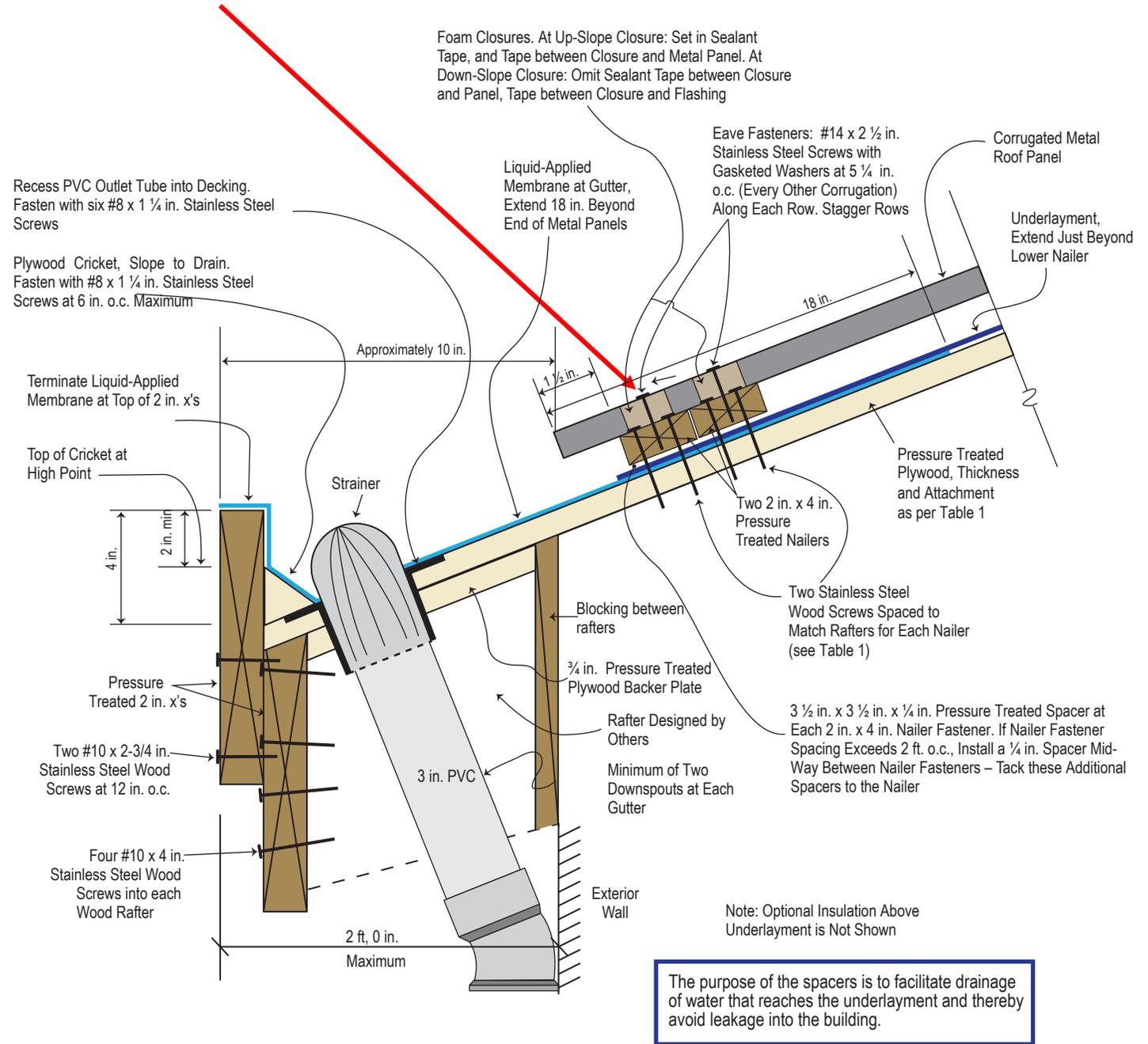


Figure 7. Eave Detail

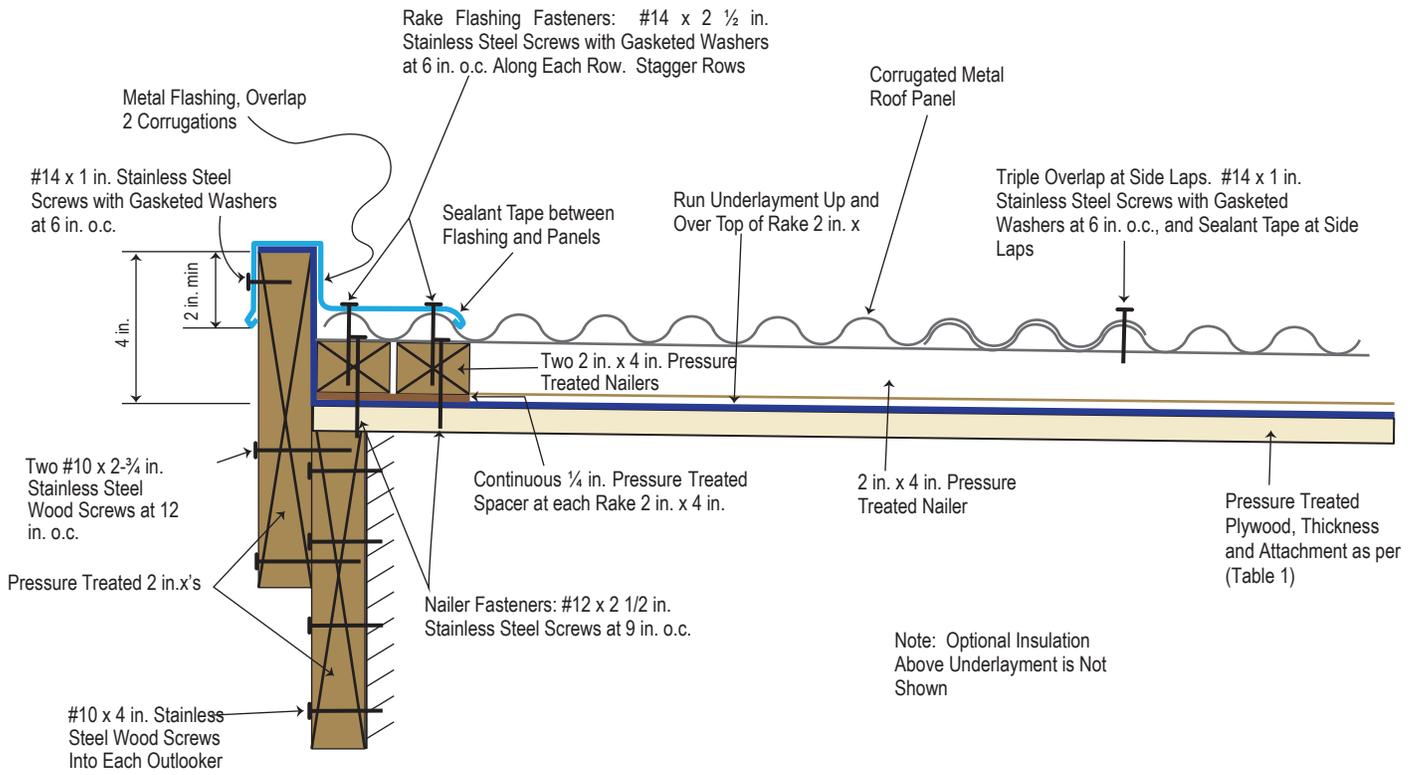
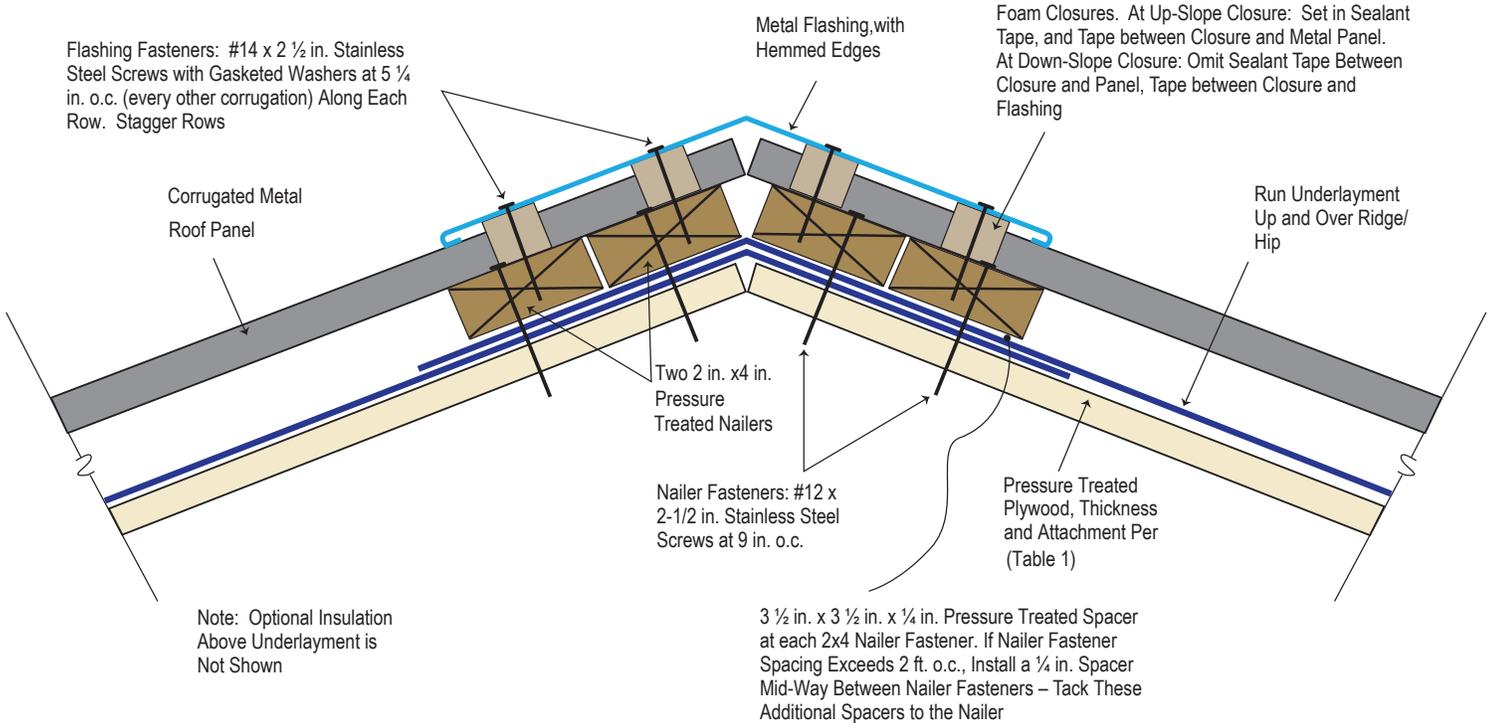


Figure 8. Rake Detail



The Purpose of the Spacers is to Facilitate Drainage of Water that Reaches the Underlayment and Thereby Avoid Leakage Into the Building.

Figure 9. Ridge Detail (Hip Similar)

Table 1. 2018 International Code Comparison to Recovery Advisory Recommendation

Roof Component Designs	Exposure B on Upper Half of a Hill, Ridge, or Escarpment or Near the Crest of an Escarpment	Exposure B	Exposure D
Metal Roof Panel Fastener Spacing along Nailers	5 1/3 in. o.c. (Every other corrugation)	10 2/3 in. o.c. (Every 4th corrugation)	8 in. o.c. (Every 3rd corrugation)
Nailer Spacing	See Roof Plans	See Roof Plans	See Roof Plans
Nailer Fasteners into Outlookers at Overhangs	#14 x 5 in. Long Stainless Steel Wood Screw @ 6 in. o.c.	#12 x 4 1/2 in. Long Stainless Steel Wood Screw @ 12 in. o.c.	#14 x 5 in. Long Stainless Steel Wood Screw @ 6 inches o.c.
Nailer Fasteners at All Other Areas at each Rafter Intersection	Two #14 x 5 in. Long Stainless Steel Wood Screws	Two #12 x 4 1/2 in. Long Stainless Steel Wood Screws	Two #14 x 5 in. Long Stainless Steel Wood Screws
Blocking for Sheathing	Blocking shall be installed under the unsupported edges of all roof sheathing which has a liquid-applied membrane	Blocking shall be installed under the unsupported edges of all roof sheathing which has a liquid-applied membrane	Blocking shall be installed under the unsupported edges of all roof sheathing which has a liquid-applied membrane
Sheathing Size: Thickness may be decreased by 1/8 in. if textured plywood is replaced with regular plywood. However minimum thickness shall not be less than 5/8 in.	Structural 1 Type 7/8 in. Textured Plywood (Pressure Treated) with 48/24 Span Rating	Structural 1 Type 23/32 in. Textured Plywood (Pressure Treated) with 32/16 Span Rating	Structural 1 Type 3/4 in. Textured Plywood (Pressure Treated) with 40/20 Span Rating
Sheathing Fasteners	Use #14 x 3 1/2 in. Long Stainless Steel Wood Screws at 3 in. o.c. at all Support Members	Use #12 x 3 inches Long Stainless Steel Wood Screws at 5 in. o.c. at all Support Members	Use #14 x 3 1/2 in. Long Stainless Steel Wood Screws at 3 in. o.c. at all Support Members

Note: guidance is based upon rafters/roof joists which are at 2 feet maximum on center. For existing conditions in which rafters/roof joists are spaced more than 2 feet on center, consult a U.S. Virgin Islands registered professional structural engineer or U.S. Virgin Islands licensed architect for a specific design. It is likely that additional rafters/roof joists will need to be added.

References and Resources

References

American Society of Civil Engineers (ASCE). 2017. *Minimum design loads and associated criteria for buildings and other structures*. ASCE/SEI 7-16. <https://www.asce.org/structural-engineering/asce-7-and-sei-standards/>.

American Wood Council (AWC). 2018. *WFCM: wood frame construction manual for one- and two-family dwellings*. <http://www.awc.org/codes-standards/publications/wfcm-2018>.

International Code Council (ICC). 2018a. *2018 IBC: International Building Code*. <https://codes.iccsafe.org/public/document/IBC2018>.

International Code Council (ICC). 2018b. *2018 IEBC: International Existing Building Code*. <https://codes.iccsafe.org/public/document/IEBC2018>.

International Code Council (ICC). 2018c. *2018 IRC: International Residential Code*. <https://codes.iccsafe.org/public/document/IRC2018>.

American Wood Protection Association (AWPA). 2017. *Use Category System: User Specification for Treated Wood*. AWPA U1-17.

Resources

U.S. Virgin Islands Department of Natural Resources. 2018. *Construction Information for a Stronger Home, 4th Edition*. (Expected date of publication March, 2018)

FEMA. 2018. *FEMA U.S. Virgin Islands*. FEMA U.S. Virgin Islands Recovery Facebook Page. <https://www.facebook.com/FEMAUSVirginIslands>. This page was created for the Hurricanes Irma and Maria recovery process and is regularly updated with useful information.

For more information, see the FEMA Building Science Frequently Asked Questions Web site at <https://www.fema.gov/frequently-asked-questions-building-science>.

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