The NRCA Roofing and Waterproofing Manual

Fifth Edition

Includes 2003 Update

The vertical line in the margin indicates an addition or change(s) in the text since *The NRCA Roofing and Waterproofing Manual, Fifth Edition*, was originally printed in 2001.

Includes 2003 Update

First Printing 2001

NATIONAL ROOFING CONTRACTORS ASSOCIATION

Published by the National Roofing Contractors Association
10255 W. Higgins Road, Suite 600, Rosemont, Il. 60018-5607

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ASPHALT SHINGLE ROOF SYSTEMS

Nails should be driven straight, flush and snug to the surface of asphalt shingles.

The nailing of hips, ridges and some roof accessories may require the use of longer nails because fasteners must penetrate through more layers of roofing and/or material.

For full-width shingles, a minimum of four nails should be used per shingle. See Figure 7.

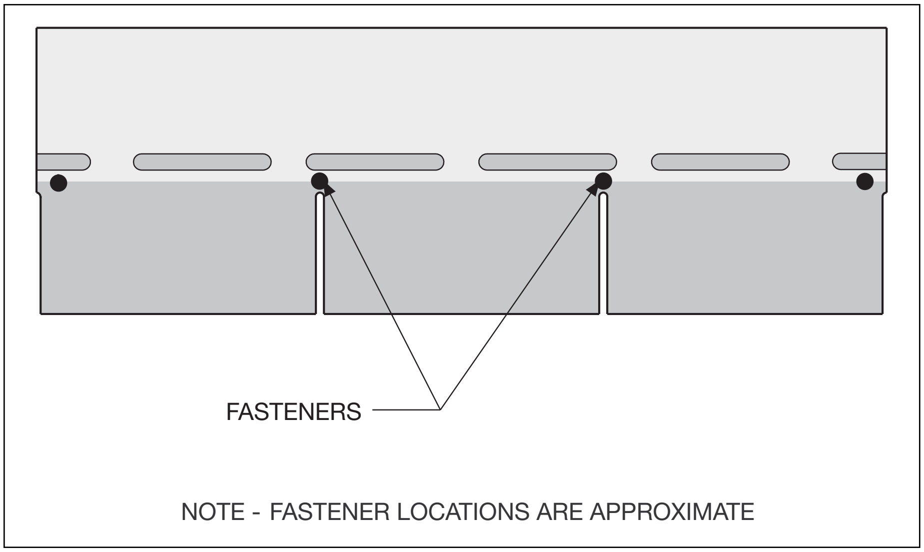


Figure 7: Approximate fastener locations for four-nail pattern

Six nails per full-width strip shingle may be required by building codes in some high-wind areas. See Figure 8.

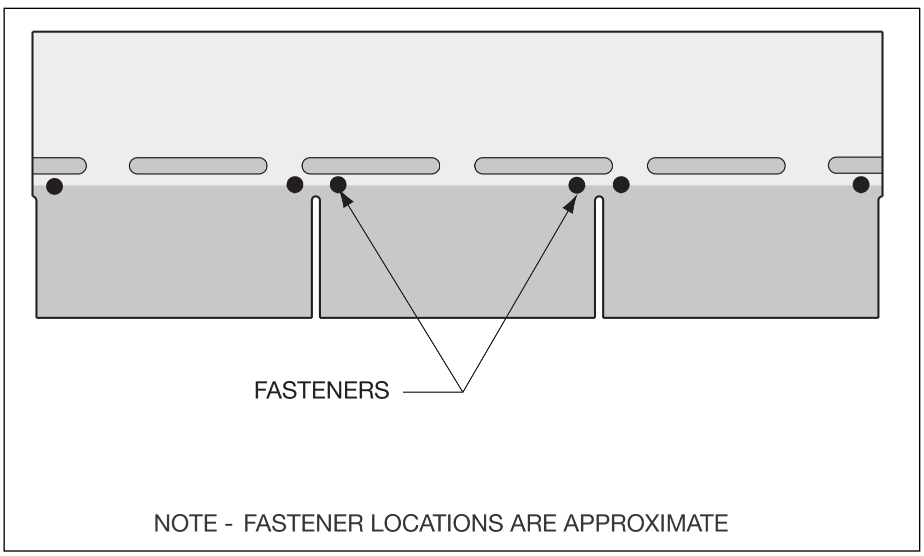


Figure 8: Approximate fastener locations for a six-nail pattern

For roof slopes 18:12 (56 degrees) and greater, NRCA recommends that asphalt shingles be fastened with six nails and manually sealed with asphalt flashing cement. The latter process is commonly known as “hand tabbing.” Some manufacturers require six nails per shingle and hand tabbing on slopes as low as 12:12 (45 degrees) depending on the shingle product. Consult manufacturers for specific product requirements.

For individual shingles, a minimum of two nails should be used per shingle.

The locations for asphalt shingle fasteners as shown in Figures 7 and 8 and manufacturers’ printed installation instructions should be recognized as the approximate locations where attachment is intended. Actual consistent fastener placement in the exact locations depicted is not possible in the application of asphalt shingles under normal rooftop conditions. The application of asphalt shingles in a rooftop environment is not an exact process and minor deviations from the intended fastener locations should be anticipated and tolerated.

3.5 Exposure and Appearance

Starter courses for asphalt shingles are consistent for each shape or style of shingle. Typical exposure for standard size strip shingles is 5 inches (125 mm) and for metric size strip shingles is 5 ⅝ inches (143 mm). The offset patterns illustrated only apply to three-tab shingles. Laminated strip shingles vary in style and appearance and each manufacturer's installation guidelines should be consulted for specific exposure and offset instructions.

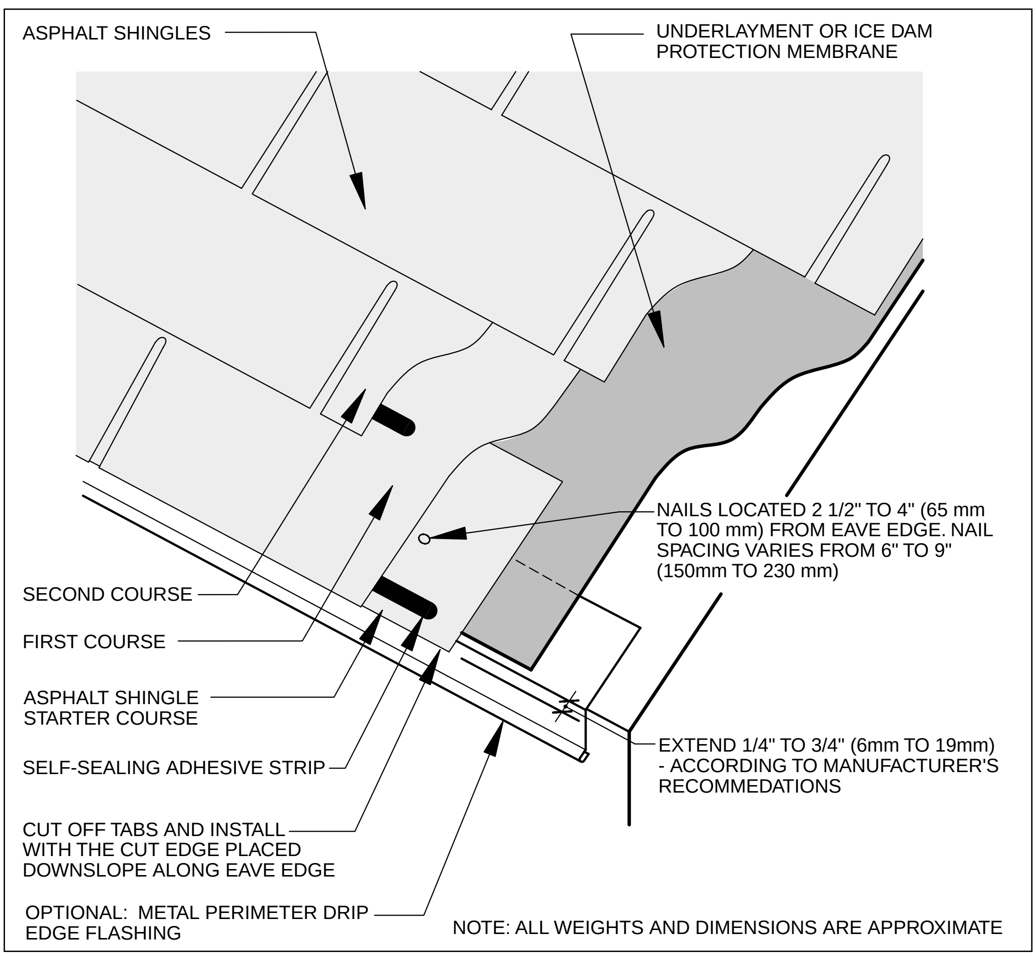
3.5.1 Starter Courses

Before the first course of shingles is installed, a starter course is applied directly over the underlayment or ice dam protection membrane along the eave of a roof system. Its primary purpose is to shed water that may migrate through the joints and cut-outs of the shingles in the overlying first course.

NRCA suggests using self-sealing asphalt shingles for starter courses. To prepare the starter course consisting of self-sealing shingles, cut the exposed tab portion off of enough shingles to accommodate the total length of the downslope perimeter roof edge (e.g., eaves). Then, cut approximately 3 to 6 inches (76 to 152 mm) off the end of the first shingle. (See Figure 17.) Alternatively, a 9 inch (229 mm) or wider starter strip of mineral-surfaced asphalt roll roofing material may be applied along the downslope edges of the roof to serve as a starter course.

The lower edge or edges of the roofing material should be even with the outer edge of the perimeter metal flashing if extended drip edge flashing is used. (See Figure 8A.) If an "L"-type metal flashing or no flashing is used, extend the starter course beyond the perimeter eave and rake edges ¼ to ¾ inch (6 to 19 mm), according to the manufacturer's recommendations, to assist in directing runoff away from the fascia board and other underlying building components. Fasten the starter course with roofing nails along a line that is parallel to and 2½ to 4 inches (65 to 100 mm) above the downslope perimeter edges of the roof. Place the nails in such a way that the nail heads will not be exposed through the overlying shingle's cutouts or at butt joints between individual shingles that make up the first course.

Figure 8A: Example of a starter course of asphalt shingles



3.5.2 Offset Patterns

There are several offset or side-lap gauge patterns used with three-tab shingles, and the pattern used generally is selected based on manufacturer or installer preference, regional or climatic experience, or common practice. However, there are three general pattern variations that are common for the application of square-butt, three-tab strip shingles.

Following are descriptions of these three patterns.

- Cutouts that break joints on thirds, or the 4-inch method — A cutout is the section of a three-tab asphalt shingle that has been cut out at a factory to separate individual tabs. For standard size shingles, the offset pattern is achieved by offsetting the consecutive shingle courses by 4 inches (100 mm) as shown in Figure 9. For metric-sized shingles, the offset pattern is achieved by offsetting each consecutive course 112 mm (4⅜ inches) . Cutouts are also referred to as key-way or water-slots. However, it is the gauging of these cutouts in neighboring shingle courses that gives a shingle roof system a particular pattern. See Figure 9.

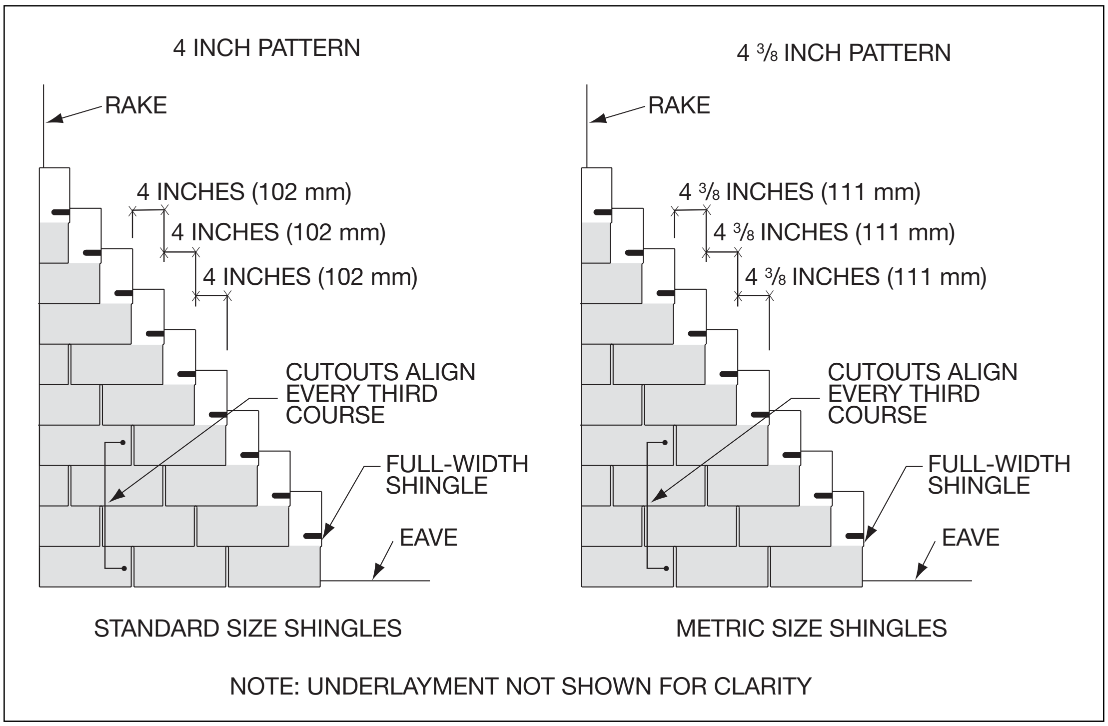


Figure 9: Example of aesthetics of a 4-inch pattern

- 5- and 5⅝-inch methods — A more random visual affect of a finished roof system can be achieved by offsetting cutouts in neighboring courses. For standard-sized shingles, the offset pattern is usually accomplished by removing approximately 5 inches (125 mm) from each consecutive course (after the first full-width shingle in the first course). For metric-sized shingles, this offset pattern is achieved by offsetting each consecutive course 143 mm (5⅝ inches) as shown in Figure 10.

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SLATE ROOFING

Standard-sized slate is fastened with two nails. All roofing slate should have a minimum of two nails. However, slate that is subject to high-wind conditions and/or ¾ inch (19 mm) and thicker should be fastened with four nails.

Holes are punched from ¼ inch to ⅓ inch (6 mm to 8 mm) the length of the slate from the upper end, and 1¼ inches to 2 inches (32 mm to 50 mm) in from the edges. Where four holes are used, it is typical to punch two additional holes approximately 2 inches (50 mm) above the two regular holes.

When attaching slates, nails should not be driven tight against the slate as if to draw the slate tight to the deck. Slating nails should be driven so that a nail's head just touches the surface of the slate so the slate hangs on the nail. See Figure 8.

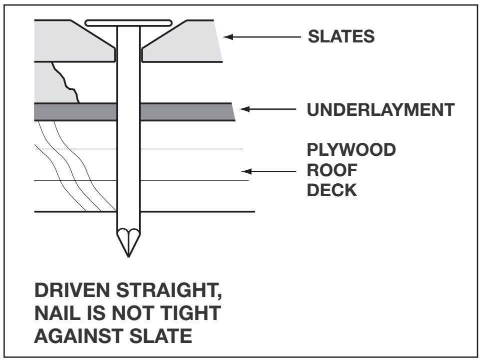

Figure 8: Example of proper nailing of slates

In high-wind areas, a 1 inch (25 mm) dab of flashing-grade roof cement, roofer's cement or polyurethane sealant placed under the exposed part of the slate near the leading edge can help secure it.

Other methods of attaching/affixing slate in certain situations are with slating hooks and wire tie systems.

3.5 Exposure and Appearance

The exposure of slate is the portion of the slate shingle that is not covered by the course above and is, therefore, the length of the slate roofing unit exposed to the weather. The proper exposure for a particular length of slate is obtained by deducting the 3 inch (76 mm) headlap from the total length of the slate then dividing that number by two. For instance, the proper exposure for a 24 inch (610 mm) slate is:

24 inches - 3 inches = 21 inches; 21 inches ÷ 2 = 10½ inches
(600 mm - 75 mm = 525 mm ÷ 2 mm = 263 mm)

Table 4 shows the proper exposures for various lengths of slate if all are to be set with a 3 inch (76 mm) headlap.

Length of Slate	Slate Exposure
24" (610 mm)	10½" (265 mm)
22" (560 mm)	9½" (240 mm)
20" (510 mm)	8½" (215 mm)
18" (460 mm)	7½" (190 mm)
16" (410 mm)	6½" (165 mm)
14" (360 mm)	5½" (140 mm)
12" (300 mm)	4½" (115 mm)
10" (250 mm)	3½" (90 mm)

Table 4: Slate exposures with a 3 inch (75 mm) headlap.

Slate can be installed to graduate by thickness and/or size. Thicker and/or longer slates are laid at eaves graduating to the thinner or smallest size at ridges. A typical graduation by thickness is ½ inch (13 mm) to ⅜ inch (10 mm) to ¼ inch (6 mm). A typical graduation by size is 20 inches (500 mm) to 18 inches (450 mm) to 16 inches (400 mm) to 14 inches (350 mm).

When multiple colors are used, the percentage of each color to be used throughout the roof system should be specified. An example is 40 percent unfading green, 40 percent weathering green and 20 percent purple. With regard to weathering slates, some quarries can reasonably predict the percent and intensity of color change from the base color to weathered color.

3.6 Starter Course

Before the first course of slate is installed, a row of starter slates is applied along the eave of a roof system to serve as the starter course. The starter course's primary purpose is to shed water that may migrate through the joints of the slates in the overlying first course.

The lower edge of the starter course should extend beyond the downslope perimeter (eave) approximately 2 inches (50 mm) to assist in directing runoff away from the fascia board and other underlying building components. When gutters or eave troughs are used, the overhang may be reduced to approximately 1 inch (25 mm) or less. Slates should be installed to extend approximately 1 inch to 2 inches (25 mm to 50 mm) beyond the rake edge.

Starter slates may be applied face down. This allows the smooth backs of the starter course and first course of slate contact each other.

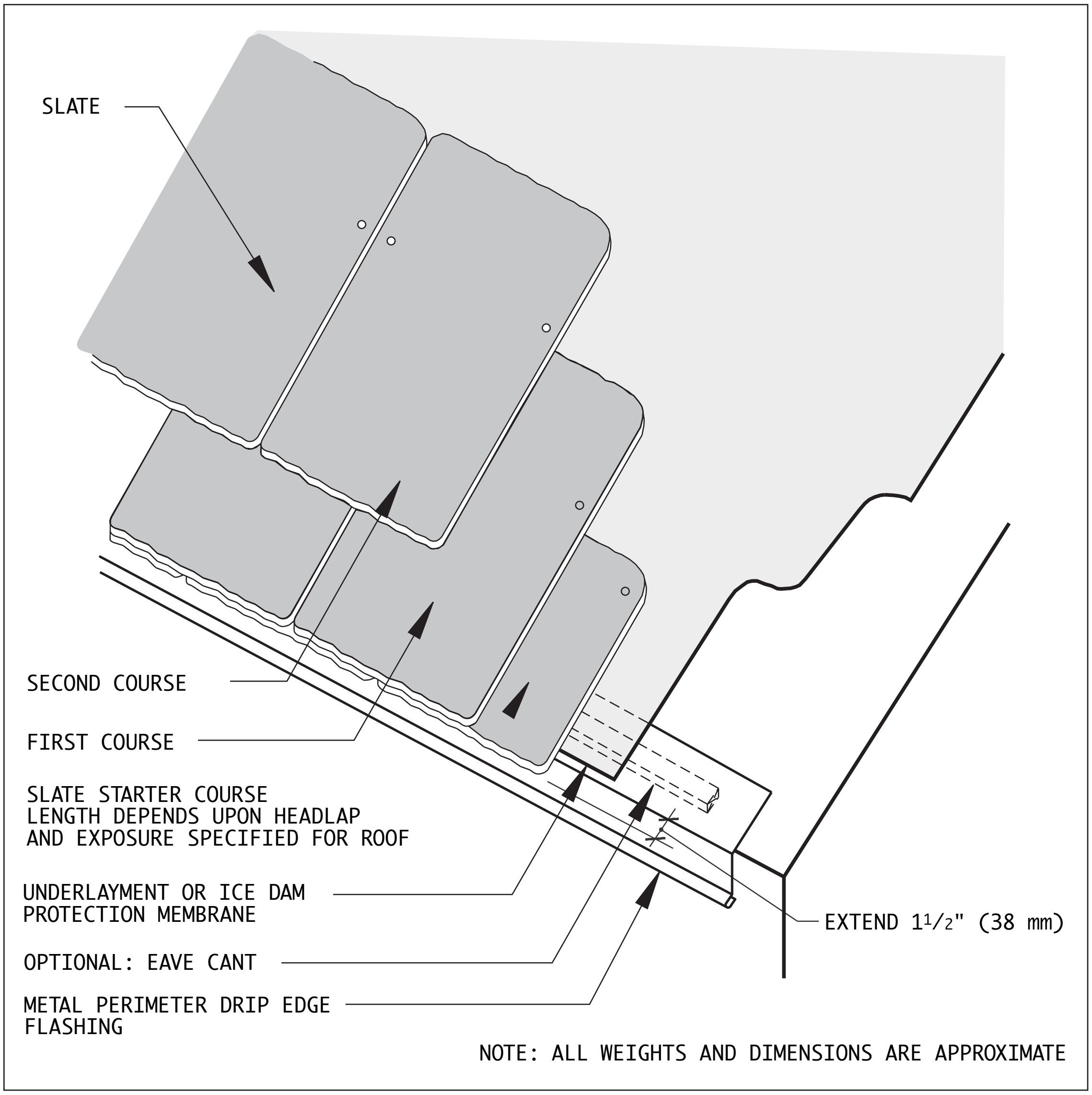

Figure 8A: Example of a starter course of slate.

3.6.1 Eave Cant

An eave cant is necessary to raise the butt edge of a starter and first course of slate the same way the headlap or third layer of slate raises the butt edge of all succeeding courses. The thickness of the eave cant should be about the thickness of the eave slates. A traditional eave cant is a wood lath ¼ inch (6 mm) thick and 2 inches (50 mm) wide. It is nailed to a deck and covered with eave flashing metal and underlayments. Beveled boards and raised metal eave flashings are also used.

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3.7 Flashings

Because steep-slope roof systems are frequently interrupted by the intersection of adjoining roof sections; adjacent walls; or penetrations, such as chimneys and plumbing soil-pipe stacks, all of which create opportunities for leakage, special provisions for weather protection must be made at these locations. These components used to control water entry are commonly called flashings. Careful attention to flashing details is essential to successful long-term roof performance regardless of the type of roof construction.

Flashings in this section are divided into the following categories:

- perimeter/edge metal
- penetrations
- valleys
- vertical surfaces

Flashing metals should be made from a material of thick enough gauge to achieve at least the expected design life of the steep-slope roof covering used with it.

3.7.1 Perimeter Edge Metal

Depending on the severity of the climate, anticipated rainfall and freeze-thaw cycling, the use of perimeter edge metal should be considered.

Where climate or roof edge construction dictates the need for perimeter edge metal, the type and minimum thickness of the metal should be commensurate with the anticipated service life for the slate roof system. NRCA suggests metal penetration flashings for slate roof systems be fabricated from one of the following metal types and minimum thicknesses.

- 24 gauge (0.025 inch [0.64 mm] thick) prefinished galvanized steel
- 24 gauge (0.024 inch [0.61 mm] thick) stainless steel
- 16 ounce (0.022 inch [0.56 mm] thick) copper
- 16 ounce (0.026 inch [0.66 mm] thick) lead-coated copper

In some regions, particularly those with mild climates, other types of metal and/or metals of lesser thickness than are shown above may be used successfully. NRCA considers these applications to be area practices. Refer to the Introduction for additional information about area practices.

WOOD ROOFING

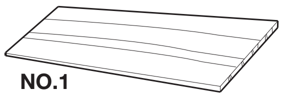
SHINGLE COVERAGE										
SHINGLES	LENGTH OF NO. 1 SHINGLES	APPROXIMATE COVERAGE IN SQ. FT. (m^2) OF ONE SQUARE (4 BUNDLES) OF SHINGLES BASED ON FOLLOWING WEATHER EXPOSURES								
		3 1/2" (89 mm)	4" (102 mm)	4 1/2" (115 mm)	5" (127 mm)	5 1/2" (140 mm)	6" (152 mm)	6 1/2" (165 mm)	7" (178 mm)	7 1/2" (191 mm)
 NO.1	16" (410 mm)	70 (6.5)	80 (7.4)	90 (8.4)	100* (9.3)	—	—	—	—	—
	18" (460 mm)	—	72.5 (6.7)	81.5 (7.6)	90.5 (8.4)	100* (9.34)	—	—	—	—
	24" (610 mm)	—	—	—	—	73.5 (6.8)	80 (7.4)	86.5 (8.0)	93 (8.6)	100* (9.3)
	* MAXIMUM EXPOSURE RECOMMENDED FOR ROOFS									

Table 4: Shingle coverage and exposure table

3.5 Starter Courses and Architectural Patterns

Wood shakes and wood shingles use a starter course on the downslope (eave) edge of a roof area in a single or double layer to satisfy the requirement for double or triple coverage in the roof's field. The first full course is generally set even with the starter course edge, and the architectural pattern of the field is built with succeeding courses. Before the first course of wood shakes or wood shingles is installed, a starter course is applied directly over the underlayment or ice dam protection membrane along the eave of the roof system.

3.5.1 Starter Courses for Wood Shakes

In order for a shake roof system to be two or three layers thick (whichever is specified) at all locations, including the downslope portion of the roof, a starter course is necessary. Generally, if the length of the shakes and the exposure specified will provide for a two-layer-thick wood roof, then the starter course may contain only one layer. If the length of the shakes and the exposure specified will provide for a three-layer-thick wood roof, then the starter course should contain two layers. The starter course is applied directly over the underlayment or ice-dam protection membrane along the downslope edge of the roof. In addition to providing longevity to the finished roof, the primary purpose of the starter course is to shed water that may migrate through the gaps or joints between the shakes in the overlying first course.

Generally, the starter course consists of 15 to 24 inch (380 to 610 mm) wood shakes or shingles as the exposure specified for the project allows. The shakes in the starter course should be laid so that the butt ends extend a minimum of 1½ inches (38 mm) beyond the finished fascia board or outer sheathing board edge (if there is no fascia). When gutters or eave troughs are used, the overhang may be reduced to approximately 1 inch (25 mm). Shakes should be laid to extend a minimum of 1 inch (25 mm) beyond the rake or gable edge.

Space the individual starter units approximately ¼ to ½ inch (6 to 13 mm) apart, and fasten each unit with two fasteners. Place the nails approximately 1½ inches (38 mm) above the exposure and approximately ¾ to 1 inch (19 to 25 mm) from the sides. If the starter course consists of two layers, offset the joints between neighboring shakes in the adjacent courses a minimum of 1½ inches (38 mm).

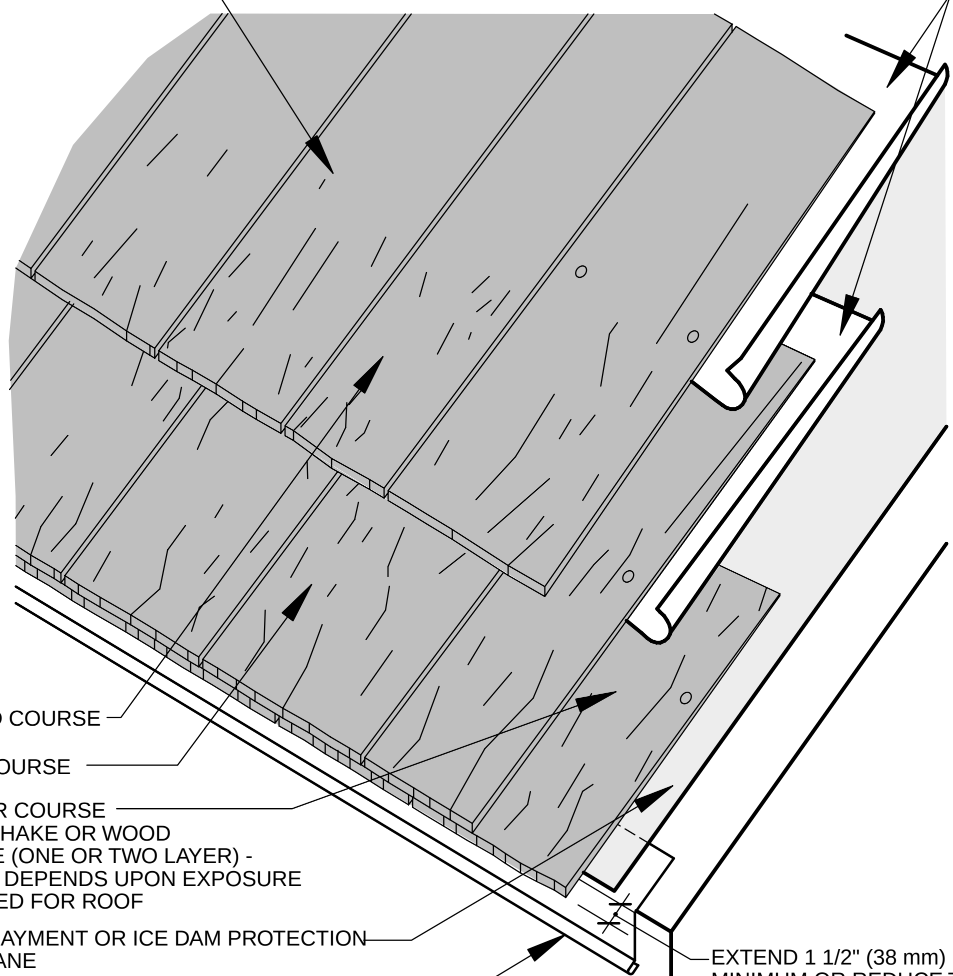


Figure 4A: Example of a one-layer starter course for wood shakes

3.5.2 Starter Courses for Wood Shingles

In order for the shingle roof system to be three layers thick at all locations, including the downslope portion of the roof, a double-layer starter course should be used. If the length of the shingles and the exposure specified will provide for a three-layer-thick wood roof, then the starter course should contain two layers. However, in many areas of the country it is common to use only a single-layer starter course. The starter course is applied directly over the underlayment or ice dam protection membrane along the downslope edge of the roof. In addition to providing longevity to the finished roof, the primary purpose of the starter course is to shed water that may migrate through the gaps or joints between the shingles in the overlying first course.

Generally, the starter course may consist of 15 to 18 inch (380 to 457 mm) wood shingles as the exposure specified for the project allows. The shingles in the starter course should be laid so that the butt ends extend a minimum of 1½ inches (38 mm) beyond the finished fascia board or outer sheathing board edge (if there is no fascia). When gutters or eaves troughs are used, the overhang may be reduced to approximately 1 inch (25 mm). Wood shingles should be laid to extend a minimum of 1 inch (25 mm) beyond the rake or gable edge.

Space the individual starter units approximately ¼ to ⅜ inch (6 to 9 mm) apart, and fasten each unit with two fasteners. Place the nails approximately ¾ to 1 inch (19 to 25 mm) from the sides. The starter course consists of two layers, offset the joints between neighboring shingles in the adjacent courses a minimum of 1½ inches (38 mm).

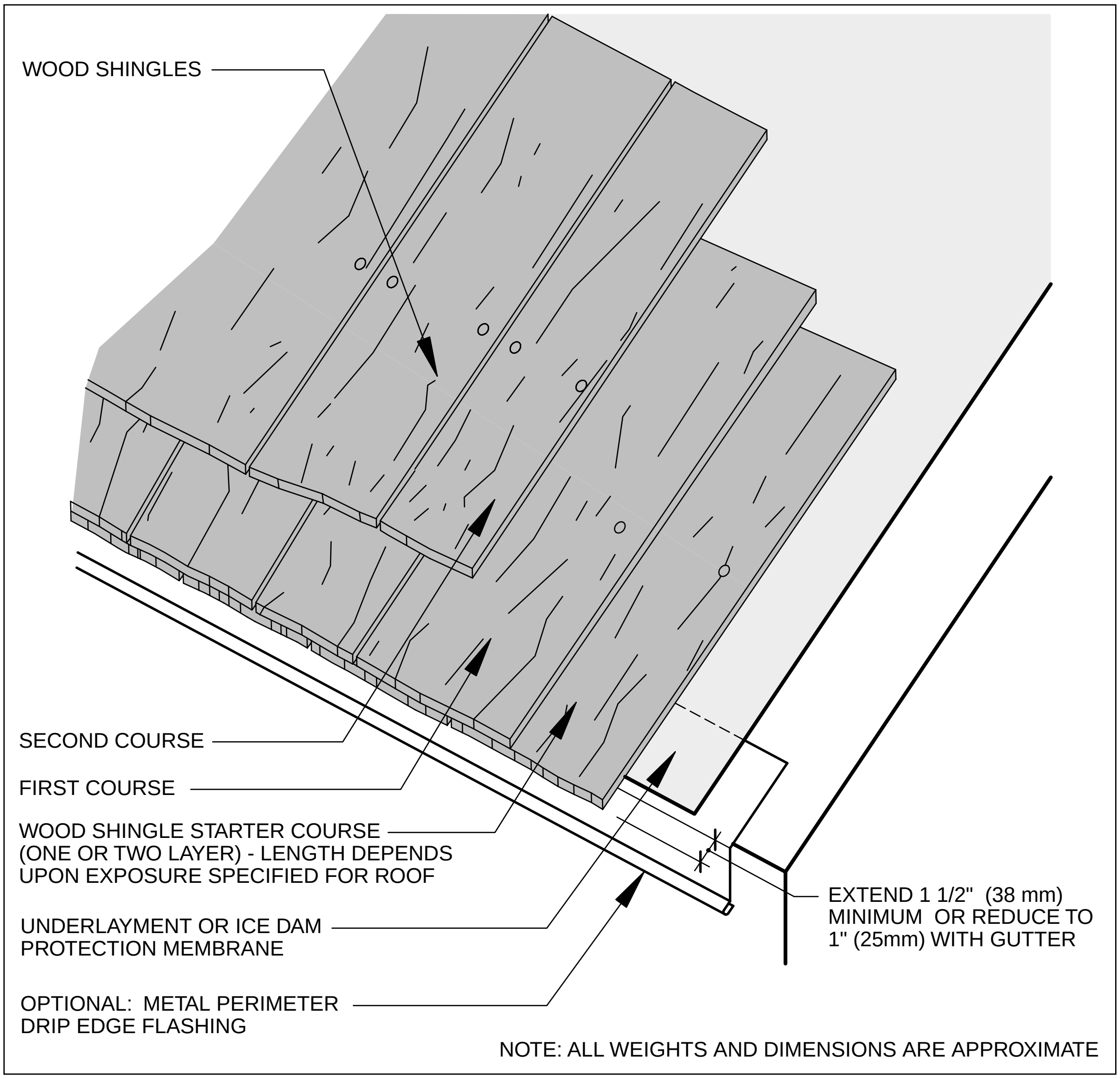


Figure 4B: Example of a starter course for wood shingles.

3.5.3 Architectural Patterns

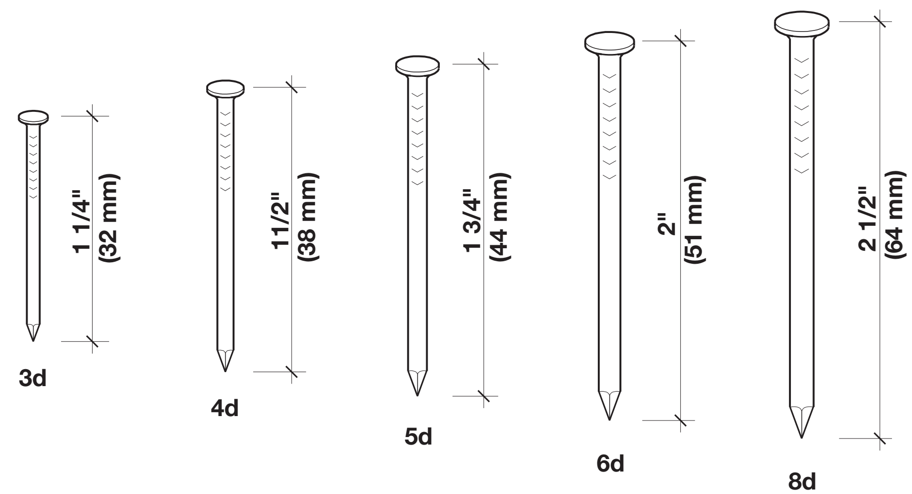
Wood roofing can be applied in a variety of patterns. The most common pattern of wood roofing application is a single straight-line course method. With a straight-line course application, the butt ends of the shakes or shingles are generally in straight alignment across any course in the field of the roof.

Other unique architectural patterns that are capable with wood roofing include:

- random pattern — the butt ends of adjacent shingles or shakes are installed offset, or staggered
- ribbon coursing — certain courses of shingles or shakes are double- or triple-layered to create strong horizontal lines in specified locations
- wave pattern — the courses, exposures and butts ends of the wood shingles are varied to create a wave pattern

3.6 Fasteners

Wood roofing may be attached to a roof deck with noncorroding, galvanized steel or stainless steel nails or noncorroding metal staples. A minimum of two fasteners should be used to attach each shake or shingle. See Figures 5 and 6.



NOTE - 1. WHEN NAILS ARE SPECIFIED, NRCA RECOMMENDS THAT BOX NAILS BE SPECIFIED IN LIEU OF COMMON NAILS
2. DIMENSIONS ARE APPROXIMATE
3. SEE MANUFACTURERS' INSTRUCTIONS FOR "NAIL-ZONE," AND SPECIFIC RECOMMENDATIONS FOR NAIL PLACEMENT LOCATIONS

Figure 5: Examples of nails used with wood roofing

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Corrosion-resistant staples are considered acceptable by NRCA for attaching wood roofing, as the varied grain structure of the wood and the manner in which it affects staple shank deformation generally provides for good withdrawal resistance of the staple. For decay resistant, preservative-treated, and/or fire-resistant-treated wood roofing, the manufacturer should be consulted for recommendations regarding acceptable fasteners.

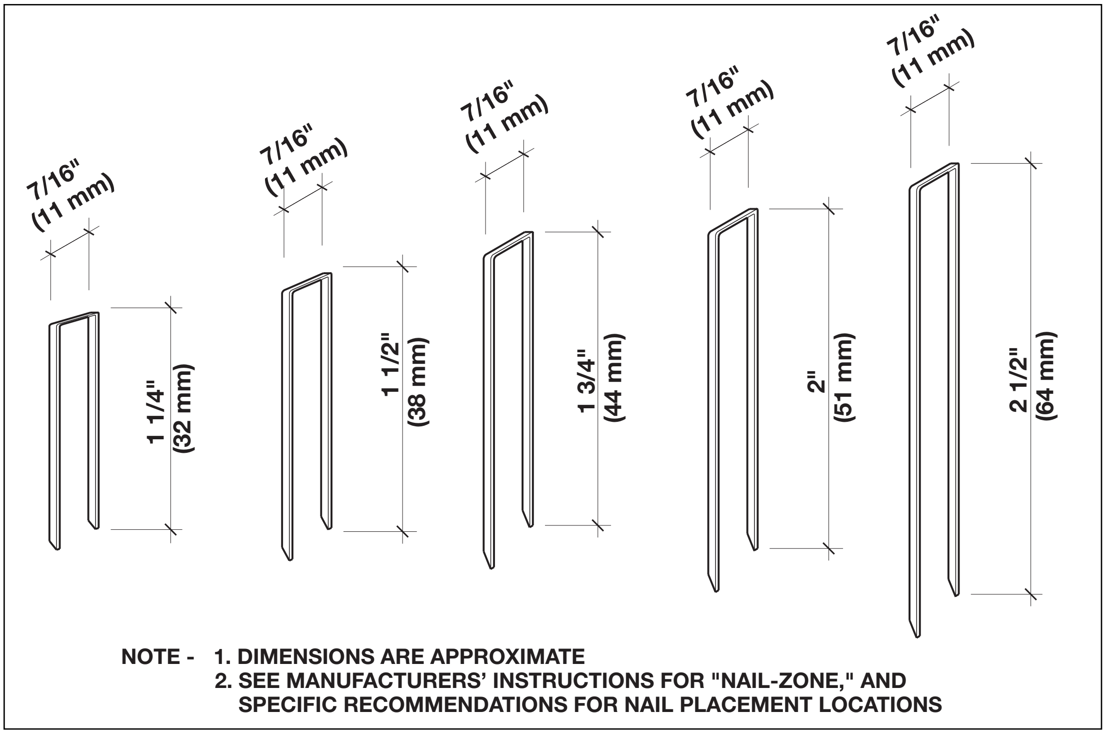

Figure 6: Example of staples used with wood roofing

In all wood shake and wood shingle applications, fasteners should be long enough to penetrate through all layers of roofing materials and achieve secure anchorage into the roof deck. Fasteners should extend through the underside of plywood or other acceptable wood panel decks, and penetrate at least ¾ inches (19 mm) into wood board or plank decks. The required length for fasteners, therefore, will vary according to the thicknesses and exposures of shakes or shingles. Longer fasteners are required when shakes and shingles are installed with reduced exposures and for hip and ridge shingles. The fastener length is determined by the thickness of the combined wood roofing materials, the type and thickness of the roof deck, and the thickness of any existing roofing materials.

Either hand-nailed or pneumatically actuated fastener applications are acceptable.

3.7 Flashings

Because steep-slope roof systems are frequently interrupted by the intersection of adjoining roof sections, adjacent walls or penetrations such as chimneys and plumbing soil-pipe stacks, all of which create opportunities for leakage, special provisions for weather protection must be made at these locations. These components used to control water entry are commonly called flashings. Careful attention to flashing details is essential to successful long-term roof system performance, regardless of the type of roof construction.

Flashings in this section are divided into four categories:

- perimeter edge metal
- penetration flashings
- valley flashings
- vertical surfaces

3.7.1 Perimeter Edge Metal

Depending upon the severity of the climate, anticipated rainfall and freeze-thaw cycling, using perimeter edge metal should be considered. Where climate and/or roof edge construction dictates the need for perimeter edge metal, NRCA recommends corrosion resistant metal be specified for perimeter edge metal.

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Location	Climatic Conditions[1]		
	Winter (°F)	Summer (°F)	
	Design Dry Bulb	Design Dry Bulb	Design Wet Bulb
Florida			
Daytona Beach	32	92	80
Jacksonville	29	96	79
Miami	44	91	79
Orlando	35	94	79
Tallahassee	27	94	79
Tampa	36	92	79
West Palm Beach	41	92	80
Georgia			
Atlanta	17	94	77
Augusta	20	97	80
Macon	21	96	79
Savannah	24	96	80
Hawaii			
Hilo	61	84	75
Honolulu	62	87	76
Idaho			
Boise	3	96	68
Lewiston	-1	96	67
Pocatello	-8	94	64
Illinois			
Chicago	-8	91	77
Moline	-9	93	78
Springfield	-3	94	79
Indiana			
Evansville	4	95	79
Fort Wayne	-4	92	77
Indianapolis	-2	92	78
South Bend	-3	91	77
Iowa			
Burlington	-7	94	78
Des Moines	-10	94	78
Mason City	-15	90	77
Sioux City	-11	95	78

Location	Climatic Conditions[1]		
	Winter (°F)	Summer (°F)	
	Design Dry Bulb	Design Dry Bulb	Design Wet Bulb
Kansas			
Dodge City	0	100	74
Goodland	-5	99	71
Topeka	0	99	79
Kentucky			
Lexington	3	93	77
Louisville	5	95	79
Louisiana			
Baton Rouge	25	95	80
Lake Charles	27	95	80
New Orleans	29	93	81
Shreveport	20	99	79
Maine			
Bangor	-11	86	73
Portland	-6	87	74
Maryland			
Baltimore	10	94	78
Massachusetts			
Boston	6	91	75
Michigan			
Alpena	-11	89	73
Detroit	3	91	76
Flint	-4	90	76
Grand Rapids	1	91	75
Transverse City	-3	89	75
Minnesota			
Minneapolis	-16	92	77
Rochester	-17	90	77
Mississippi			
Jackson	21	97	79
Meridian	19	97	80
Missouri			
Columbia	-1	97	78
Kansas City	2	99	78
Saint Louis	2	97	78
Springfield	3	96	78

Location	Climatic Conditions[1]		
	Winter (˚F)	Summer (˚F)	
	Design Dry Bulb	Design Dry Bulb	Design Wet Bulb
Montana			
Billings	-15	94	67
Helena	-21	91	64
Miles City	-20	98	70
Nebraska			
Grand Island	-8	97	75
North Platte	-8	97	74
Omaha	-8	94	78
Scottsbluff	-8	95	70
Nevada			
Elko	-8	94	63
Ely	-10	89	60
Las Vegas	25	108	71
Lovelock	8	98	66
Reno	5	95	64
Tonopah	5	94	64
Winnemucca	-1	96	64
New Hampshire			
Concord	-8	90	74
New Jersey			
Newark	10	94	77
New Mexico			
Albuquerque	12	96	66
Roswell	13	100	71
Tucumcari	8	99	70
New York			
Albany	-6	91	75
Binghamton	-2	86	73
Buffalo	2	88	74
Massena	-13	86	73
New York	11	92	76
Rochester	1	91	75
Syracuse	-3	90	75
North Carolina			
Asheville	10	89	75
Charlotte	18	95	77
Greensboro	14	93	77
Raleigh	16	94	78
North Dakota			
Bismarck	-23	95	73
Fargo	-22	92	76
Minot	-24	92	72

Location	Climatic Conditions[1]		
	Winter (°F)	Summer (°F)	
	Design Dry Bulb	Design Dry Bulb	Design Wet Bulb
Ohio			
Akron	1	89	75
Cincinnati	1	92	77
Columbus	0	92	77
Dayton	-1	91	76
Toledo	-3	90	76
Youngstown	-1	88	74
Oklahoma			
Oklahoma City	9	100	78
Tulsa	8	101	79
Oregon			
Astoria	25	75	65
Medford	19	98	70
Portland	17	89	69
Salem	18	92	69
Pennsylvania			
Allentown	4	92	76
Erie	4	88	75
Harrisburg	7	94	77
Philadelphia	10	93	77
Pittsburgh	1	89	74
Rhode Island:			
Providence	5	89	75
South Carolina			
Charleston	24	93	81
Columbia	20	97	79
Greenville	18	93	77
South Dakota			
Huron	-18	96	77
Pierre	-15	99	75
Rapid City	-11	95	71
Sioux Falls	-15	94	76
Tennessee			
Chattanooga	13	96	78
Knoxville	13	94	77
Memphis	13	98	80
Nashville	9	97	78
Texas			
Abilene	15	101	75
Amarillo	6	98	71
Austin	24	100	78
Brownsville	35	94	80

Location	Climatic Conditions[1]		
	Winter (°F)	Summer (°F)	
	Design Dry Bulb	Design Dry Bulb	Design Wet Bulb
Corpus Christi	31	95	80
Dallas	18	102	78
Del Rio	26	100	79
El Paso	20	100	69
Fort Worth	17	101	78
Houston	27	96	80
Laredo	32	102	78
Lubbock	10	98	73
Lufkin	25	99	80
Midland	16	100	73
Port Arthur	27	95	81
San Angelo	18	101	75
San Antonio	25	99	77
Waco	21	101	78
Wichita Falls	14	103	77
Utah			
Cedar City	-2	93	65
Salt Lake City	3	97	66
Vermont			
Burlington	-12	88	74
Virginia			
Norfolk	20	93	79
Richmond	14	95	79
Roanoke	12	93	75
Washington			
Olympia	16	87	67
Seattle/Tacoma	21	84	66
Spokane	-6	93	65
Yakima	-2	96	68
West Virginia			
Charleston	7	92	76
Wisconsin			
Eau Claire	-15	92	77
Green Bay	-13	88	76
LaCrosse	-13	91	77
Madison	-11	91	77
Milwaukee	-8	90	76
Wyoming			
Casper	-11	92	63
Cheyenne	-9	89	63
Rock Springs	-9	86	59
Sheridan	-14	94	66

[1] Climatic conditions data derived from Table 1, *1993 ASHRAE Handbook–Fundamentals,* pages 24.4-24.15

APPENDIX 4: PSYCHROMETRIC TABLE

Dew-Point Temperature (°F)															
Relative Humidity	**Design Dry Bulb (Interior) Temperature (°F)**														
	32°F	**35°F**	**40°F**	**45°F**	**50°F**	**55°F**	**60°F**	**65°F**	**70°F**	**75°F**	**80°F**	**85°F**	**90°F**	**95°F**	**100°F**
100%	32	35	40	45	50	55	60	65	70	75	80	85	90	95	100
90%	30	33	37	42	47	52	57	62	67	72	77	82	87	92	97
80%	27	30	34	39	44	49	54	58	64	68	73	78	83	88	93
70%	24	27	31	36	40	45	50	55	60	64	69	74	79	84	88
60%	20	24	28	32	36	41	46	51	55	60	65	69	74	79	83
50%	16	20	24	28	33	36	41	46	50	55	60	64	69	73	78
40%	12	15	18	23	27	31	35	40	45	49	53	58	62	67	71
30%	8	10	14	16	21	25	29	33	37	42	46	50	54	59	62
20%	6	7	8	9	13	16	20	24	28	31	35	40	43	48	52
10%	4	4	5	5	6	8	9	10	13	17	20	24	27	30	34
Adapted from ASHRAE Psychrometric Chart, *1993 ASHRAE Fundamentals Handbook*.															

APPENDIX 7

Quality Control Guidelines for the Application of Spray Polyurethane Foam Roofing

Note:

This document is not a specification. It does not supersede job specifications, which are the prerogative of the designer (specifier) and/or material manufacturers. It merely provides general guidelines for following accepted spray polyurethane foam-based roofing construction practices.

Statement of Purpose

This document provides guidelines for on-site evaluation of spray polyurethane foam- (SPF-) based roof systems during the application process.

Introduction

This document addresses on-site evaluation guidelines during the application of SPF-based roof systems. It stresses thorough, continuous inspections during construction to recognize and correct variances as they are detected. It provides guidelines to evaluate the quality of application. This document also provides information about the installation of specific components above the structural deck. Where appropriate, the guidelines describe expected variances in the application of primers, vapor retarders, cover board insulation and base sheets, fasteners, SPFs, surfacings and metal flashings.

The application of an SPF-based roof system involves the skillful arrangement of multiple components in a specified process. The quality of workmanship during the application process is measured by application criteria and inspection procedures and is a critical element to roof system performance. Roof system performance is also determined by other factors, including building design, project specifications and details, material quality and suitability for the specific application, and roof system maintenance.

The application of SPF-based roof systems, similar to other types of roof systems, is not an exact science. It is a craft involving people who handle a broad range of materials, designs, practices and techniques, climates and changing weather conditions. The National Roofing Contractors Association (NRCA) and Spray Polyurethane Foam Alliance (SPFA) recognize the importance of these critical factors as they affect quality SPF-based roof systems.

The guidelines presented in this document are based on the technical knowledge and experience of practicing and knowledgeable roofing professionals, including contractors, manufacturers and roofing technologists. Their collective experience resulted in a consensus as expressed in this document.

The Spray Polyurethane Foam-based Roof System Quality Control Application Checklists have been developed to assist quality control and quality assurance personnel who perform inspections while SPF-based roof system application is in progress. The checklist is located in Appendix 1.

Terminology

Terminology used in this document can be found in Appendix 4.

System Description

SPF-based roof systems consist of a fully adhered base layer of closed-cell polyurethane foam covered with a protective surfacing.

The polyurethane foam is spray-applied by mixing two chemically reactive liquid components through a high-pressure mixing gun. As the liquid mixture is applied to a roof substrate, the chemical components react immediately, expand 20 times to 30 times their original liquid volume and set to a rigid foam layer. The foam formed is closed-cell, providing thermal insulation and some degree of water resistance.

Elastomeric coatings with or without aggregate and membrane surfacings protect the foam from ultraviolet light and mechanical damage. An elastomeric coating or membrane surfacing provides the long-term weatherproofing characteristics of SPF-based roof systems.

Quality Control/Assurance

Quality control and quality assurance are essential elements of SPF-based roof system construction.

Quality control is performed by a contractor who installs SPF-based roof systems. The roofing contractor designates an individual to be on-site during the entire roof system application process; that individual may be a working member of the crew. This person understands the system being installed and has the authority to correct noncompliant work.

Quality assurance, when performed, is the responsibility of a building owner's representative (e.g., architect, engineer, roof consultant) or representative of the material manufacturer/supplier. The person performing quality assurance also must understand the system being installed and its methods of application. The quality assurance person should verbally notify the roofing contractor immediately if noncompliant work is observed so necessary corrective action can be taken. Written documentation should follow every inspection with copies distributed the following day to field personnel and offices of all pertinent parties.

Visual Examination

The most effective means to evaluate the quality of an SPF-based roof system installation is by thorough, continuous visual inspection and evaluation at the time of application by a person who is knowledgeable of SPF roofing technology and good workmanship practices.

The following list will assist quality assurance and quality control inspectors before and during roof system inspections of an in-progress roof application. Many items on these lists are discussed in the following sections of this document. A detailed checklist is found in Appendix 1. If deficiencies are found during inspection of a roof system application, corrective action should be taken.

Inspectors should visually ensure the following before and during application:

Before application

- Specifications and drawings are available for review, including specific details.
- All certifications or approvals have been received for the deck and roof system materials where applicable.
- Material manufacturers'/suppliers' literature and application specifications and recommendations are available for information and review.
- Safety precautions and material safety data sheets (MSDS) have been reviewed and are on-site during application.
- Specified materials and quantities, as verified by on-site inspection of product labels, are at the project site and are visually suitable for application (e.g., packaging is not damaged, labels are intact).
- Materials are stored according to manufacturers'/suppliers' recommendations (e.g., materials are at proper temperature, covered, off the ground and on pallets).
- Equipment is in good working order and functioning properly.
- Edge nailers, curbs, drains and penetrations have been installed in the areas to receive SPF.
- Drainage patterns for proper SPF-based roof system installation have been identified.
- When fastener pull-out tests are specified, tests have been conducted and the results have been approved by the specifier and/or manufacturer.

During application

- Weather and project conditions are suitable for application.
- Substrate is sufficiently dry and suitably prepared to receive the SPF-based roof system.
- When specified, rigid insulation cover boards are butted together with joints staggered and offset.
- When specified, a separation layer (e.g., cover board, base sheet) is firmly attached to the substrate with the specified type and number of fasteners or is embedded in the specified adhesive.
- When specified, temporary tie-ins are installed at the end of each day's work as required.
- Surfacing is applied as specified.
- Materials and the applied roof system are not abused by other trades.

Decks—New Construction/Tear-off

The quality assurance and quality control of roof decks are beyond the scope of this document, and therefore, this document does not consider the roof deck as part of an SPF-based roof system. However, there are important roof deck factors that affect final SPF-based roof system performance. These factors include but are not limited to structural load capabilities, slope and drainage, expansion joints and flashing details.

A building owner, designer and deck manufacturer/installer are responsible for providing for the support, attachment, fastener pull-out testing (when specified), proper deck alignment, structural integrity, construction details, and compensation for expansion and contraction of the structural roof deck in a manner that will provide a stable base for an SPF-based roof system.

Roofing contractors inspect and accept roof deck surfaces to schedule roofing applications. Attention to deck surface dryness and cleanliness is essential during application.

Existing Roof Substrates

When re-covering an existing roof system, a designer is responsible for analyzing the structural roof deck (described under the section Decks—New Construction/Tear-off), including deck integrity, system compatibility, load capacity, damage, moisture condition, wind uplift and building code requirements.

The following chart provides specific criteria and corrective action for the evaluation of existing roof substrates.

Evaluation of Criteria
Visual examination at the time of application is the most effective means of evaluating the substrate to which an SPF-based roof system is applied. Visual examination may include routine measurements where applicable. During evaluation of an application, reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.

Criterion	Corrective Action
The substrate surface is sufficiently dry, clean and prepared to receive a new SPF-based roof system.	Delay the installation until substrate conditions have been corrected.
The substrate surface is suitably prepared for a re-cover application. The surface should be secure and clear of loose material. Aggregate embedded in bitumen is considered acceptable.	As appropriate, cut, remove or repair blisters, ridges, splits and other defects that appear likely to affect the security and adhesion of a new SPF-based roof system.
Areas of the existing roof system that are too wet, as determined by the designer, have been removed.	Delay installation of a new SPF-based roof system until the designated areas have been removed and replaced.

Primers

SPF adheres well to most construction materials. Primers are often used to enhance the adhesion and/or increase the surface temperature of a substrate. Primers are not intended as a substitute for a properly prepared surface.

The following chart provides specific criteria and corrective action for the evaluation of primer application.

Evaluation of Criteria
Visual examination at the time of application is the most effective means of evaluating primer application. Visual examination may include routine measurements where applicable. During evaluation of an application, reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.

Criterion	Corrective Action
The substrate surface is sufficiently dry, clean and prepared to receive the primer.	Delay the installation until substrate conditions have been corrected.
Primer is applied at the specified rate.	Adjust application to comply with the specified rate.

Vapor Retarders

The entry of water vapor and its subsequent condensation can be detrimental to a roof system's performance. Vapor retarders can be used to control migration of water vapor into a roof system. Determining the need for a vapor retarder, its compatibility with other materials and the details of its construction is the responsibility of the designer.

The following chart provides specific criteria and corrective action for the evaluation of vapor retarder application.

Evaluation of Criteria Visual examination at the time of application is the most effective means of evaluating vapor retarder application. Visual examination may include routine measurements where applicable. During evaluation of an application, reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
Criterion	**Corrective Action**
The substrate surface is sufficiently dry, reasonably smooth and clear of potentially damaging objects.	Delay installation of the vapor retarder until substrate conditions have been corrected.
Materials are protected from inclement weather and abuse from other trades.	Cover materials and remove damaged materials from project site.
The location of the vapor retarder is as specified.	Remove vapor retarder from incorrect location, and install it in specified location.
Number of plies is as specified.	Should examination reveal missing plies, install additional plies to comply with the specification.
Adhesive for vapor retarder is applied as specified.	Remove the membrane vapor retarder from the deficient area, and install a new membrane vapor retarder to meet the specification.
Liquid-applied vapor retarder is applied continuously and at the specified rate.	Adjust application to comply with the specified rate.
The vapor retarder extends continuously across the plane of the deck. End laps, side laps, openings and penetrations are sealed as specified.	Install specified vapor retarder to incomplete or noncontinuous areas. Add additional plies or sealant to ensure adequate seals.
The vapor retarder is sealed at the perimeter as specified.	Adjust work to ensure perimeter detailing and sealing comply with the specification.
The vapor retarder is tied into any other air or vapor retarders as specified.	Add additional plies or sealant to ensure adequate tie-in, and correct work to comply with the specification.

Separation Layer

A separation layer, typically either an insulation cover board or asphalt base sheet, is often installed over certain structural roof decks or other substrates to provide a physical separation between an SPF-based roof system and substrate. An example is an insulation cover board installed over irregular or uneven substrates, such as a metal roof deck or a precast concrete plank roof deck, to provide a smooth surface to which an SPF-based roof system can be applied.

Separation Layer: General Criteria

The following chart provides specific criteria and corrective action for the evaluation of separation layer application.

Evaluation of Criteria

Visual examination at the time of application is the most effective means of evaluating application of a separation layer. Visual examination may include routine measurements where applicable. During evaluation of an application, reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.

Criterion	Corrective Action
Separation layer materials are as specified.	Remove noncompliant materials from the job site.
Separation layer materials are protected from inclement weather before, during and after installation.	Protect the material. Do not use damaged or wet material.
At the end of each day's work, temporary tie-ins are applied to seal the separation layer at the edge of SPF.	Install temporary tie-ins at the end of each day's work. Replace damaged materials.

Separation Layer: Insulation Boards

The following chart provides specific criteria and corrective action for the evaluation of separation layer/insulation board application.

Evaluation of Criteria
Visual examination at the time of application is the most effective means of evaluating the application of insulation boards as a separation layer. Visual examination may include routine measurements where applicable. During evaluation of an application, reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.

Criterion	Corrective Action
Insulation materials are as specified.	Remove noncompliant materials from the project site.
Insulation is protected from inclement weather before, during and after installation.	Protect the material. Do not use damaged or wet insulation.
Insulation boards are butted together. Because of manufacturing tolerances, dimensional stability, variances during installation and the nature of insulation boards, some variance in joint spacing can be expected. Occasional gaps between boards not exceeding 1⁄4 inch (6 mm) are acceptable as long as the gaps are not continuous for more than the length of one insulation board.	Insulation gaps in excess of 1⁄4 inch (6 mm) should be filled with appropriate insulation board, SPF or compatible material.
Insulation end joints are staggered unless otherwise specified.	Remove nonstaggered insulation boards. Adjust boards to appropriate stagger.
Finished surface of adjacent insulation boards is not vertically offset more than 1⁄4 inch (6 mm).	Correct vertical offset of insulation boards by shaving the insulation board, filling or leveling the gap with compatible material, adding tapered insulation as applicable or adding mechanical fasteners with plates.
When an insulation board is mechanically attached, the type, corrosion resistance, size, and length of fasteners and plates or washers are as specified.	Immediately change to the proper fastener. Remove improper fasteners, if necessary, and add specified fasteners to meet attachment objectives.
When the insulation board is mechanically attached, the minimum number of fasteners are installed and correct fastening pattern specified is followed.	Install additional fasteners as needed and space them appropriately.
When an insulation board is mechanically attached, fasteners are properly driven.	Immediately adjust operations. Remove improperly driven fasteners, if necessary, and add fasteners to maintain the minimum number of fasteners with appropriate spacing.
When an insulation board is applied in hot asphalt, the asphalt is applied at a rate sufficient to visually cover the surface area being bonded. The insulation board is embedded in the asphalt while the asphalt is hot and fluid.	Replace unadhered insulation boards with properly embedded insulation boards.
When an insulation board is adhered with cold adhesive, the adhesive is applied at the specified coverage rate and pattern. Recommended open times should be followed to ensure adequate adhesion.	Readhere or replace unadhered insulation boards with properly adhered insulation boards.

Separation Layer: Base Sheet

The following chart provides specific criteria and corrective action for the evaluation of separation layer/base sheet installation.

Evaluation of Criteria Visual examination at the time of application is the most effective means of evaluating the application of a base sheet as a separation layer. Visual examination may include routine measurements where applicable. During evaluation of an application, reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
Criterion	**Corrective Action**
Base sheet laps should be installed as follows: • Head lap: as specified, with a tolerance of minus 1 inch (25 mm) but with a 1-inch (25-mm) minimum. No maximum limit. • End lap: as specified, less 2 inches (50 mm) but with a 2-inch (50-mm) minimum. No maximum limit. • Side lap: as specified, less 2 inches (50 mm) but with a 2-inch (50-mm) minimum. No maximum limit.	If the examination reveals less than the minimum width for head laps, side laps or end laps, install an additional layer of base sheet material over the deficient area.
When a base sheet is applied in adhesive, the adhesive is applied at a rate sufficient to visually cover the surface area being bonded.	Replace an unadhered base sheet with a properly adhered base sheet.

Application of Spray Polyurethane Foam

SPF can be applied in various densities, each exhibiting different physical properties. The thickness of SPF applied, number of lifts, temperature of the substrate, ambient temperature and humidity affect the in-place physical properties of SPF.

Most SPF manufacturers offer various seasonal grades of foam used for SPF-based roof systems. Grades are formulated according to the anticipated weather conditions for a project and the ambient and surface temperatures that are anticipated during the time of application.

The following chart provides specific criteria and corrective action for the evaluation of SPF application.

Evaluation
Visual examination at the time of application is the most effective means of evaluating SPF application. Visual examination may include routine measurements where applicable. During evaluation of an application, reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.

Criterion	Corrective Action
Materials are as specified.	Remove noncompliant materials from the job site.
Temperature, humidity and ambient conditions are as specified.	Discontinue SPF application until conditions are within specification.
Wind conditions are acceptable for proper application and protection against overspray.	Discontinue SPF application until wind conditions subside, or use wind screens as necessary.
Equipment is operating at the proper pressure and temperature.	Adjust or repair equipment as necessary to provide proper pressure and temperature.
SPF is rising and/or reacting properly.	Remove defective SPF. Adjust work practices.
Minimum lift thickness is ½ inch (13 mm) or as specified except where a feathered edge is necessary to complete a pass.	Adjust work practices.
Minimum overall SPF thickness should be 1 inch (25 mm) or as specified for coated and membrane-surfaced systems and 1½ inches (38 mm) or as specified for aggregate-covered systems and over rough, textured surfaces.	Adjust work practices. Apply additional SPF over any area with less than the specified minimum SPF thickness.
SPF is applied uniformly over the entire surface with a tolerance of plus ¼-inch-per-inch (25 percent) of specified thickness, minus zero except where variations are required to provide for proper drainage or to complete a feathered edge.	Adjust work practices. Remove any excess SPF that will impede proper drainage. Apply additional SPF over any area with less than the specified minimum SPF thickness.
Surface texture is as specified.	Adjust work practices. Consult with SPF and coating manufacturers regarding affected area.
SPF should be terminated neatly above the roof line at all penetrations and building junctions as specified.	Adjust work practices. Remove excess SPF and overspray.
Sprayed-in-place cants and crickets should be relatively smooth and uniform to allow for proper drainage.	Adjust work practices. Remove any excess SPF that will impede proper drainage. Apply additional SPF if necessary.
SPF is applied in the full thickness within the same day.	If SPF is exposed for more than 24 hours, consult the manufacturer for specific surface preparation instructions.

Application of Elastomeric Coating

An elastomeric coating is applied to an SPF-based roof system to protect SPF from ultraviolet rays and mechanical damage and enhance weatherproofing. An elastomeric coating can also be specified to provide for other performance criteria (e.g., fire resistance, chemical resistance, vapor permeability).

The following chart provides specific criteria and corrective action for the evaluation of elastomeric coating application.

Evaluation
Visual examination at the time of application is the most effective means of evaluating elastomeric coating application. Visual examination may include routine measurements where applicable. During evaluation of an application, reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.

Criterion	Corrective Action
Coating materials are as specified.	Remove noncompliant materials from the job site.
Coating materials are mixed as specified.	Consult coating manufacturer for appropriate remedial action.
Temperature, humidity and ambient conditions are as specified.	Discontinue coating application until conditions are within specification.
Wind conditions are acceptable for proper application and protection against overspray.	Discontinue coating application until wind conditions subside, or use wind screens as necessary.
Equipment is operating at the proper pressure and temperature.	Adjust or repair equipment as necessary to provide proper pressure and temperature.
Unless otherwise specified, base coat is applied the same day as SPF.	If SPF or the base coat is exposed for more than 24 hours, consult the manufacturer for specific surface preparation instructions.
Coating is applied at the specified rate.	Adjust application to comply with the specified rate. In the deficient area, apply additional coating material to achieve the minimum specified coverage rate.
Overall coating dry film thickness is as specified.	Adjust application to comply with the specified film thickness. In the deficient area, apply additional coating material to achieve the specified dry film coating thickness.
Layers of coating are applied within the manufacturer's specified time periods.	Consult coating manufacturer for appropriate remedial action.
For granule-surfaced or aggregate-surfaced coatings, surfacing is applied in a continuous uncured coating at the specified coverage rate to achieve a continuous embedded surfacing.	Immediately adjust operations to ensure embedment of the specified amount. Whenever visual observation indicates an inadequate amount of adhered granules, loose granules are to be removed, and coating and granules are to be reapplied.

Application of Aggregate Surfacing Cover

Aggregate can be applied to low-slope SPF-based roof surfaces to protect the SPF from ultraviolet rays and mechanical damage.

Quality control and quality assurance guidelines are provided here for aggregate-surfaced SPF-based roof systems even though NRCA in the Spray Polyurethane Foam-Based Roofing section of The NRCA Roofing and Waterproofing Manual, Fifth Edition, *does not recognize the use of an aggregate surfacing without the use of a water-resistant elastomeric coating over SPF. Guidelines for design and application of aggregate-surfaced SPF are included in APC/SPFA Document AY-110,* Spray Polyurethane Foam Aggregate Systems for New and Remedial Roofing*.*

The following chart provides specific criteria and corrective action for the evaluation of aggregate surfacing application.

Evaluation Visual examination at the time of application is the most effective means of evaluating aggregate coating application. Visual examination may include routine measurements where applicable. During evaluation of an application, reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
Criterion	**Corrective Action**
Aggregate type and size are as specified.	Remove noncompliant materials from the job site.
Aggregate application rate is as specified.	Adjust work practices. Add additional aggregate in the deficient area.
Aggregate is distributed evenly over the roof surface without bare spots.	Redistribute aggregate over the deficient area.

Application of Membrane Surfacing Adhered with Adhesive/Low-rise Foam

This section discusses application of membrane surfacings over SPF using an adhesive/low-rise foam. Membrane surfacings are applied to SPF-based roof systems to protect SPF from ultraviolet rays and mechanical damage and to be the primary weatherproofing surface. Membrane surfacings may also provide other performance criteria (e.g., fire resistance, chemical resistance).

The following chart provides specific criteria and corrective action for the evaluation of the application of membrane surfacing adhered with adhesive/low-rise foam.

Evaluation of Criteria
Visual examination at the time of application is the most effective means of evaluating membrane surfacing application. Visual examination may include routine measurements where applicable. During evaluation of an application, reasonable variances from specified amounts are to be expected. Significant deviation from any particular criteria should be corrected as soon as possible.

Criterion	Corrective Action
Membrane surfacing materials are as specified.	Remove noncompliant materials from the job site.
SPF surface is acceptable to receive adhesive/low-rise foam application.	Discontinue adhesive/low-rise foam application until SPF surface is within specification.
Temperature, humidity and ambient conditions are as specified.	Discontinue adhesive/low-rise foam application until conditions are within specification.
Wind conditions are acceptable for proper application and protection against overspray.	Discontinue adhesive/low-rise foam application until wind conditions subside, or use wind screens as necessary.
Equipment is operating at the proper pressure temperature.	Adjust or repair equipment as necessary to provide pressure and temperature.
Unless otherwise specified, adhesive/low-rise foam and membrane are applied the same day as SPF.	If SPF is exposed for more than 24 hours, consult the adhesive/low-rise foam manufacturer for specific surface preparation instructions.
Membrane surfacing is properly positioned, unrolled and folded.	Do not apply adhesive/low-rise foam until membrane surfacing is properly positioned, unrolled and folded.
Adhesive/low-rise foam is applied uniformly over the entire surface. Consult manufacturer for application rate or thickness and tolerances.	Adjust work practices.
Adhesive/low-rise foam is rising and/or reacting properly.	Remove defective adhesive/low-rise foam. Adjust work practices.
Membrane surfacing is folded into the wet adhesive/low-rise foam and rolled with a weighted roller to secure membrane surfacing into adhesive/low-rise foam.	Adjust work practices.
Appropriately seam the membrane surfacing per manufacturer's recommendations.	Adjust work practices. Reference the *NRCA/SPRI Quality Control Guidelines for the Application of Thermoset Single-ply Roof Membranes.*

Metal Flashings

For SPF-based roof systems, the use of metal flashings, when specified, can be divided into the following three general categories:

- Water conveyance flashings include exterior water collector boxes (e.g., conductor heads), gutters and downspouts.

- Independent watershedding flashings are attached, sealed and mounted above the top edge of a roof covering and penetration flashings. These flashings prevent moisture penetration into wall cavities, behind base flashings, through curb-mounted equipment, or into or behind penetration flashings. Metal coping or cap flashings, surface-mounted counterflashing, curb caps, rain collars and through-wall flashings are examples of independent watershedding flashings. Independent watershedding flashings are independent from a roof system.

- Integral component and edge flashings include metal roof jacks; pipe flashings; through-wall scuppers; electrical utility line penetration flashings; and light-gauge (i.e., 24- or 26-gauge [0.64- or 0.48-mm]) low-profile metal edge flashings (e.g., gravel/foam stops). These types of flashings differ from the other categories in one primary characteristic—they require integration or sealing of their metal flanges directly into a roof system. Metal flashing flanges typically provide a minimum of 3 1⁄2 inches (90 mm) of sealing surface.

The following chart provides specific criteria and corrective action for the evaluation of metal flashing application.

Evaluation Visual examination at the time of application is the most effective means of evaluating metal flashing application. Visual examination may include routine measurements where applicable. During evaluation of an application, reasonable variances from specified amounts are to be expected. Significant deviation from any particular criterion should be corrected as soon as possible.	
Criterion	**Corrective Action**
Metal flanges are primed with specified primer.	Prime metal flanges, and allow to dry before sealing in.
Metal flanges are set in a bed of sealant when specified and secured as specified.	Remove flashing and reinstall as specified, or add fasteners as required to meet specified spacing.
Metal edge laps are sealed as detailed with specified sealant.	Remove flashings sufficiently to install inter-lap sealant.
Metal edge is supported by continuous wood blocking or decking, and flanges are not extended past the wood blocking.	Install wood blocking before metal edge flashing to support metal flanges adequately.

Appendix 1—Spray Polyurethane Foam-based Roof System Quality Control Application Checklists

The following checklists are offered to assist quality control and quality assurance inspectors before and during roof system inspections while roof system application is in progress. These are not specifications and do not cover every detail of SPF-based roof system application inspection procedures.

The intent of these checklists is to guide quality control and quality assurance inspectors by highlighting key application areas affecting successful SPF-based roof system performance.

Before application

❑ Specifications and drawings are available for review, including specific details.

❑ All certifications or approvals have been received for the deck and roof system materials where applicable.

❑ Material manufacturers'/suppliers' literature and application specifications and recommendations are available for information and review.

❑ Safety precautions and material safety data sheets (MSDS) have been reviewed and are on-site during application.

❑ Specified materials and quantities, as verified by on-site inspection of product labels, are at the project site and are visually suitable for application (e.g., packaging is not damaged, labels are intact).

❑ Materials are stored according to manufacturers'/suppliers' recommendations (e.g., materials are stored at proper temperature, covered, off the ground and on pallets).

❑ Equipment is in good working order and functioning properly.

❑ Edge nailers, curbs, drains and penetrations have been installed in the area to receive SPF.

❑ Drainage patterns for proper SPF-based roof system installation have been identified.

❑ When fastener pull-out tests are specified, tests have been conducted and the results have been approved by the specifier and/or manufacturer.

During application

❑ Weather and project conditions are suitable for application.

❑ Substrate is sufficiently dry and suitably prepared to receive an SPF-based roof system.

❑ When specified, rigid insulation cover boards are butted together with joints staggered and offset.

❑ When specified, a separation layer (e.g., cover board, base sheet) is firmly attached to the substrate with the specified type and number of fasteners or is embedded in the specified adhesive.

❑ When specified, temporary tie-ins are installed at the end of each day's work as required.

❑ Surfacing is applied as specified.

❑ Materials and the applied roof system are not abused by other trades.

Appendix 2—Slit Samples/Core Samples

Taking slit samples and core samples during the application of SPF and coatings is important for routine quality control and quality assurance for SPF-based roof systems. Taking slit samples and core samples at the completion of an SPF-based roofing project should not be substituted for quality control and quality assurance provided by continuous visual inspection during application.

Final slit samples and core samples of a completed SPF-based roof system are taken at the discretion of the manufacturer/supplier warranting the roof system.

Appendix 3—Spray Polyurethane Foam Surface Texture Photographs

The following photographs show various SPF surface textures that have been established as industry reference standards.

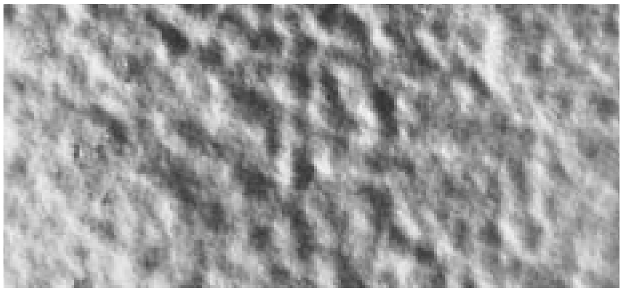

Photo 1: Smooth surface texture

The surface shows spray undulation and is acceptable for receiving an elastomeric coating. Even though the surface texture is classified as smooth, the theoretical coverage rate cannot be used without adding additional material to adequately cover the smooth surface texture to achieve the specified dry film thickness.

Photo 2: Orange peel surface texture

The surface shows a fine texture that is compared with the exterior skin of an orange. This surface is considered acceptable for receiving an elastomeric coating. The theoretical coverage rate cannot be used without adding additional material to adequately cover the orange peel texture to achieve the specified dry film thickness.

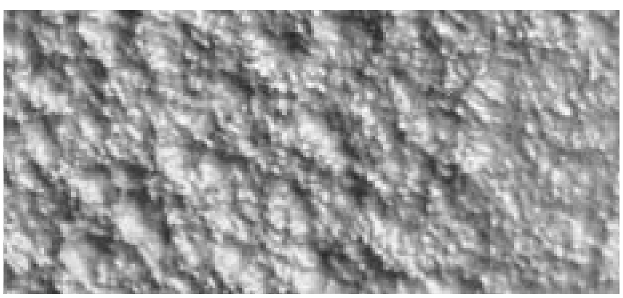

Photo 3: Coarse orange peel surface texture

The surface shows a texture where nodules and valleys are approximately the same size and shape. This surface is acceptable for receiving an elastomeric coating because of the roundness of the nodules and valleys. The theoretical coverage rate cannot be used without adding additional material to adequately cover the coarse orange peel texture to achieve the specified dry film thickness.

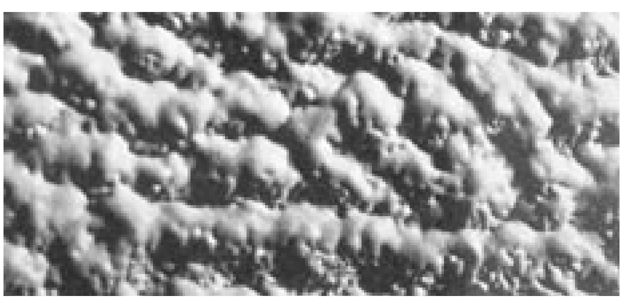

Photo 4: Verge of popcorn texture

The verge of popcorn texture is the roughest texture suitable for receiving an elastomeric coating. The surface shows a texture where nodules are larger than valleys, and the valleys are relatively curved. This surface is acceptable for receiving an elastomeric coating only because of the relatively curved surface texture of the irregularities. However, the verge of popcorn surface texture is considered undesirable because of the additional amount of coating material required to protect the surface properly. The theoretical coverage rate cannot be used without adding additional material to adequately cover the verge of popcorn texture.

Photo 5: Popcorn surface texture

The surface shows a coarse texture where valleys form sharp angles. This surface is unacceptable for coating.

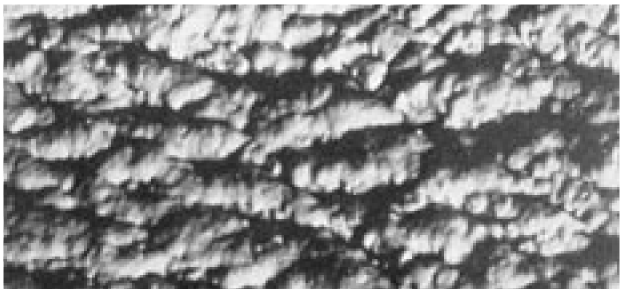

Photo 6: Treebark surface texture

The surface shows a coarse texture where valleys form sharp angles. It is a "rolling-foam" surface texture where the valleys are sharply angled because the foam is sprayed at an angle. This surface is unacceptable for coating.

Photographs courtesy of the U.S. Navy, Naval Facilities Engineering Command and the Spray Polyurethane Foam Alliance.

Appendix 4—Terminology

For the purpose of this document, terms are defined as follows:

Dry film thickness: the thickness, commonly expressed in mils, of a cured coating material.

Mil: a unit of measure (1 mil is equal to 0.001 inches or 25.4 micrometers) often used to indicate the thickness of a coating.

Slit sample: a small half-moon-shaped cut generally a minimum of 1 inch long by 1⁄2 inch wide by 1⁄2 inch deep (25 mm by 13 mm by 13 mm) used to measure foam lift thickness and/or coating film thickness.

Spray polyurethane foam (SPF): a material formed by spraying two components, polymeric methylene diphenyl diisocyanate ([A] component) and a polyol resin ([B] component), to form a rigid, fully adhered, water-resistant foam plastic.

The NRCA Roofing and Waterproofing

Manual

Fifth Edition

Includes 2003 Update

Volume 4

The vertical line in the margin indicates an addition or change(s) in the text since *The NRCA Roofing and Waterproofing Manual, Fifth Edition*, was originally printed in 2001.

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INTRODUCTION

The Construction Details section of *The NRCA Roofing and Waterproofing Manual, Fifth Edition*, has been written to provide technical information concerning the design and installation of construction details for quality low- and steep-slope roof systems. This introduction is intended to supplement the special notes on the individual construction details.

Roof systems can generally be divided into two categories: low-slope and steep-slope. The incline or slope of a roof is the primary factor in determining into which of these categories a particular roof system falls. *The NRCA Roofing and Waterproofing Manual, Fifth Edition*, defines these categories as follows:

> Low-slope roofs: a category of roofs that generally includes weatherproof membrane types of roof systems installed on slopes at or less that 3:12 (14 degrees).
>
> Steep-slope roofs: a category of roofs that generally includes water-shedding types of roof coverings installed on slopes greater than 3:12 (14 degrees).

In some instances, roof systems designed for low-slope applications are used when roof slopes are greater than 3:12 (14 degrees). Some steep-slope roofing materials are used when roof slopes are less than 3:12 (14 degrees). For either application, it is important to realize certain design modifications may be necessary.

In the Construction Details section of *The NRCA Roofing and Waterproofing Manual, Fifth Edition*, construction details are provided for the following roof system types:

Low-slope membrane roof systems:

- Built-up membrane
- Polymer-modified bitumen sheet membrane
- Thermoset single-ply membrane
- Thermoplastic single-ply membrane
- Steep-slope roof systems:
  - Asphalt shingle
  - Slate
  - Clay and concrete tile
  - Wood shake and shingle
- Sheet metal
- Architectural metal panel roof systems
- Structural metal panel roof systems
- Spray polyurethane foam-based roof systems
- Waterproofing systems

The information contained in this manual is intended to deal primarily with new construction situations. When considering reroofing projects, the Reroofing Manual section of *The NRCA Roofing and Waterproofing Manual, Fifth Edition*, should be consulted regarding the decision to re-cover or remove existing roof systems and for general information applicable to reroofing of low- and steep-slope roof systems. Once a decision to re-cover or remove existing roof systems is made, most information contained within the Construction Details section of *The NRCA Roofing and Waterproofing Manual, Fifth Edition*, can apply to reroofing.

Because of the wide variety of roofing products, this manual cannot address all the different methods and practices for designing and installing all the products available to designers, contractors and building owners.

In this manual, the National Roofing Contractors Association (NRCA) attempts to present a consensus of opinions from professional roofing contractors throughout North America as to the principles of good roofing practice. Where this manual provides specific suggestions or recommendations, it should be noted that these may be a more conservative approach than may be commonly provided by individual product manufacturers, roof designers or roofing contractors. The roof system design and application procedures included in this manual generally are recognized to be sound and time-proven and apply throughout North America.

The recommendations contained in the Construction Details section of *The NRCA Roofing and Waterproofing Manual, Fifth Edition*, should not be construed as the only methods for designing and installing roof systems. Some design criteria and application techniques may vary according to climatic conditions, and some geographical areas employ "area practices" that are sound and time-proven. NRCA does not mean to imply by any statement or exclusion that time-tested and proven area practices are unsatisfactory. Users of this manual are encouraged to contact NRCA members in the geographical area for specific advice concerning area practices and current technical information.

NRCA suggests the Construction Details section of *The NRCA Roofing and Waterproofing Manual, Fifth Edition*, be used in the design of roof systems only after a number of criteria have been carefully considered, including:

- Climate and geographic location
- A building's intended use and design life expectancy
- Exterior and interior temperature and humidity conditions
- Code requirements
- Type of roof deck
- Slope and drainage
- A roof's configuration
- Building movement
- Fire, wind and impact resistance
- Type and amount of insulation needed
- Need for ventilation
- Maintenance, repair and reroofing
- Compatibility with adjacent components, including potential material discharge onto a roof
- Construction sequencing
- Worker safety
- Potential building additions
- Odors, noise and dust generated by certain system application methods
- Rooftop traffic

These criteria play important roles in the success or failure of every roof assembly and must be considered by a designer to determine the appropriate components of a roof assembly, applicable specification and construction details to be used.

In addition, specific to a roof system's construction details, NRCA recommends designers consider the following factors:

Other components. Components that may be provided or installed by other trades that are integrated into roof systems can be critical to the watertight integrity of completed roof systems. These components may include:

- Metal counterflashings at curbs and other penetrations
- Lead flashings and drains and plumbing vent stacks
- Drain heads/clamps/strainers
- Sheet metal vents
- Sheet metal pitch pans
- Thru-wall flashings
- Skylight components and flashings
- Expansion joints and related components
- Wood blocking and attachment
- Pipe or conduit supports
- Crickets
- Siding or cladding
- Chimney caps
- Wall flashing
- Permanent safety anchors or guardrails

Definition of responsibility for the above components should be determined prior to job initiation.

Wood nailers and blocking. Many of the construction details illustrated in this manual depict wood nailers and blocking at roof edges and other points of roof termination. Integral wood nailers and blocking should be preservative pressure-treated wood or decay-resistant wood, such as cedar or redwood. Among other advantages, the nailers provide protection for the edges of rigid board insulation and provide a substrate for anchoring flashing materials. To provide an adequate base, nailers should be securely attached to a roof deck, wall and/or structural framing. In the design of specific details for a project, a designer should describe and clearly indicate the manner in which wood nailers and/or blocking should be incorporated into construction details. A designer should specify the means of attachment, as well as the fastening schedule for all wood nailers and blocking.

Job-site-fabricated components. A majority of the construction details illustrated in this manual depict job-site-fabricated construction. Many roof system manufacturers offer prefabricated flashing components or have guidelines that permit the use of materials other than those indicated in these details. Flashing materials may vary greatly; individual manufacturer's requirements should be examined and evaluated for construction compatibility.

Metal flashing components. Because metals have thermal expansion and contraction characteristics that differ from most other roof covering materials, it is advisable to isolate metal flashings from the primary roof covering and flashing when possible. Embedding or sandwiching metal flashing flanges into a roof membrane or membrane flashing may fatigue the membrane materials and eventually cause splits, tears or cracks in the membrane as a result of differential movement. NRCA suggests avoiding, where possible, flashing details that require rigid metal flanges to be embedded or sandwiched into roof membranes.

Illustrations of metal component joinery, such as concealed or cover plates, are located in the sheet-metal portion (Details SM-1 to SM-26) of the Construction Details section of this manual. NRCA does not recommend caulking the joint between the bottom of the exterior vertical face of a coping cap or metal edge flashing and building exterior because it does not add to the waterproofing integrity of the assembly and it may, in fact, hinder the ability of the wall construction to dissipate moisture. Proper gauge, girth and continuous cleat fastening should minimize wind-uplift damage.

Rooftop equipment and associated flashing. NRCA does not recommend using a roof as a location for heating, ventilating and air-conditioning (HVAC) equipment. Weatherproofing-related problems may be encountered because of the design of an HVAC unit. There is often a lack of clearly defined responsibility for the weatherproofing of HVAC units among the parties involved, such as contractors, material suppliers and manufacturers. In an effort to minimize rooftop penetrations, run conduits and pipes within the interior of rooftop curbs.

Many weatherproofing problems related to HVAC equipment may be attributed to one or more of the following:

- Improper design of the equipment's exterior shell or housing. This may allow water to enter the building directly through the unit.
- Improper design or penetration of condensate pans or drainage lines. This may allow water to enter the building below the HVAC equipment.
- Improper design of premanufactured HVAC equipment curbs. There are often no means to properly attach base flashings.
- Inadequate design of the structural framing or roof deck intended to support the weight of HVAC units. This may result in excessive roof deflection and subsequent ponding water.
- Improper flashing of the penetration(s), such as pipes, conduits and drain lines, that extend through the roof to service the HVAC equipment.
- Lack of service walkways to and around mechanical equipment for rooftop traffic.

Parapet walls and roof decks. Parapet walls and deck/wall intersections often require specific additional components to accommodate vertical flashings or coping caps. These items can take various forms and be made of various materials.

- Tapered, continuous, rigid shims for top of parapet walls provide positive slope for drainage and may be composed of wood, insulation, metal or other compatible material.

- Tapered cants at bases of wall include preservative-treated wood, perlite, fiberboard or appropriate poured-in-place material.

- Flashing substrate materials on vertical walls and backsides of parapets may include brick or concrete masonry, precast or poured-in-place concrete, wood and gypsum board.

- Through-wall flashing materials, weepholes and masonry caulking are typically furnished and installed by masonry contractors. Sheet-metal receivers are often furnished by a sheet-metal contractor and installed by masonry and wall-cladding contractors.

- Prior to installing metal caps, parapet walls may be covered by a sheet membrane liner in lieu of installing the flashing up and over the parapet wall.

- Concrete, masonry, metal and gypsum board walls should be primed in preparation for bituminous membrane flashings. Any combustible surfaces should have a first ply fastened or adhered and a second ply adhered prior to applying torch-grade flashing membranes.

Penetrations. Roof drains, pitch pockets and vertical sides of curbs often have particular installation or attachment requirements, which follow:

- Interior roof drain bowls and under-deck clamps are typically furnished and installed by others. Clamping rings and dome strainers are generally furnished by others and installed by a roofing contractor.

- Prefabricated flashing, metal sleeves and curbs with premolded pipe flashings are preferred for sealing pipes or irregularly shaped support legs. Pitch pockets or pitch pans are acceptable as a last alternative. Pourable sealer is the recommended top fill material for pitch pockets. Modified bitumen roofing cement may be acceptable as a top fill material for pitch pockets in bituminous roof systems.

- Vertical wood curb nailers may be secured to a structural member or the roof deck using additional wood blocking, metal angle supports or a combination of wood and metal. Curbs may consist of prefabricated (insulated where appropriate) metal curbs and, when securing flashing is necessary, should have nailers at the top edge.

Membrane flashing and stripping plies. The type of membrane system, substrate and surfacing method usually dictates the number, type and method of attachment for backer plies, flashing sheets and stripping plies.

- Specific configuration of backer plies and/or membrane flashing may vary with the individual roof system. Installation of membrane flashing may entail lacing field and flashing plies for a modified bitumen system or using one or two backer plies for torch-applied modified bitumen flashing, depending on the substrate and other application possibilities. Consult the roof system manufacturer's specific requirements for membrane flashing.

- A recommended maximum membrane flashing height may no longer be applicable for certain roof membrane types. Polymer-modified bitumen sheets applied in a strapped configuration and single-ply membranes are acceptable for vertical installations. However, it is suggested a separator consisting of a sheet-metal receiver and removable sheet or cladding be installed to separate the roof flashing from the wall covering.

- Mineral-surfaced polymer-modified membrane sheets should be degranulated (heated with granules pressed into the membrane bitumen) at tie-ins of end laps, flashing base laps or stripping ply overlaps.

- Stripping plies for BUR and modified bitumen systems may consist of two plies of ply sheet, one ply of field ply sheet, and one ply of modified bitumen sheet or one ply of heavyweight reinforced polymer modified bitumen sheet.

- Stripping plies for single-ply roof systems may consist of the same membrane as the roof system; a self-adhering membrane strip; or an unreinforced, uncured membrane sheet.

Roof assembly components — deck, insulation and membrane. In all the construction details, unless otherwise noted, the primary components of each construction detail are illustrated as generic components. In addition, NRCA recommends designers consider the following:

- Rigid board roof insulation depicted in the details is generic and represents a base layer and top layer. The base layer may consist of single layer, double layer or tapered insulation system composed of one or a combination of the materials described in the Rigid Board Roof Insulation section of the Low-Slope Membrane Roofing section of the manual. The top layer of an insulation system should be an appropriate cover board.

- Some single-ply membranes may require a slip sheet beneath the membrane when installed over some insulations or substrates. Such slip sheets are not depicted in the construction details for clarity. Consult the membrane system manufacturer for specific recommendations regarding slip sheets.