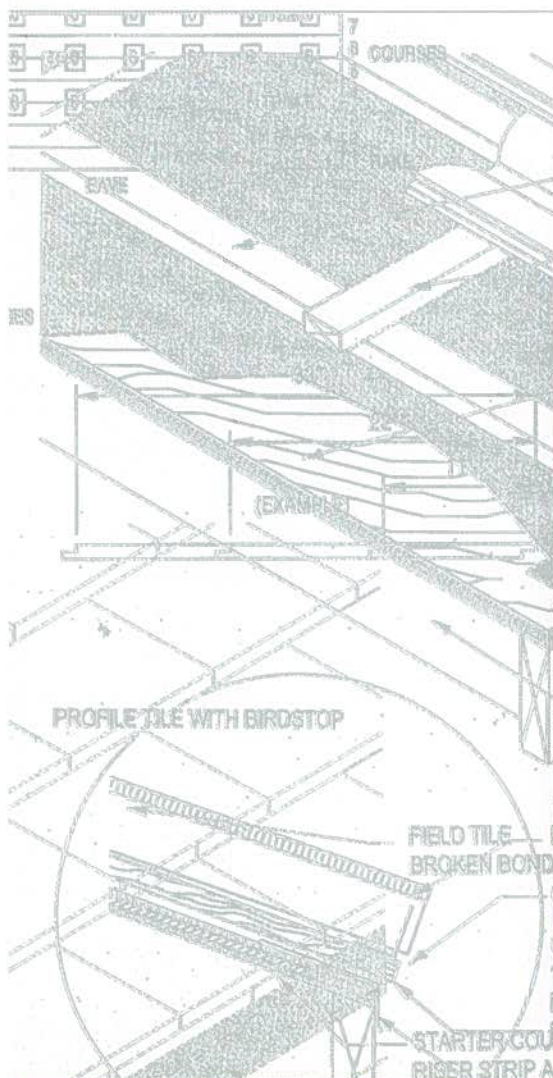


Design Criteria

Installation Manual for Cold and Snow Regions



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**Western States Roofing
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Concrete and Clay Tile Roof Design Criteria Manual for Cold and Snow Regions

by

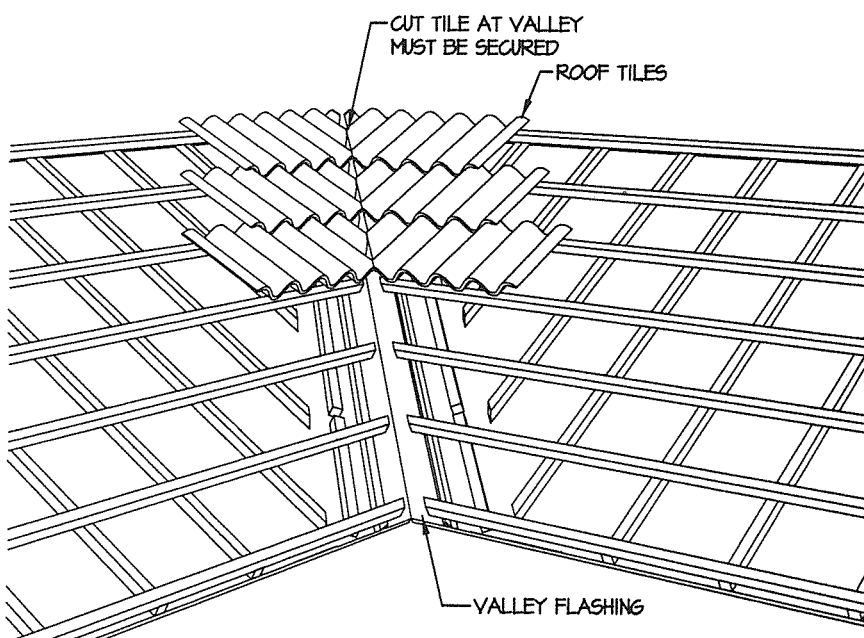
**Tile Roofing Institute
(TRI)**

**Western States Roofing Contractors
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Produced by

Leland E. Gillan, P.E. and Terry Anderson

Review comments by Wayne Tobiasson



Published by:

Tile Roofing Institute
230 Ohio St., Suite 400
Chicago, IL 60611
Phone: (312) 670-4177 • Fax: (312) 644-8557
Web: www.tilerroofing.org

Western States Roofing Contractors Association
1098 Foster City Blvd., Suite 204
Foster City, CA 94404
Phone: (650) 570-5441 • Fax: (650) 570-5460
Web: www.wsrca.com

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Table of Contents

Table of Figures	v
-------------------------------	----------

Preface	ix
----------------------	-----------

Disclaimer	ix
-------------------------	-----------

Chapter 1

Background on Ice Dams

by Leland E. Gillan, P.E.	1-1
Ice Damming	1-1
Super Insulated Roofs	1-4
Cold Roofs	1-4
Cold Roof Concerns	1-9
Snow Movement	1-10
Low-Slope Roofs	1-10

Chapter 2

Design Identification of Cold and Snow Climate Types	2-1
Three Climate Types	2-1

Chapter 3

Climate Type I	3-1
Section I. General Considerations	3-1
Section II. Criteria for Tile	3-1
Section III. Criteria for Architectural Design	3-2
Section IV. Criteria for Underlayment, Asphalt Felts or Waterproofing Membrane	3-3
Section V. Criteria for Decking and Batten Boards	3-4
Section VI. Criteria for Metal Flashing	3-4
Section VII. Criteria for Snow Retention	3-5

Chapter 4

Climate Type II	4-1
Section I. General Considerations	4-1
Section II. Criteria for Tile	4-1
Section III. Criteria for Architectural Design	4-3
Section IV. Criteria for Underlayment, Asphalt Felts or an Ice and Waterproofing Membrane	4-11

Section V. Criteria for Decking and Batten Boards	4-13
Section VI. Criteria for Metal Flashing	4-21
Section VII. Criteria for Snow Retention	4-23

Chapter 5

Climate Type III	5-1
Section I. General Considerations	5-1
Section II. Criteria for Architectural Design	5-1

Chapter 6

Detail Design for Climate Types II and III	6-1
---	------------

Appendix A

Climate Condition Examples	A-1
---	------------

Appendix B

B-1 Ventilation	B-1
Section I. Vapor Drive	B-1
Section II. Controlling Vapor Drive	B-4
B-2 General Field Tile Fastening Guidelines	B-5

Appendix C

References	C-1
-------------------------	------------

Appendix D

About the Editors	D-1
--------------------------------	------------

Glossary

Index

Table of Figures

Chapter 1

Figure 1-1: Icing at eaves	1-3
Figure 1-2: Features of a simple cold roof	1-5
Figure 1-3: Cold roof using scissors truss	1-7
Figure 1-4: Cold roof snow and ice layers	1-8
Figure 1-5: Draining onto a low-slope roof	1-11

Chapter 2

Figure 2-1: Climate type identification map	2-3
---	-----

Chapter 3

Figure 3-1: Roof plan showing straight or full bond tile installation pattern	3-1
Figure 3-2: Roof plan showing staggered or half bond flat tile installation pattern	3-1
Figure 3-3: Good venting is recommended.	3-2
Figure 3-4: Allowable loads in pounds per square foot for No. 2 western cedar horizontal batten boards	3-4
Figure 3-5: Snow bracket placement	3-5

Chapter 4

Figure 4-1: Roof plan showing straight or full bond tile installation pattern	4-1
Figure 4-2: Roof plan showing staggered or half bond flat tile installation pattern	4-2
Figure 4-3: Standard head lap	4-2
Figure 4-4: Increased head lap	4-3
Figure 4-5: Good venting is recommended.	4-4
Figure 4-6: Furnace stack placement	4-5
Figure 4-7: Roof venting with clerestory windows	4-6
Figure 4-8: Ridge vent extension in deep snow	4-7
Figure 4-9: Equivalent soffit and ridge venting	4-7
Figure 4-10: Gable vents installed with ridge and eave vents are not recommended.	4-8
Figure 4-11: One-sided cricket	4-8
Figure 4-12: Draining onto a low-slope roof	4-9
Figure 4-13: Zig zagged heat tracing at roof eave	4-10
Figure 4-14: Heat tracing underneath tile head lap	4-10
Figure 4-15: Heat panel at roof eave	4-11
Figure 4-16: Ice and waterproofing membrane installation	4-12
Figure 4-17: Ice and water protection problem	4-13

Figure 4-18: Condensation problems can occur on a poorly designed roofing and insulation system	4-13
Figure 4-19: Vertical and horizontal batten boards	4-14
Figure 4-20: Typical roof venting	4-15
Figure 4-21: Nomograph to determine vertical batten height	4-17
Figure 4-22: Insulation and batten boards around skylight penetration	4-18
Figure 4-23: Insulation and batten boards around pipe penetration	4-18
Figure 4-24: Ventilation of long valleys is difficult.	4-19
Figure 4-25: Air inlets at the face of a dormer	4-19
Figure 4-26: Areas which may need heating systems if a large open attic is not used	4-19
Figure 4-27: Batten board attachment.....	4-20
Figure 4-28: Allowable loads in pounds per square foot for No. 2 western cedar horizontal batten boards	4-20
Figure 4-29: View of an open valley, typical European design	4-21
Figure 4-30: View at end of valley, typical European design	4-22
Figure 4-31: View of a closed valley with a "W W" flashing.....	4-22
Figure 4-32: View at end of valley with "W W" flashing	4-23
Figure 4-33: Snow bracket placement.....	4-24
Figure 4-34: Tile specific snow fence design	4-24
Figure 4-35: Roof joist attachment snow fence design	4-25

Chapter 5

Figure 5-1: Wall placed to minimize ice damming	5-2
---	-----

Chapter 6

CWT 6-1: Batten board installation.....	6-2
CWT 6-2a: Vertical battens - for deep trough valley	6-3
CWT 6-2b: Horizontal battens - for deep trough valley	6-4
CWT 6-2c: Tile & valley layout - for deep trough valley	6-5
CWT 6-3: Valley metal - for deep trough valley	6-6
CWT 6-4a: Vertical battens - for shallow trough valley	6-7
CWT 6-4b: Horizontal battens - for shallow trough valley	6-8
CWT 6-4c: Tile & valley layout - for shallow trough valley	6-9
CWT 6-5: Valley metal - for shallow trough valley	6-10
CWT 6-6a: Chimney saddle or cricket flashing	6-11
CWT 6-6b: Chimney saddle or cricket flashing	6-12
CWT 6-7: Step flashing at chimney	6-13
CWT 6-8: Ventilated headwall metal flashing	6-14
CWT 6-9: Sheet metal ridge vent.....	6-15
CWT 6-10: Tiled over ridge vent	6-16
CWT 6-11: Alternate ridge vent	6-17
CWT 6-12: Roof flashing at eave	6-18
CWT 6-13: Sidewall flashing.....	6-19
CWT 6-14: Rake flashings	6-20
CWT 6-15: Snow bracket	6-21

CWT 6-16: Tile specific snow fence bracket	6-22
CWT 6-17: Roof Joist attachment snow fence	6-23
CWT 6-18: Pipe penetration flashing	6-24

Appendix B

Figure B-1: Example of difference in size between oxygen and nitrogen	B-1
Figure B-2: Example of condensation	B-2
Figure B-3: Example of vapor drive	B-2
Figure B-4: Vapor drive and ventilation	B-3

Preface

This manual was written to assist architects, engineers, owners and roofing contractors with the process of designing, specifying and installing tile roofs in areas of snow and ice. Tile roofs have qualities that lend themselves well to use in snow and ice climates. Tile roofs have performed well for centuries in Europe and Asia in high mountain areas.

Due to snow movement and ice accumulation, there have been numerous installations of all types of roofs in North America that have required annual repairs, have damaged property below the roof and have either threatened or harmed people. These negative characteristics apply to all roofs **improperly designed** for the region in which they are built.

It is important to learn that it is neither difficult nor expensive to design a roof structurally capable of supporting an accumulation of snow that is much larger than the tile weight. The purpose of most of the designs presented in this manual is to keep the snow on the roof until it melts off. This approach is more compatible with activities on the ground, below the roof, and keeps people off the roof where tiles can be damaged by foot traffic.

Disclaimer

It is not the intent of this manual to take the place of the manufacturer's installation recommendations or code requirements. Rather, this manual provides supplemental information to give a better understanding of how to deal with conditions in snow and ice regions.

The people responsible for the design and installation of tile should be familiar with manufacturer's installation recommendations, local codes and climate conditions. The total responsibility for the adequate performance of a roof in a snow and ice region rests solely with the people responsible for the design, application and construction of the roof.

The text and figures within this manual should not be used or relied upon for any specific application without competent professional examination and verification of their accuracy, suitability and applicability.

Chapter 1

Background on Ice Dams by Leland E. Gillan, P.E.

Roof designs for buildings in the mountains of Colorado should not be the same as those in southern California. Roofs in cold, snowy climates require special considerations to function well. Ignoring these differences can lead to impractical, problematic roofs that require excessive maintenance.

Maintenance and repair work often consists of:

- ♦ shoveling snow and ice off roofs to slow leaks and then shoveling it off driveways and other access ways below;
- ♦ repairing roof damage;
- ♦ repairing eaves damaged by ice;
- ♦ repairing roof damage caused by shoveling;
- ♦ repairing interior damage caused by roof leaks;
- ♦ installing electrical heat tape in attempts to “fix” design problems.

In cold snowy regions, people are kept busy repairing inadequately designed roof systems.

Ice Damming

Snow and ice accumulation at the down-slope eaves creates a dam that backs up water on the roof. Most steep roofs are designed to shed water, and they are not covered with waterproof membranes. When water backs up on these roofs, they leak unless special precautions are taken.

Ice weighs approximately 57 pounds per cubic foot. The unit weight of snow on a roof can be close to that of ice or as low as 4 pounds per cubic foot. Most snow on roofs that has been compacted with warming and cooling cycles weighs between 10 and 25 pounds per cubic foot. Ice dams extending out beyond the roof edge and large icicles hanging from them create a tremendous load on the eaves. Structurally, it is difficult to design for this load. It is much more appropriate to

design roofs so that such loads do not occur.

A combination of two effects creates ice dams at eaves in regions with high snow accumulation.

1. The largest effect is associated with heat moving from inside a warm building, through the ceiling, attic or roof joist assembly into the snow on its roof. Depending on the amount and type of insulation, the amount of ventilation, the depth of snow and the outside temperature, this heat may melt the snow.

If the base of the snow pack warms to 32°F, snow will slowly melt. The water produced runs down the slope of the roof. If the outside temperature is cold enough, generally below 22°F, the water refreezes when it reaches the cold eave of the roof.

2. The second effect is related to solar heating and night time cooling. It is a minor effect at lower elevations but can be a powerful consideration in mountain areas due to intense solar radiation and the thin mountain air at high altitudes.

- a) Intense solar radiation penetrates the snow and melts some of it, even when the ambient temperature may be below 32°F. If the melt water flows into a shaded area, it may freeze.

Snow will only hold about 2 to 5 percent water. As the water drops through the snow, a small portion of the water refreezes, releasing enough energy to heat the surrounding snow to 32°F. From a thermal stand point, it takes approximately one British Thermal Unit (BTU) of heat to raise the temperature of 1 pound of snow by .5°F. It takes 144 BTUs to turn 1 pound of ice to water. Very little water will raise the temperature of snow to 32°F.

- b) It often gets very hot on clear days in the mountains and very cold on clear nights. Melt water produced during such days may refreeze on eaves because of the drastic temperature drop from day to night.

Ice accumulation at the eave can happen quickly on a cold night if there is snow on the roof and excessive heat loss from the building into the roof system. Ice dams have long icicles hanging down from them. Water ponds up slope from the ice

dam. This water is insulated from the cold by the snow above, and it receives heat from the building below. This heat often prevents the water from freezing behind the ice dam. The water is located above an exterior wall. In high altitude areas, the water behind the ice dam will freeze at night if the heat loss from the building is low.

Ice dams that accumulate over a longer period of time from minor heat loss from the building or the effects of high altitude look more like the ice dam shown in Figure 1-1. Water freezes at the outer edge of the ice dam and backs up the additional water flowing down the roof. When the water overflows the buildup at the edge, additional water freezes and builds the ice dam a little higher and farther out.

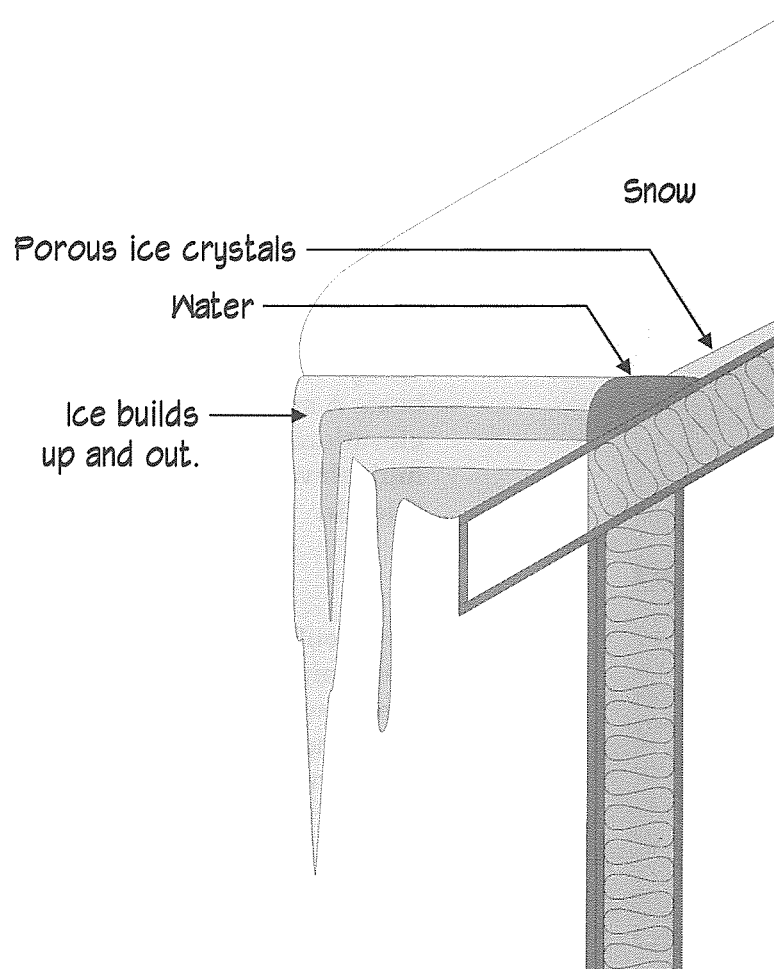


Figure 1-1: Icing at eaves

Water ponded behind an ice dam penetrates at head and side laps. The water often turns to ice beneath the roofing material on the cold eaves. As ice forms, it expands; this action can loosen fasteners. Ice under the roofing material becomes part of the ice dam. The overhanging ice mass may overturn, taking the roofing material with it. It may also overload the eaves, causing them to fail.

Super Insulated Roofs

Super insulated roofs have a thermal resistance rating of R-45 or greater and a vapor retarder on the warm side of the insulation. Generally these systems are not vented or are vented only enough to avoid creating a vapor trap in the attic or roof joist space. A super insulated roof greatly reduces, but does not stop, heat escaping the building. In some places, super insulation without ventilation is enough to eliminate chronic icing at eaves.

It is almost impossible with standard building materials and construction techniques to prevent some vapor and heat loss into an attic or roof joist space to prevent melting snow. Generally architects design more complicated buildings that require more than four walls. For these reasons providing good venting space between the insulation and the roof deck is always recommended as a means to carry off any escaping heat. **A super insulated roof is not recommended at low elevations. Further, a super insulated roof will not work in high elevation applications due to high solar radiation and thin air.**

Cold Roofs

Cold roofs are recommended for most roofs in snow regions that drain to cold eaves where ice dams form. Cold roofs are vented well enough to prevent snow on them from melting when the outside ambient temperature is 22°F or colder. When it is warmer than 22°F, outside melt water usually does not refreeze on cold eaves. Figure 1-2 shows a cold roof.

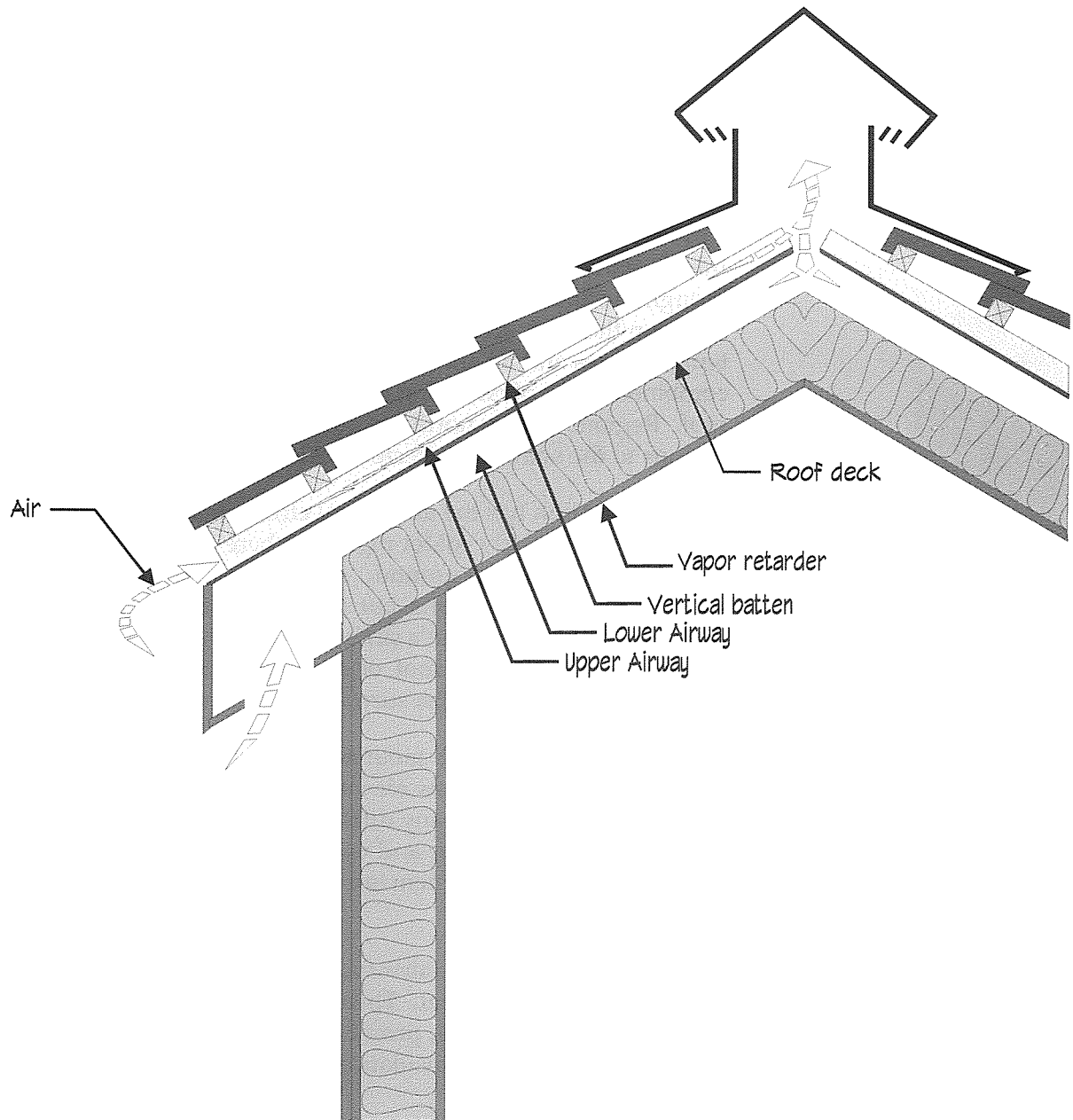


Figure 1-2: Features of a simple cold roof

Cold roofs at high elevations above sea level need more ventilation than roofs in other cold snowy regions. Intense solar radiation and thin mountain air also promote the buildup of ice dams. Europeans have used dual airway systems of venting in high mountain areas for many years. See Figure 1-2. Substantial insulation and a continuous vapor retarder are important features of such roofs.

Intense solar radiation will melt the snow on the roof even though the ambient temperature is less than 20°F, causing ice dams on the roof. Intense solar radiation can also mean higher temperatures and no snow. Elevation and latitude have a combined effect of changing the sun's intensity radiating to the roof. Regions farther north are affected during spring, whereas regions to the south are affected during late winter.

Higher elevation has the additional effect of creating colder days and particularly colder nights as there is less atmosphere to hold the heat on the ground. The radiant heat of the sun is greater at higher elevations, but so is the heat loss caused by the emissivity of the earth's surface heat to the sky. At night, the temperature of a tile roof, or any object exposed to the clear sky, will be colder than the surrounding air temperature.

Ice dam research for high mountain areas is limited. Ice dam prevention is based on low elevation ice dam research and visual observations of many different roof systems in high mountain areas. Tight air and vapor retarders, heavy insulation and a ventilation system are needed to avoid ice damming in the mountains.

Cathedral ceilings where airways exist between solid joists are hardest to adequately vent. The use of a scissors truss can avoid individual airways, promote cross ventilation and provide a large area for insulation and venting. See Figure 1-3.

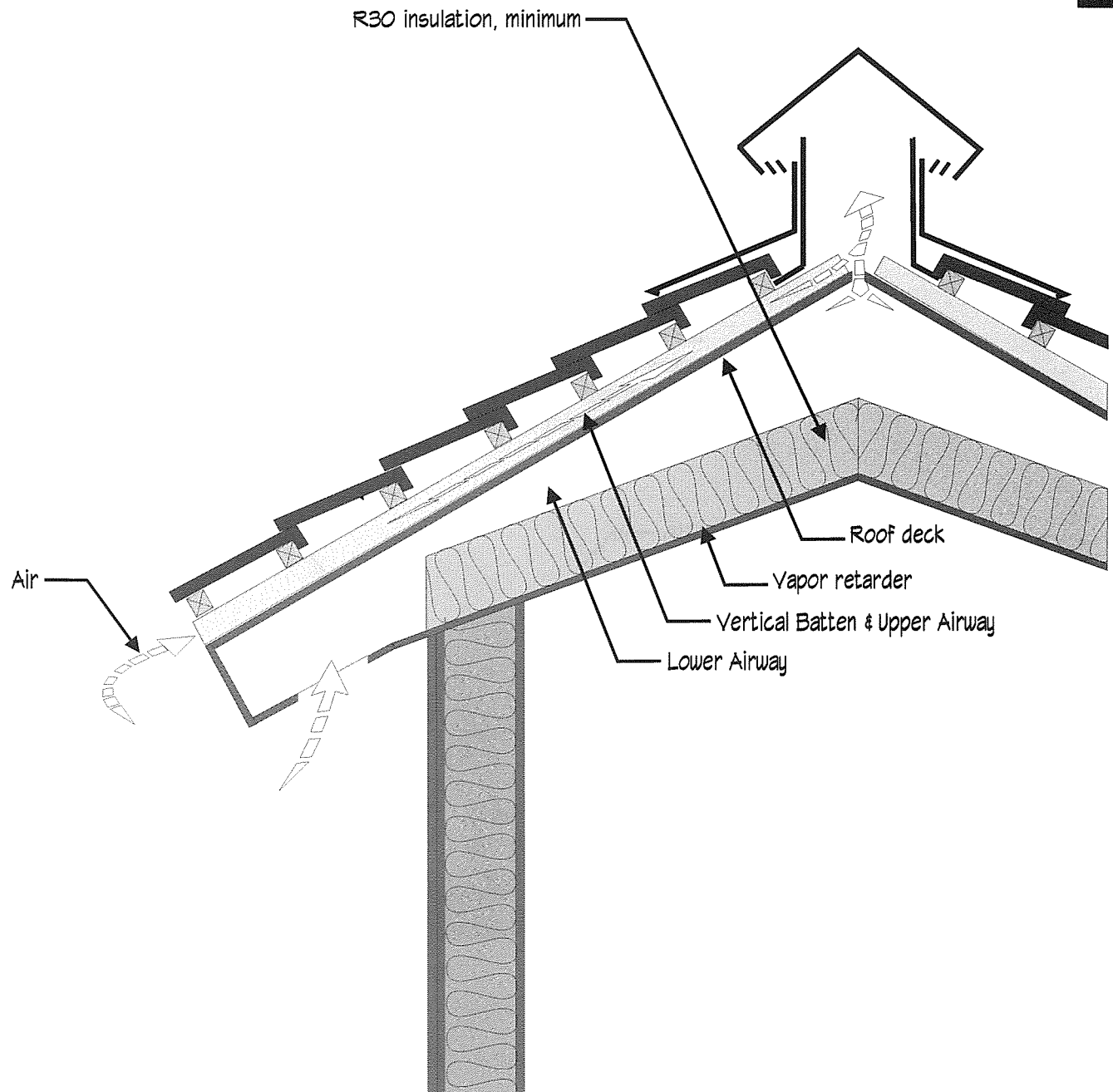


Figure 1-3: Cold roof using scissors truss

Shaded areas of a roof, such as roofs exposed to the sun over most of its surface but shaded at the lower roof edge by trees, are problematic in mountainous areas. Melt water refreezes in the shaded areas. In the same way, dormers and other roof surface interruptions cause shadows or differing amounts of solar radiation on the roof. Ice may also form in these areas. Observations show that the problems created by shaded areas can be reduced by increasing roof ventilation.

With a cold roof, when the sun goes behind a cloud, the snow on the roof is returned to the temperature of the surrounding air from above and to a lesser extent from below. Water in the snow refreezes in small crystals, creating what can be referred to as ripened snow. This ripened snow provides a flow path for future melt water to run off. See Figure 1-4.

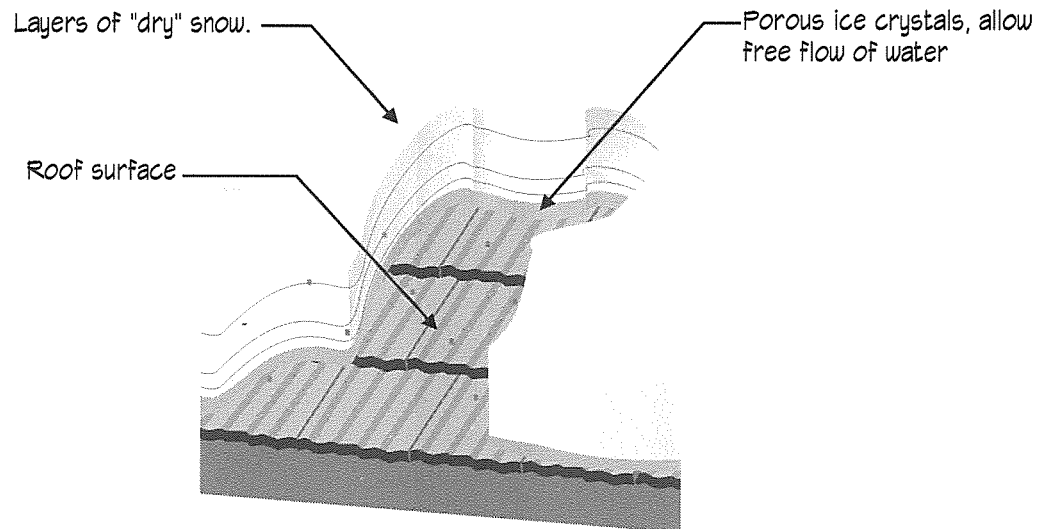


Figure 1-4: Cold roof snow and ice layers

Cold Roof Concerns

The concerns typically encountered with unsuccessful cold roofs include:

- ♦ The airway is too small or blocked.
- ♦ Ventilation in the attic is constricted or blocked at the outside walls where the vertical distance between the roof and the ceiling is minimal.
- ♦ Airway inlet is inadequate.
- ♦ Air flow is blocked in rafter spaces by cathedral ceilings, hips, valleys and roof penetrations such as chimneys and skylights.
- ♦ Screen mesh openings at the eave or ridge are too small or clogged with snow or debris and do not allow adequate free air movement.
- ♦ Ridge ventilation is inadequate or placed so that it becomes obstructed with snow.
- ♦ Mechanical equipment blows warm air onto the snow.
- ♦ Roof penetrations add heat to the cold ventilation space.
- ♦ Air exfiltration allows excessive building heat and moisture to enter the roof.
- ♦ Heat losses from the building are excessive due to inadequate or poorly installed insulation.
- ♦ At high elevations above sea level, high intensity solar radiation shines more directly onto south facing roofs. On those that drain to a shaded area, the melt water refreezes. Generally, a simple roof makes it easier to create a design that will require less maintenance in a mountain environment. Skylights, chimneys and dormers create shaded areas and are difficult to vent around.

Snow Movement

Steep roofs should be designed to **prevent the snow from moving on the roof**. At lower slopes and in areas that do not experience much snow, the tile surfaces may be able to prevent snow movement. Snow guards (fences or brackets) must be considered. A recommended slope of between 4:12 (4 inches vertically to 12 inches horizontally) and 9:12 should be considered for a reasonable number of snow retention devices. Steeper roofs increase the need for snow retention. Some snow retention systems are under designed, and snow rips them from the roof.

Consult a structural engineer or snow guard manufacturer for anchor placement and design. If insufficient snow retention devices are used, the snow may rip them from the roof.

Allowing snow to slide off a roof requires special considerations and is not recommended. Snow does not come off a roof in a controlled fashion. Variable weather conditions before, during and after a snow fall prevent predictable snow slides. Dormers, waste stacks and other roof plane breaks are difficult, if not impossible, to design around. The impact zone of falling snow prevents a good building design from incorporating trees or shrubs in the area. The buildup of snow along a building can deteriorate siding and direct melt water into the building. Pedestrian walkways, driveways, lower roofs, gas meters and garage entrances can be adversely affected by sliding snow.

Low-Slope Roofs

Low-slope roofs that drain to an eave or downspout on the exterior of a building are exposed to the cold and are prone to freezing. This can cause extensive areas of ponding and increase the chance for leaks. They are a contributing factor to many roof collapses. The roofs are designed to carry heavy wet snow and some ice load. Ice blocking the scupper or eave and backing up water may overload the roof. In addition, external drains ice up and overflow onto building siding, causing additional maintenance problems.

Low-slope roofs should drain the melt water to a low area in the roof located within the heated walls of the building. A drain should be installed and heated by the building's heat, ensuring the drain will always be open to carry off water.

Condensation on cold interior roof drain piping can be a problem in a warm attic area. For this reason it is best to use drain piping which is wrapped with appropriate vapor sealing insulation on the warm side of the insulation. A plastic roof drain pipe may provide enough insulation to prevent condensation if the relative humidity in the attic is not too high. Consult with local building officials to determine if plastic pipe such as PVC or ABS is allowed.

As shown in Figure 1-6, low-slope, internally drained roofs can be used to keep water from a steep roof from reaching cold eaves. The low-slope roof acts as a heated gutter to drain off the water. The vertical offset between the two roofs should be close enough together that snow buildup will bridge the gap between the roofs and prevent ice dams from forming. The steep roof will usually require snow retention devices to prevent snow movement or even snow creep. Parapet walls in this type of design have been broken due to snow creep.

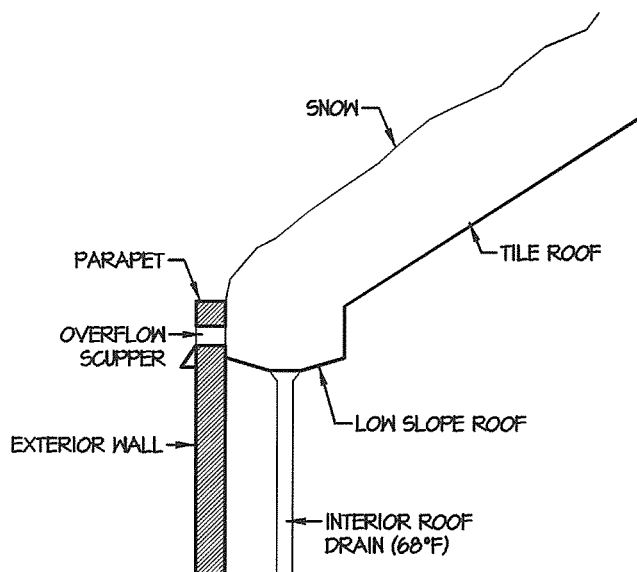


Figure 1-5: Draining onto a low-slope roof

Chapter 2

Design Identification of Cold and Snow Climate Types

Three Climate Types

A.1. It is convenient to think in terms of three climate types for roofing in cold and snow regions. Use the following table to give an initial indication of the type of climate in which the site is located. Then, use the information following the table to more specifically define the type of climate and an appropriate design.

Climate Type	Ice Dams?	Cause?	Refer to:
Climate Type I	No	N/A	Chapter 3
Climate Type II	Yes	Building Heat Loss	Chapter 4 and Appendices A and B
Climate Type III	Yes	Building Heat Loss and High Solar Radiation	Chapter 5 and Appendices A and B

Table 2-1: Initial climate type identification

Note: This table gives only an initial indication of the climate type. See the rest of Chapter 2 and Appendices A and B for more information.

B.1. The **three climate types** reached in the table have the following general characteristics:

B.1.1. Climate Type I experiences snow and cold on occasion, but it is so often warm during winter that deep snow packs and chronic icing problems do not develop.

B.1.2. Climate Type II is generally a cold, snowy climate where snow remains on roofs for weeks or more at a time. Ice dams are primarily caused by heat escaping from the building. Generally, this climate experiences cold air below 30°F for many days and nights at a time.

B.1.3. Climate Type III is a high elevation cold, snowy climate. Ice damming is caused by heat escaping from the building and by **high day time solar radiation**.

Generally, these areas have dramatic temperature fluctuations from day to night.

C.1. The following **climate-related** questions will help classify the site's weather conditions. Consideration of these items may lead to a more specific climate classification. (Appendix A gives specific examples.)

C.1.1. Does the local code require a self-adhering ice and waterproofing membrane to extend from the roof edge to some distance inside the interior wall? If so, how far? This indicates the presence and possible size of ice dams and may indicate Climate Type II or III.

C.1.2. Does wind blow often or constantly? What is the design wind load in the area? The snow can blow off the roofs and may not become a problem. This may indicate Climate Type I.

C.1.3. Are there special considerations such as a large body of warm water or mountains in the area? These can cause unexpected local climate conditions. For instance, in some areas, the mountains can cause a Chinook wind that will melt the snow in the area. A Chinook wind is caused by air moving across the mountains and dropping down into the valley. The air warms as it is compressed by dropping to a lower elevation. This may indicate Climate Type I where you would otherwise expect Climate Type II.

C.1.4. What is the elevation above sea level in feet? Elevation gives an indication of the effect of the solar heat gain. This information may help determine if ice dams are formed more by the sun's radiation or heat loss from the building. Also, does the temperature fluctuate a great deal from day to night in the thin air? High elevations are more likely to be Climate Type III.

C.1.5. How long does the snow stay on the roofs? If generally less than two weeks, this may indicate Climate Type I.

D.1. Climate Types in the United States: The Cold Regions Research and Engineering Laboratory (CRREL) has compiled a map of 50 year mean recurrence interval (50 year) ground snow loads. It was prepared by Wayne Tobiasson and Alan Greatedorex of the U.S. Army Corps of Engineering, CRREL, Hanover, New Hampshire. This map, shown in Figure 2-1 on Pages 4 to 5, along with Table 2-2 on Page 6 can be used to **help** determine climate type. Notes on the map explain the elevation limits (numbers in parenthesis).

D.1.1. In "CS" areas on the map, a snow load Case Study or local experience is needed to determine the 50 year ground snow load. Once the 50 year value is established, Table 2-2 can be used to determine the climate type.

D.1.2. Example: Per Figure 2-1, an area in the northwest corner of New Mexico at an elevation 6,500 feet would have a 50 year ground snow load of 15 pounds per square foot. According to Table 2-2, this building would be in Climate Type I. See Appendix A for more examples.

D.1.3. As with the information in the rest of the chapter, some areas or regions may not perfectly indicate one climate type. Consequently, be sure to review all the information in this chapter.

D.1.4. Ground snow loads shown in Figure 2-1 are often less than the local building department roof load requirements. These ground snow loads are based on actual measurements of accumulated snow loads over many years. These measurements are used to create a projection of the heaviest accumulated load that may be seen over a 50 year period. The roof load from building departments is generally referred to as live load. This load takes into account snow loads, a safety factor for snow drifts, ice dams and uneven distribution of weight during roofing installation.

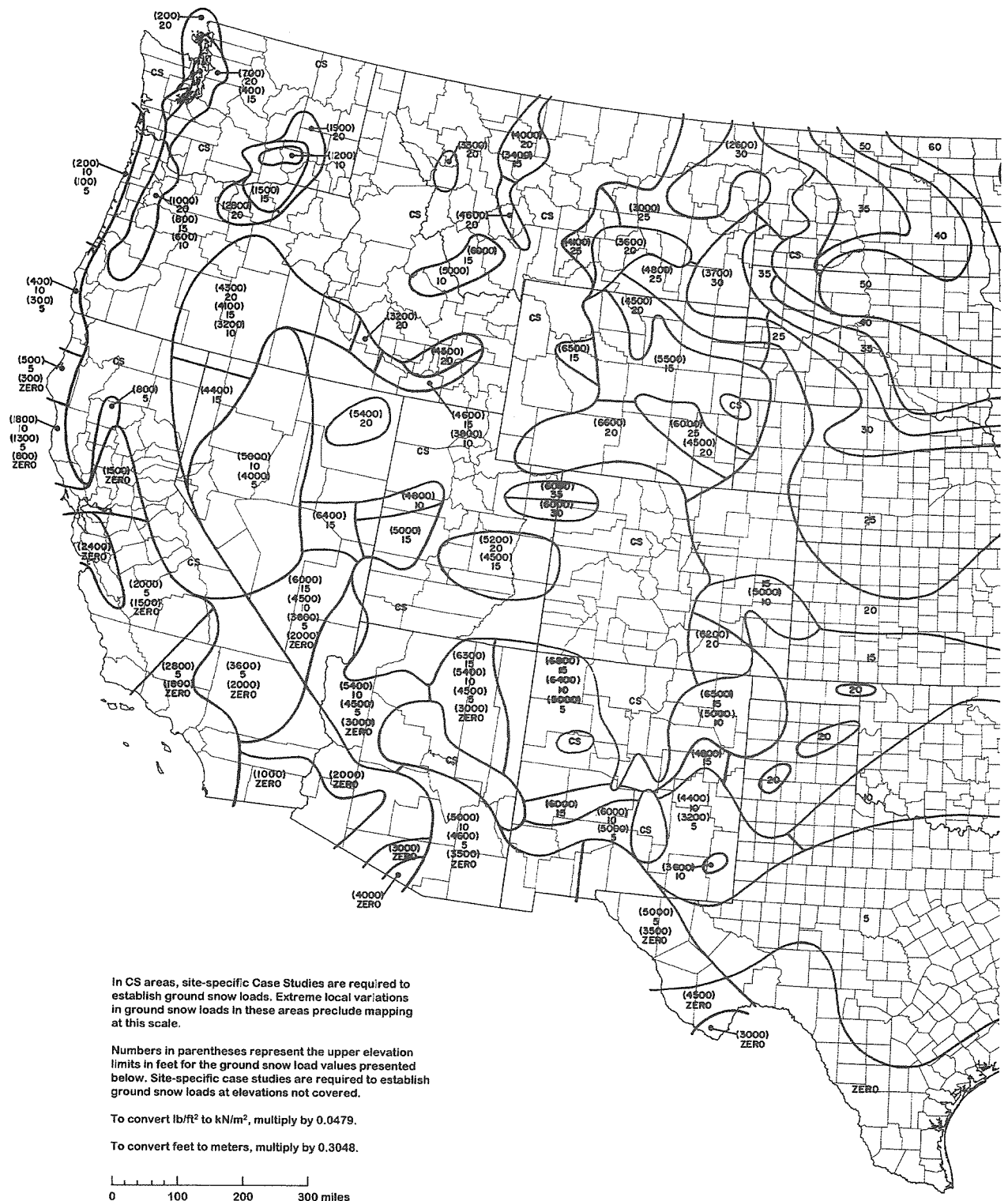
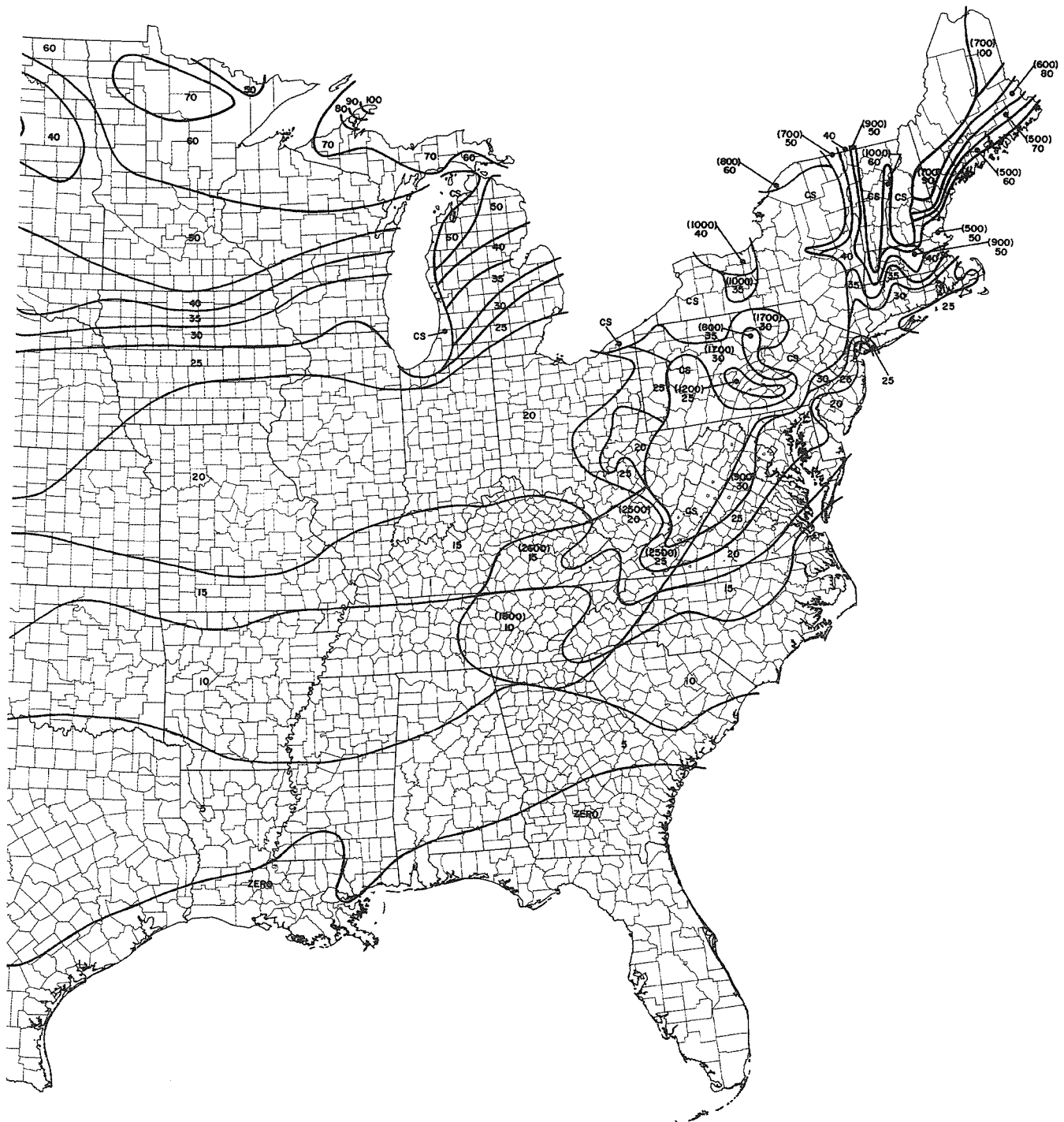


Figure 2-1: Climate type identification map



Ground Snow Load**Climate Type**

0 and 5

This manual does not apply

10

May be Type I

15 through 25

I

30 or more

II

30 or more with elevation
above 6,000 feet

III

Table 2-2: Climate types

Chapter 3

Climate Type I

Section I. General Considerations

A.1. Climate Type I is a cold and snow region, but ice dams are not a recurring problem.

B.1. Consider a minimum of R-30 insulation.

Section II. Criteria for Tile

A.1. **Clay Tile.** Use grade 1 clay tile in accordance with ASTM standard C1167. This tile is specified for use in climates with freeze-thaw cycles.

B.1. **Concrete Tile.** Use tile with integral color only.

C.1. The straight or full bond method of roof tile installation can be useful in snow and ice regions. See Figure 3-1. This method allows the batten boards beneath the tiles to be more flexible without breaking the tiles. Flat tiles are designed to have a staggered or half bond to better carry the water in the side channels. See Figure 3-2. Consult with the tile manufacturer for installation recommendations.

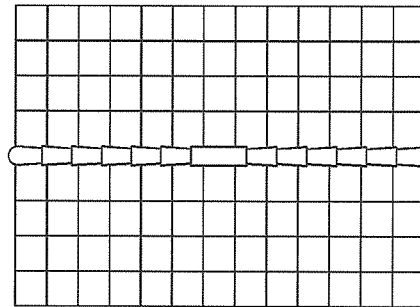


Figure 3-1: Roof plan showing straight or full bond tile installation pattern

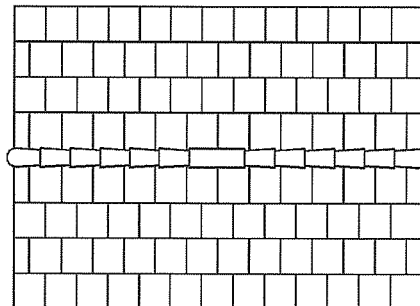


Figure 3-2: Roof plan showing staggered or half bond flat tile installation pattern

C.2. Install tile fasteners according to the manufacturer's instructions and code requirements for the region.

C.3. In addition to other required fasteners, an approved construction adhesive properly applied on rake, ridge, hip and cut pieces will give additional securement. Adhesives applied incorrectly will not allow for proper tile movement. Consult with the tile manufacturer for installation procedures.

C.4. There are many different types of tile. This manual is written for the more common tiles found. Some deviations may be required for the installation of various tiles. Consult with the tile manufacturer for installation procedures.

Section III. Criteria for Architectural Design

A.1. Roof slope or steepness affects the ability to retain snow on the roof. From a practical stand point, a roof slope of **over** 9 inches vertically to 12 inches horizontally (9:12) will require an excessive number of tile fastener and snow retention devices. Snow retention devices may be required on roof slopes less than 4:12.

B.1. Install venting to reduce the temperature and moisture accumulation in attics and rafter spaces of cathedral ceilings. These areas should have cross ventilation (equal intake and exhaust areas) with openings protected against the entrance of driving rain and blowing snow. The net free ventilation system area should not be less than 1/300 of the area of the space ventilated if the roof/ceiling assembly has a vapor retarder. See Figure 3-3 and Appendix B.

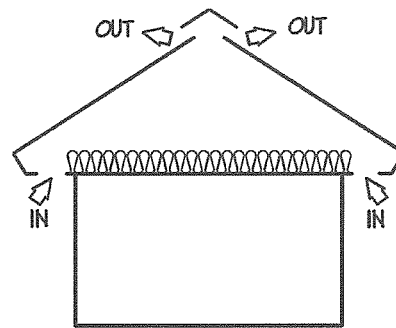


Figure 3-3: Good venting is recommended.

C.1. An eave overhang will provide protection from water dripping down the siding or onto decks, causing damage to both. Such overhangs also provide an area for air inlets. A minimum overhang of 1 foot beyond the building wall line or deck that the roof covers is recommended.

D.1. Vapor retarders are needed. Although they need a perm rating less than 1.0 to minimize diffusion of moist air up into the roof, they must have continuity to resist air movement. Most moisture problems in such roofs are the result of inadequate resistance to exfiltration of warm moist indoor air. Stopping air exfiltration is the key to avoiding condensation problems.

Section IV. Criteria for Underlayment, Asphalt Felts or Waterproofing Membrane

A.1. Felt underlayments are intended to protect the building from wind driven snow or rain. They are required by code. Even a good tile may allow a dry light snow to blow in under it and onto the felt where melting will eventually occur.

B.1. On a well designed tile roof, the underlayment generally wears out before the tile. Two layers of ASTM D226, Type II, No. 30 asphaltic felt overlaid in shingle fashion is the recommended minimum.

C.1. Asphaltic felt deterioration is caused in various ways.

C.1.1. Exposure to the sun's ultraviolet rays deteriorates the felt's surface very quickly. This exposure often takes place after the roof felt has been installed but not yet covered with tiles. In some cases, months have passed before felts are covered with tile.

C.1.2. Water running over or, much worse, ponding on the felts removes the asphalt's oils. Dirt collecting on the felts behind horizontal batten boards placed directly on the felts will hold water. This will keep felts moist for extended periods of time, causing rapid deterioration. Placing vertical batten boards (i.e., counter battens) below the horizontal batten boards that hold the tile, allows water to drain off the felts quickly and helps prevent dirt accumulation.

C.1.3 As the asphalt oxidizes from exposure to air, it becomes brittle. This is okay on a roof as long as it is not exposed to sunlight or handled since the old brittle asphalt felt will rip very easily.

D.1. While an adhered waterproofing membrane may not be required in valleys and along eaves, it can a cost-effective valuable addition to prolong the life of the roof.

Section V. Criteria for Decking and Batten Boards

A.1. Horizontal batten boards should be designed by a structural engineer to support the weight of the tiles and design snow load or live load of the roof. Deflection should be no more than the distance between batten boards divided by 240. Larger deflection can result in tile breakage, generally at the corners of tiles. This is the typical deflection allowed by code for a roof. Figure 3-4 shows allowable loads for horizontal batten boards.

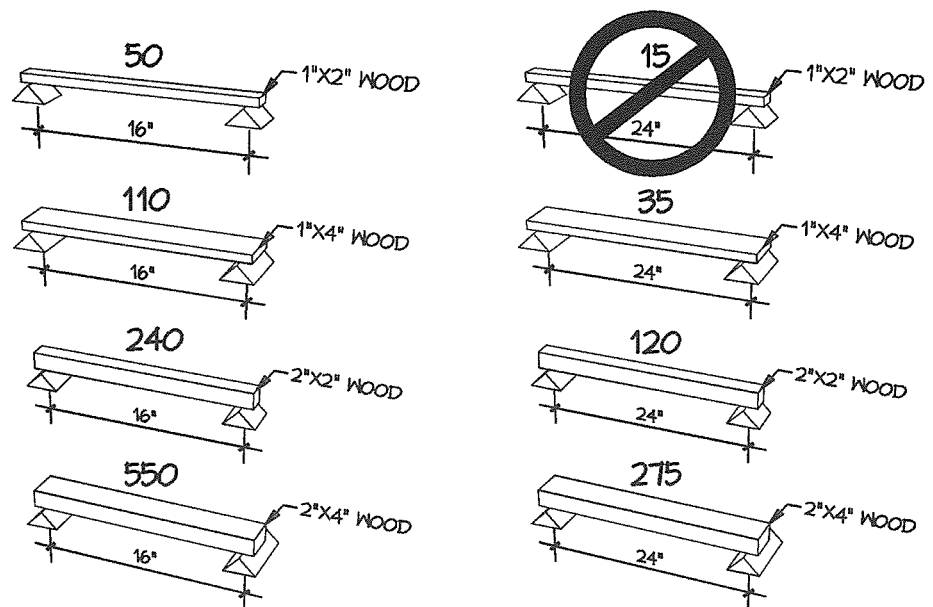


Figure 3-4: Allowable loads in pounds per square foot for No. 2 western cedar horizontal batten boards

B.1. Nailing tables for wind loads and snow loads with respect to roof slope can be found in tile manufacturers' installation recommendations.

C.1. All fasteners must be corrosion resistant.

Section VI. Criteria for Metal Flashing

A.1. Flashing for tile roofs must do more than just keep water out of the building; it must also keep water out from under the tile. At pipe or vent penetrations, a jack should be used at the roof deck and on the roof surface. Along walls, a waterproofing membrane shall be used from the deck up the walls 6 inches. The tile surface shall be flashed to prevent water from getting below the tile. This is critical in snow areas since the tile can be lifted by the collection of ice below the tile.

B.1. Minimum thickness of metal flashing shall be to local code requirements.

C.1. Siding should always be terminated a minimum of 2 inches above the roof or horizontal flashing to prevent it from absorbing water, collecting debris and deteriorating prematurely.

D.1. Lead or other malleable products must be used with profile tiles to direct water onto the tile where the top edge of the tile butts against a wall.

Section VII. Criteria for Snow Retention

A.1. Snow bracket design is critical. There are many roofs with flattened out snow brackets that were inadequately sized for either strength or quantities.

A.1.1. Place the snow load bearing part of the brackets on the overlap so the batten boards support the weight of the snow on the bracket. See Figure 3-5.

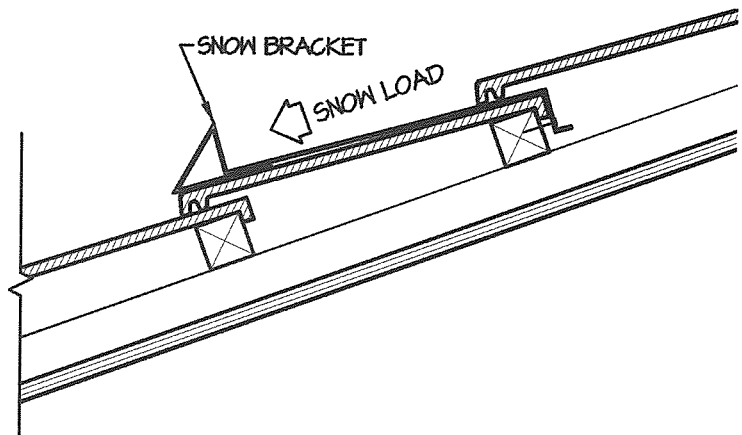


Figure 3-5: Snow bracket placement

A.1.2. Snow brackets should be spaced evenly over the entire roof in a staggered pattern.

A.1.3. Consult with the bracket manufacturer for an adequate design and layout. A structural engineer may be needed if the bracket manufacturer will not accept responsibility for the design.

B.1. The snow retention device manufacturer will need the following information for proper design:

- ♦ Roof dimensions and slope
- ♦ Type of tile
- ♦ Deck information including vertical and horizontal batten boards, deck thickness and material and fasteners used to hold the roof and batten boards together
- ♦ Aesthetic look
- ♦ Roof snow load
- ♦ Local code requirements
- ♦ Vertical and horizontal batten board sizes, layout and fastening

C.1. Request the following information from the snow retention bracket manufacturer and/or structural engineer:

- ♦ Snow loads used
- ♦ Installation instructions
- ♦ Sizing
- ♦ Load on each snow bracket
- ♦ Layout
- ♦ Requirements to seal any penetrations

Chapter 4

Climate Type II

Section I. General Considerations

A.1. Climate Type II is a cold and snow region where ice dams caused by building heat loss are a recurring problem.

B.1. Consider a minimum of R-30 insulation.

C.1. An air and vapor retarder should be standard in all ceilings. An effective air and vapor retarder will restrict vapor drive, thereby helping to prevent excessive condensation within the roof assembly. This helps keep the latent heat from the roof system. (Appendix B)

D.1. An unvented super insulated system can be successful if well designed and built. In the real world of construction, it is best to use a cold ventilated roof.

Section II. Criteria for Tile

A.1. **Clay Tile.** Use grade 1 clay tile in accordance with ASTM standard C1167. This tile is specified for use in climates with freeze-thaw cycles.

B.1. **Concrete Tile.** Use tile with integral color only, meeting ASTM standard C1492.

C.1. The straight or full bond method of roof tile installation can be useful in snow and ice regions. See Figure 4-1. This method allows the batten boards beneath the tiles to be more flexible without breaking the tiles. Flat tiles are designed to have a staggered or half bond to better carry the water in the side channels. See Figure 4-2. Consult with the tile manufacturer for installation recommendations.

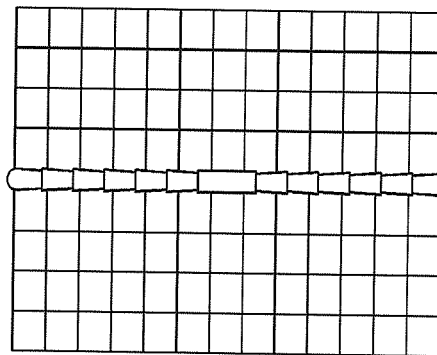


Figure 4-1: Roof plan showing straight or full bond tile installation pattern

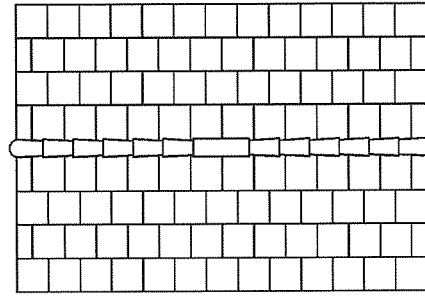


Figure 4-2: Roof plan showing staggered or half bond flat tile installation pattern

C.2. Install tile fasteners according to the manufacturer's instructions and code requirements for the region.

C.3. In addition to other required fasteners, an approved construction adhesive properly applied on rake, ridge, hip and cut pieces will give additional securement. Adhesives applied incorrectly will not allow for proper tile movement. Consult with the tile manufacturer for installation procedures.

C.4. Tiles can take heavy snow loads. Tiles are designed and tested for an average load of 300 pounds and a minimum load of 250 pounds. These test loads are concentrated at the center of the tile. Snow loads are spread over the entire tile.

C.5. Increasing head lap will not reduce the loading on most tiles. Rather, the purpose of increasing the head lap on most tiles is to prevent wind driven snow and rain from getting underneath the tile on lower sloped roofs. With most tiles, reducing the distance between batten boards will not reduce the span of the tile. To prevent wind driven rain and snow from getting under the tile, the lower batten edge of the tile has a lip to ensure contact with the tile below. This lip and the upper hook in the tile, not the batten board spacing, determine the span of the tile. Consult with the manufacturer for design specifics. See Figures 4-3 and 4-4.

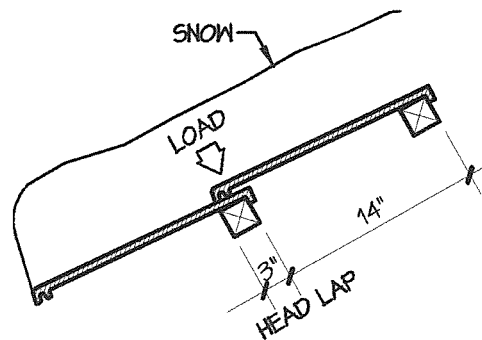


Figure 4-3: Standard head lap

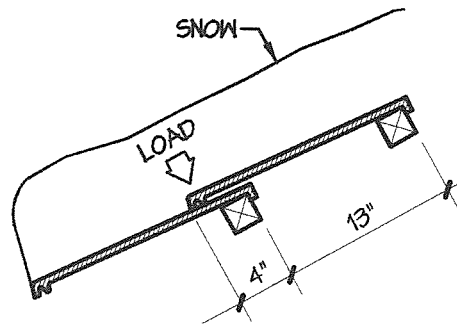


Figure 4-4: Increased head lap

Note: The load does not transfer directly through to the batten; instead, the load transfers through the span of the tile. The tile span is the same as in Figure 4-3 (about 17 inches) with the same snow load. The snow load is just transferred through the tile below instead of through the batten. In addition, the weight on the tile is increased by the additional tile necessary to create the larger overlap.

C.6. There are many different types of tile. This manual is written for the more common tiles found. Some deviations may be required for the installation of various tiles. Consult with the tile manufacturer for installation procedures.

Section III. Criteria for Architectural Design

A.1. Roof slope or steepness affects the ability to retain snow on the roof. From a practical stand point, a roof slope of **over** 9 inches vertically to 12 inches horizontally (9:12) will require an excessive number of tile fastener and snow retention devices. Snow retention devices may be required on roof slopes less than 4:12. See Section VII of this chapter.

A.2. Too shallow a slope, less than 4:12, hinders the air flow under the tiles.

B.1. Install venting to reduce the temperature and moisture accumulation in attics and rafter spaces of cathedral ceilings. These areas should have cross ventilation (equal intake and exhaust areas) with openings protected against the entrance of driving rain and snow. The net free ventilation system area should be designed to remove the heat escaping from the building and maintain a cold attic. See Section V of this chapter for design information. Some locations have very dry winter climates, and local code officials do not require vents for condensation control. However, vents are recommended to prevent heat from getting to the roofing system. In some cases, the venting prevents moisture-laden warm air from condensing under the roof deck or within the roof assembly. See Figure 4-5 and Appendix B.

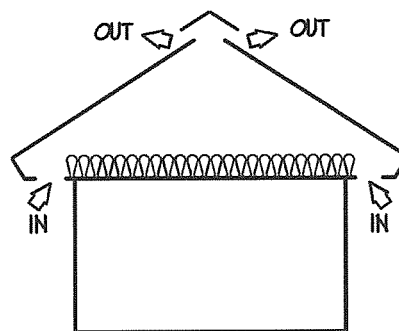


Figure 4-5: Good venting is recommended.

B.2. Vapor retarders are needed. Although they need a perm rating less than 1.0 to minimize diffusion of moist air up into the roof, they must have continuity to resist air movement. Most moisture problems in such roofs are the result of inadequate resistance to exfiltration of warm moist indoor air. Stopping air exfiltration is the key to avoiding condensation problems.

B.3. Unventilated super insulated roofs (R-45 or greater) can avoid ice damming if they are well built. To avoid moisture problems, an unventilated system must contain excellent air and vapor retarders. The construction of unventilated roofs takes special skills and high attention to detail. All penetrations in the air and vapor retarders must be tightly sealed. If this can not be achieved, a ventilated system should be used.

C.1. If recessed lights are to be used, install them so that neither the insulation nor the vapor retarder is compromised.

D.1. Design and construct roof penetrations such as plumbing vent stacks or exhaust vents so that excessive heat is not added to the attic, rafter space or directly to the roof surface. Roof penetrations that exhaust warm air should be installed within 5 feet of the ridge to prevent heat from blowing over a large portion of the roof and melting snow. Furnace stacks should be installed in enclosed structures like a chimney to reduce snow melt around them. The stack should be high enough above the ridge so heat coming out of the stack will not be blown down onto the roof and melt the snow. See Figure 4-6.

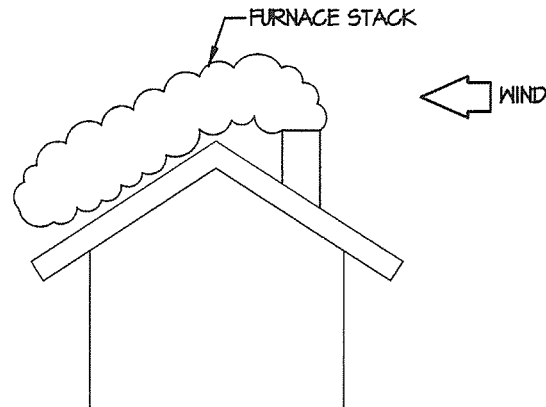


Figure 4-6: Furnace stack placement

D.2. On buildings with commercial kitchens or large boilers the amount of heat generated and exhausted through roof vents can blow over the top of the roof and melt a tremendous amount of snow. Positioning such vents on the downwind side of the prevailing wind and above the ridge line will help reduce this effect. Where hot vents melt a lot of snow on a roof, a snow melting system may be needed at the eaves to restrict ice dam growth.

E.1. Ventilation design and components (i.e., soffit, ridge vents, screens and louvers) have a large effect on air flow that is often overlooked.

E.1.1. The air flow through a duct (i.e., the chase cavity either between roof rafters or the space between vertical batten boards) is limited both by getting air in and out of the duct at the eave and ridge and by moving air flow through the duct. It is best to make the entrance at the eave and the exits at the ridge as large as practical but at least as large as the smaller portion of the duct.

E.1.2. Air flow is reduced by the screens or mesh on the vent openings, so code requirements for venting are based on the net free area of a screened opening. Some codes require a minimum of 1/4 inch mesh or screen to keep out birds and squirrels. However, this will not keep out most insects.

E.1.3. Smaller screens will keep many insects out but may also reduce the air flow. Fine mesh or screen tends to collect air born debris that over time clogs the tiny openings.

E.1.4. There are several manufactured eave and ridge vents on the market. Most do not have information about air flow losses through their products. There is a large difference between products which should be investigated.

E.1.5. Some manufacturers have recognized that a clean screen is much better and have fabricated their vent screens using nonstick material.

E.2. Adequate clearance must be left for venting where roofs rise into vertical walls. Often these walls have clerestory windows. See Figure 4-7. Enough space must be provided for adequate venting of the tile and/or rafter space below the window.

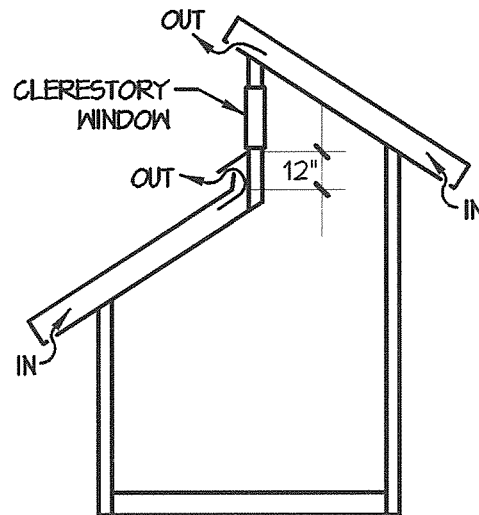


Figure 4-7: Roof venting with clerestory windows
See also Chapter 6, CWT 8

E.3. Deep snow may accumulate at the ridge of gable roofs located in sheltered areas. A ridge extension may be needed to bring the venting above the snow. See Figure 4-8. Depending on the roof design and location, a mechanical venting system might be considered. Cupolas installed for venting purposes can also be decorative.

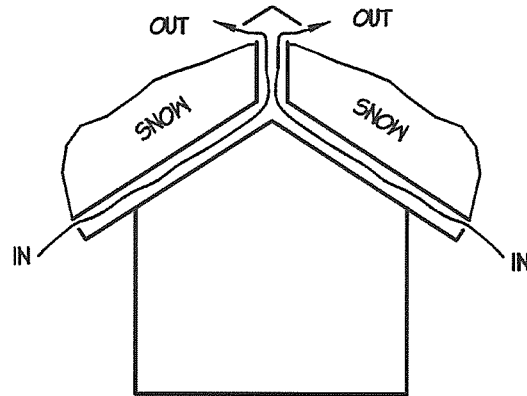


Figure 4-8: Ridge vent extension in deep snow
See also Chapter 6, CWT 6-7

F.1. To keep a positive air flow through the attic or cold roof, the net free area of the vent openings at the ridge should be equal to the net free area of air intakes at the eaves. See Figure 4-9.

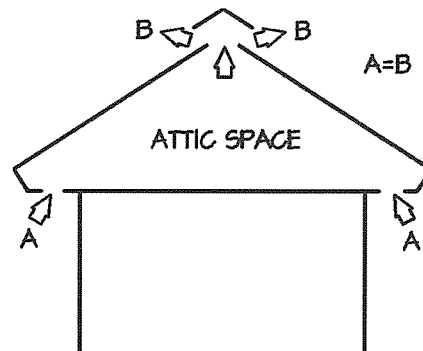


Figure 4-9: Equivalent soffit and ridge venting

F.2. The maximum air flow with the best air distribution is gained by taking in air all along the eaves and exhausting it all along the ridge.

F.3. Gable vents seldom create an even distribution of ventilation air in an attic and therefore may be inadequate. When gable end vents are installed in combination with continuous ridge and eave vents, blowing snow and rain may be sucked into the building through the gable vent. See Figure 4-10.

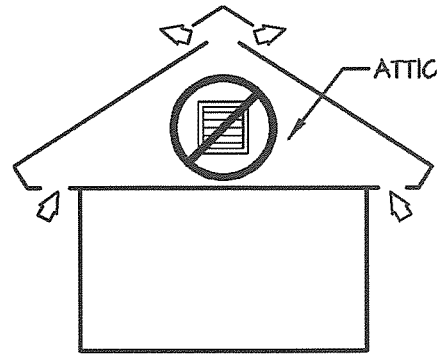


Figure 4-10: Gable vents installed with ridge and eave vents are not recommended. The gable vent can “short circuit” intended ventilation and may suck in blowing snow and rain.

G.1. An eave overhang will provide protection from water dripping down the siding or onto decks, causing damage to both. Such overhangs also provide an area for air inlets. A minimum overhang of 1 foot beyond the building wall line or deck that the roof covers is recommended.

H.1. Chimney structures located adjacent to exterior gables or near the ridge of a roof hinder air flow in attics or rafter spaces much less. A one-sided chimney cricket should be used to force water to a roof surface rather than over the rake where the water will drain down the siding. See Figure 4-11.

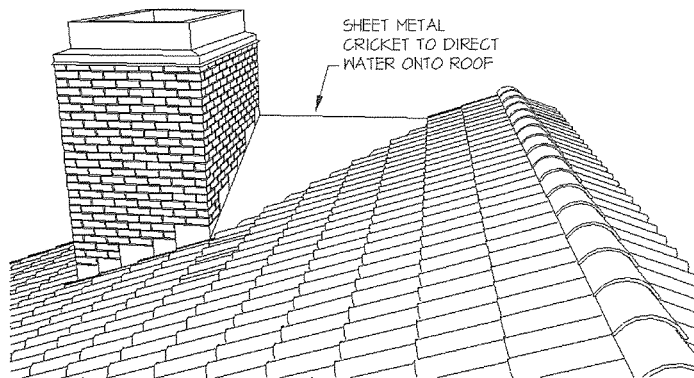


Figure 4-11: One-sided cricket

I.1. Passive design may be defined as a low maintenance roof that requires no external heating systems to control ice damming. The architectural design for some parts of a complicated roof may cause ice dams to form. The following may be considered.

I.1.1. Low-slope internally drained roofs can be used to keep water from a steep roof from reaching cold eaves. The low-slope roof acts as a heated gutter to drain off the water. The vertical offset between the two roofs should be close enough that snow buildup will bridge the gap between the roofs and prevent ice dams from forming. The steep roof will usually require snow retention devices to prevent snow movement or snow creep. Parapet walls have been broken due to snow creep with this type of design. See Figure 4-12.

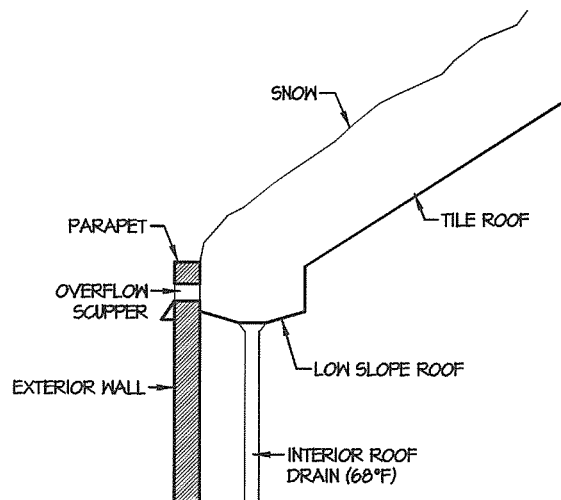


Figure 4-12: Draining onto a low-slope roof

I.1.2. The interior roof drain should be piped directly to an underground storm drain line or the outside of the building. If the latter option is chosen, the drain should discharge approximately 6 inches above the ground in a snow covered landscaped area with good slope away from the building. Metal drain spouts on the exterior of the building are not recommended. Water coming out of the spouts will freeze before it can drip off the metal spouts.

I.2. A cold roof design may be passive if the bottom of the roof deck's temperature is below 30°F when the outside temperature is below 22°F.

J.1. Non-passive design, or designs that rely on external heating systems, may allow more flexibility in roof aesthetics. However, they require additional maintenance and are more likely to be problematic.

J.1.1. Heat tracing can be zig zagged up and down the roof. See Figure 4-13. This only works moderately well, and sunlight deteriorates cables. Aesthetically this wiring is unattractive in the summer; in the winter the snow on the roof melts in a strange looking pattern. Often the tracing is installed too far up the roof or too far apart and causes additional water to run down to the roof edge, creating larger ice dams and icicles at the eaves than if there were no heat tracing.

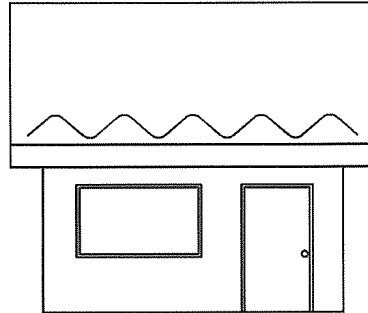


Figure 4-13: Zig zagged heat tracing at roof eave

J.1.2. Heat tracing underneath the tile head lap with approximately 10 watts per foot of tracing wire has proven to be effective in preventing ice dams. It is important that the tile rest tightly on the tracing. The wire is protected from the sun and is aesthetically pleasing. See Figure 4-14.

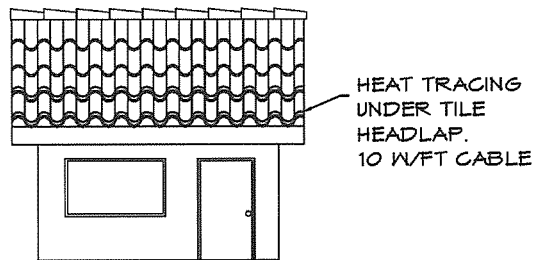


Figure 4-14: Heat tracing underneath tile head lap

J.1.3. Heat tracing under metal "apron" panels works well; the panels protect the wiring, distribute the heat, and aesthetically give a nice line of snow. The panels can blend in with tile roofs. See Figure 4-15.

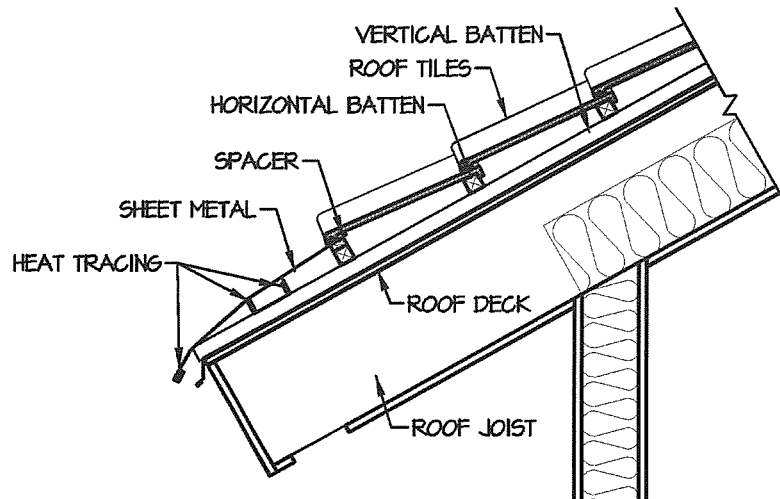


Figure 4-15: Heat panel at roof eave

J.1.4. The disadvantages of electrical heat tracing are:

- ♦ It wears out, often in the middle of the winter, when it is discovered that the roof is iced up. Its durability is not predictable.
- ♦ Some heat tracing deteriorates quickly in the sun. Poor quality heat tracing may only last one season. Better quality heat tracing may last 20 years if it is protected from the sun, 10 years if exposed.
- ♦ It is expensive to install, and electricity costs are high.
- ♦ There can be potential fire danger if the wire is not installed correctly. A licensed electrician should do the installation.

J.2. Hydronic heating panels use a glycol heating system. This system may be less expensive to run than heat tracing because it generally uses the building gas fired boiler heating system.

Section IV. Criteria for Underlayment, Asphalt Felts or an Ice and Waterproofing Membrane

A.1. Felt underlayments are intended to protect the building from wind driven snow or rain. They are required by code. Even a good tile may allow a dry light snow to blow in under it and onto the felt where melting will eventually occur.

B.1. On a well designed tile roof, the underlayment generally wears out before the tile. Two layers of ASTM D226, Type II, No. 30 asphaltic felt overlaid in shingle fashion is the recommended minimum.

C.1. Asphaltic felt deterioration is caused in various ways.

C.1.1. Exposure to the sun's ultraviolet rays deteriorates the felt's surface very quickly. This exposure often takes place after the roof felt has been installed but not yet covered with tiles. In some cases, months have passed before felts are covered with tile.

C.1.2. Water running over or, much worse, ponding on the felts removes the asphalt's oils. Dirt collecting on the felts behind horizontal batten boards placed directly on the felts will hold water. This will keep felts moist for extended periods of time, causing rapid deterioration. Placing vertical batten boards (i.e., counter battens) below the horizontal batten boards that hold the tile allows water to drain off the felts quickly and helps prevent dirt accumulation.

C.1.3 As the asphalt oxidizes from exposure to air, it becomes brittle. This is okay on a roof as long as it is not exposed to sunlight or handled since the old brittle asphalt felt will rip very easily.

D.1. While an adhered waterproofing membrane may not be required in valleys and along eaves, it can a cost-effective valuable addition to prolong the life of the roof.

D.2. Peel and stick waterproofing membrane should extend from the eave up the roof a minimum of 24 inches above the inside wall. Some local building departments may require additional coverage. This application may prevent the entry of water should an ice dam back water up onto the roof. It is also prudent to install similar protection in valleys, at crickets and around dormers and other similar roof penetrations. See Figure 4-16.

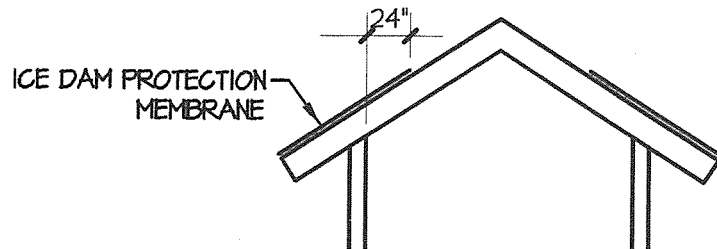


Figure 4-16: Ice and waterproofing membrane installation

E.1. Caution: A roof completely covered in a waterproofing membrane, sometimes with asphaltic felts, and either an inadequate vapor retarder or no vapor retarder with no venting may prevent adequate vapor removal from the attic or rafter joist space. Apparent roof leaks that are actually the accumulation of condensation may develop. See Figures 4-17, 4-18 and Appendix B.

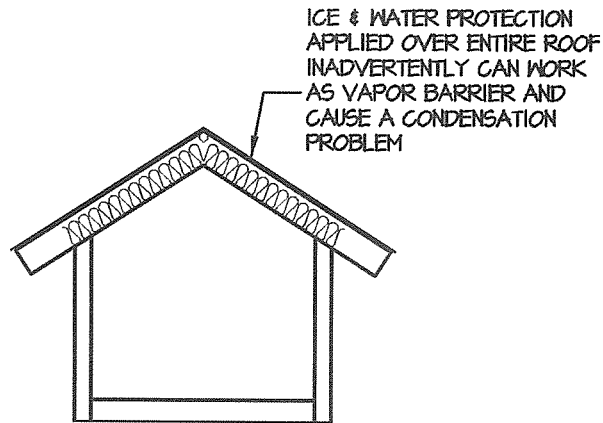


Figure 4-17: Ice and water protection problem

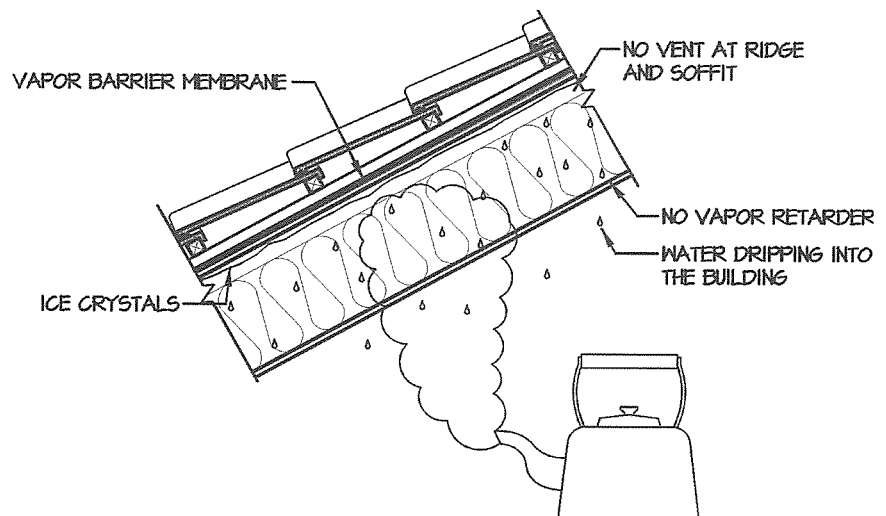


Figure 4-18: Condensation problems can occur on a poorly designed roofing and insulation system

Section V. Criteria for Decking and Batten Boards

A.1. Height of batten for air flow:

A.1.1. Vertical batten boards create a duct through which cold ambient air can travel, maintaining the temperature under the roof below freezing in cold weather. See Figure 4-19.

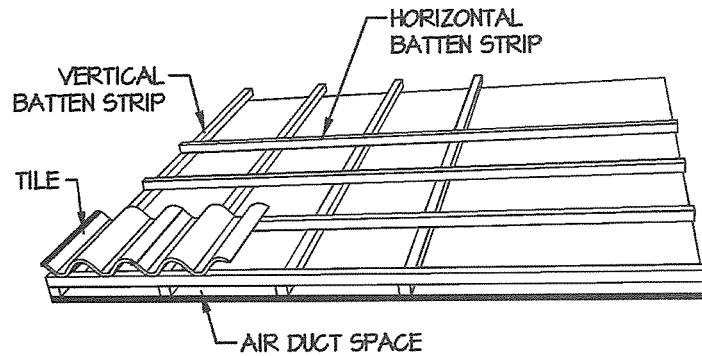


Figure 4-19: Vertical and horizontal batten boards
Note: Flashing is not shown for clarity.

A.1.2. There are many factors that affect how high the tile should be raised off the roof:

- ♦ Distance from eaves to ridge (i.e., length of airway)
- ♦ Roof slope
- ♦ Amount of insulation present
- ♦ Quality of vapor retarder and air barrier
- ♦ Size of airways
- ♦ Number and size of airway interruptions
- ♦ Size of inlet and outlet openings
- ♦ Wind
- ♦ Inside temperatures

A.1.3. To allow flexibility in design, there are three suggested ways of determining cold roof venting requirements for **Climate Types II and III** (i.e., attic ventilation, dual airway ventilation or vertical batten ventilation only.) In each system, any roof penetration must be well insulated.

A.1.3.1. Unobstructed attic space venting.

Provide 1 square foot of net free intake area at eaves and 1 square foot of net free exhaust area at the ridge for every 125 square feet of attic. To obtain the ridge venting area, cupolas or some other ridge structure may be needed. See Section III of this chapter for more information.

Openings at the eaves and ridge must allow for even distribution of ventilating air below the entire roof deck. A well sealed vapor retarder on the warm side of a minimum of R-40 insulation is required. Vertical batten boards at least 3/4 inch high are recommended above the deck to create an upper airway and allow free drainage of any moisture that gets under the tiles.

A.1.3.2. Dual airway venting with an attic or rafter space. The information in the following tables is from the *Bramac Tile Venting Manual* containing Austrian standard B 2219. All values are for a minimum of R-35 insulation and a well sealed vapor retarder on the warm side of the roof. More ventilation is needed when these requirements are not met. See Figure 4-20 and Tables 4-1 and 4-2.

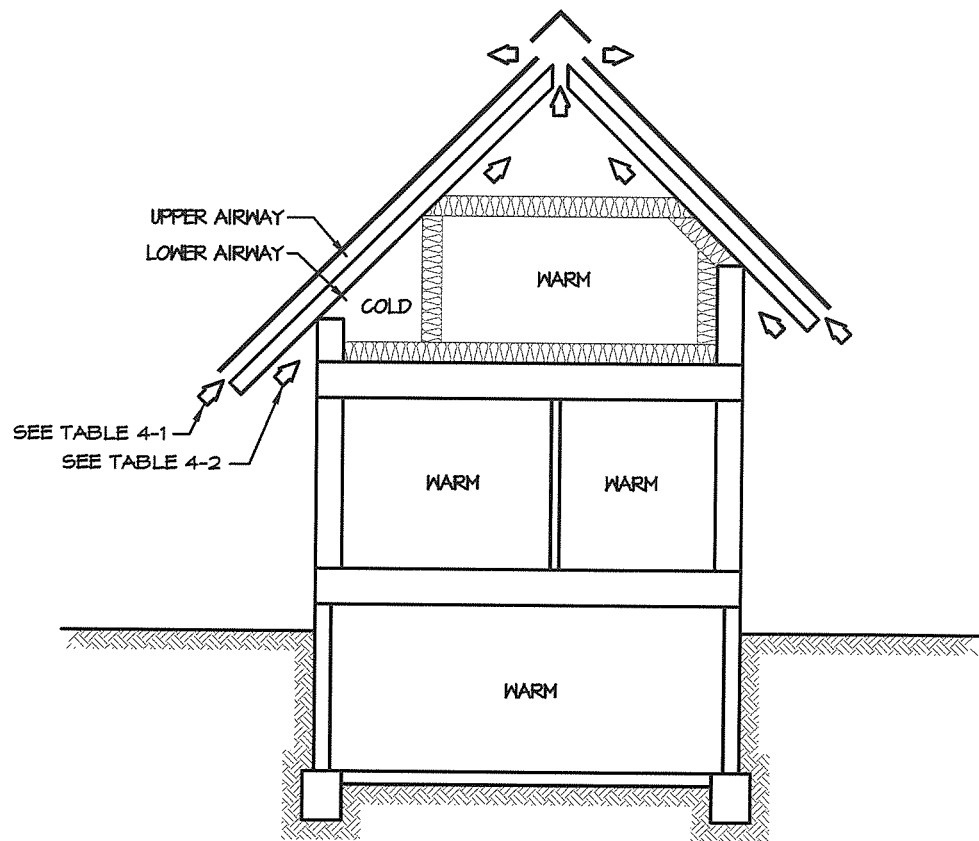


Figure 4-20: Typical roof venting

Note: A vapor retarder on the warm side of minimum R-35 insulation is required.

Rafter Length (feet)	Roof Slope		
	4:12	6:12	7:12
16	2	2	2
33	2	2	2
49	2.5	2	2
66	4	2.5	2
82	4	3	2.5

Table 4-1: **Height of upper airway.** Vertical batten board height in inches as a function of roof slope and rafter length. Note: On a ridge where two roof planes meet, the total outlet opening area must equal the inlet opening areas from both sides of the roof. This chart must be used in conjunction with properly vented rafter spaces below the deck. See Table 4-2.

Rafter Length (feet)	Roof Slope					
	4:12		6:12		7:12	
	Inlet	Outlet	Inlet	Outlet	Inlet	Outlet
16	3.8	4.7	3.3	4.25	2.8	3.8
33	7.6	9.5	6.6	8.5	5.7	9.5
49	11.3	14.2	9.9	12.7	8.5	11.3
66	15.1	18.9	13.2	17	11.3	15.1
82	18.9	22.7	16.4	19.8	14.2	17

Table 4-2: **Venting below roof deck (lower airway).** Inlet and outlet opening sizes in square inches per running foot of eaves as a function of rafter length. At the ridge where the two roof planes meet, the outlet sizes must be added together.

Example: Given a 6:12 roof pitch with an eave to ridge distance of 49 feet, per Table 4-1, the counter batten board height is 2 inches. Per Table 4-2, the inlet and outlet opening sizes into, through and out of an attic or rafter space are 9.9 square inches per foot of free open area for the inlet and 12.7 square inches per foot of free open area for the outlet.

A.1.3.3. Vertical Batten Space Venting Only. This system can only perform well if a well sealed vapor retarder and air exfiltration membrane is used. The nomograph in Figure 4-21 was derived using the same basic relationships between roof pitch, roof length, air velocities and practical experience of what has worked on roofs.

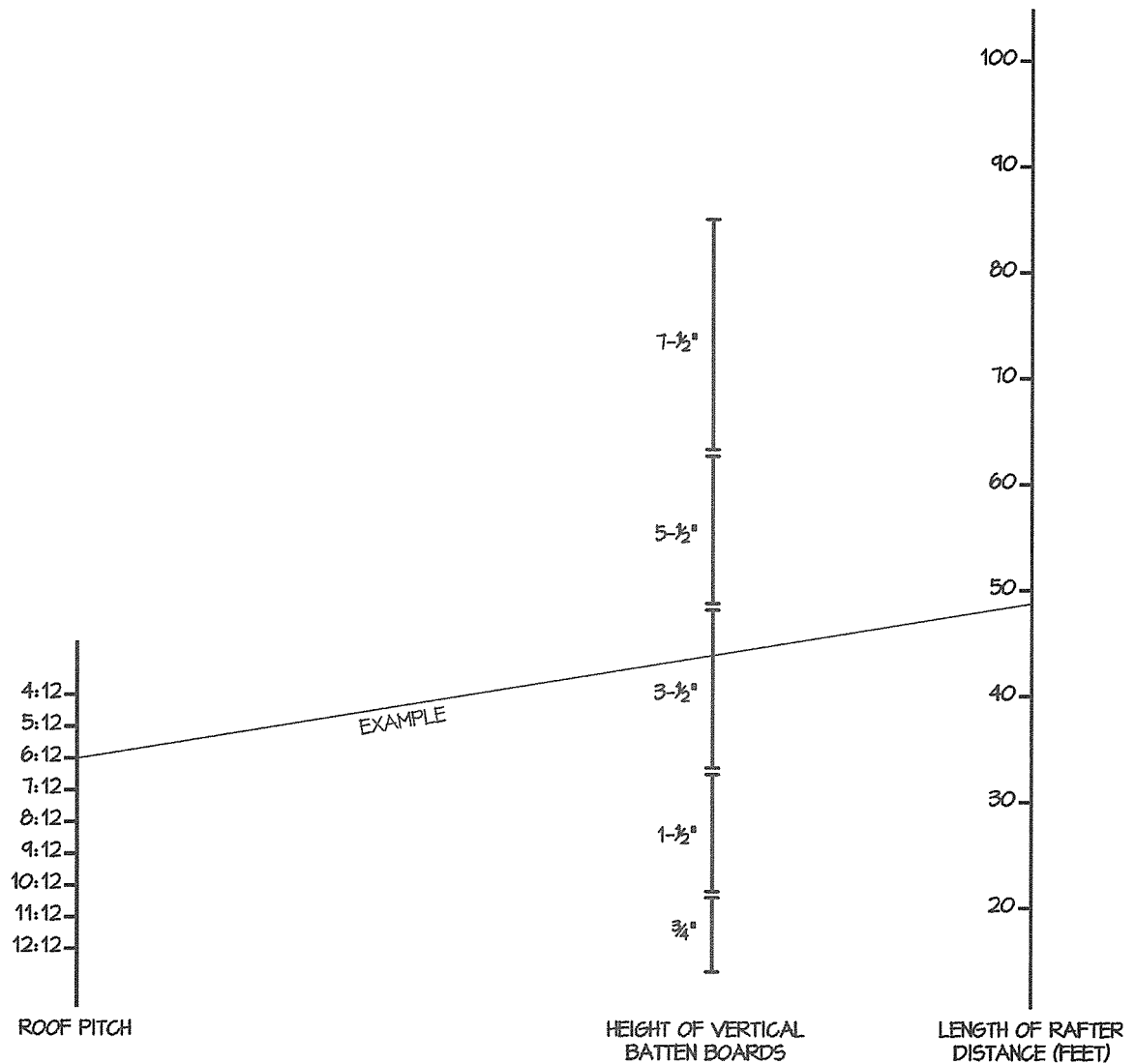


Figure 4-21: Nomograph to determine vertical batten height

Note: Move to next nominal size up if large penetrations such as skylights are placed on roofs.

Example: Given a 6:12 pitch roof with a rafter length of 49 feet, use 2 x 4 inch vertical batten boards with 4 inches as the vertical dimension. Use 2 x 6 inch batten boards if skylights are present. The soffit and ridge vents must provide openings equal to the vent area created by the vertical batten boards.

A.2. Roof penetrations such as waste stacks or skylights will add heat to the cold air space and block air flow. Areas around such penetrations should be insulated and the batten boards spaced to allow air flow around them. See Figures 4-22 and 4-23.

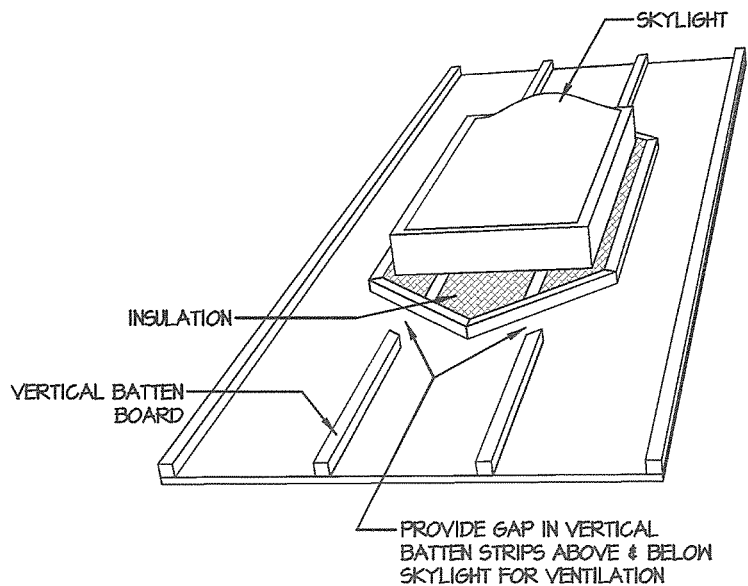


Figure 4-22: Insulation and batten boards around skylight penetration

Note: Horizontal batten boards and tiles have not been shown for clarity. The insulation will help reduce the heat loss from the skylight.

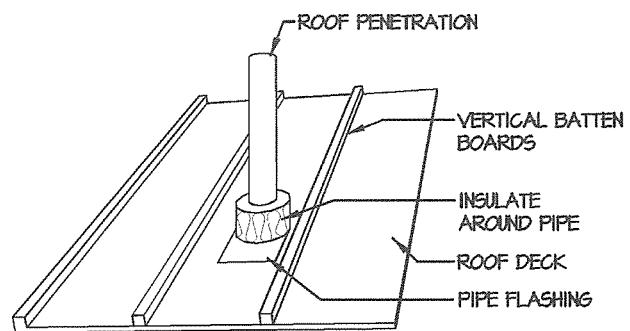


Figure 4-23: Insulation and batten boards around pipe penetration

Note: Horizontal batten boards and tiles are not shown for clarity.

A.3. It is difficult to provide adequate ventilation at valleys since inlets are limited. See Figure 4-24. Exhaust at the ridge should be continued to the valley top since that will promote some lateral air movement up over the tops of the vertical batten boards. This will help cool the valley. Vertical batten boards should be held back from the valley to provide a direct flow up it.

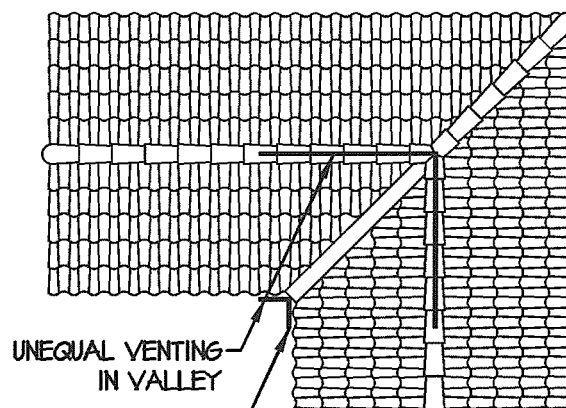


Figure 4-24: Ventilation of long valleys is difficult.

A.3.1. Some air can be brought in from the rake edge of the dormers through horizontal batten boards. However, this is not very effective. Power venting in these areas may be necessary. See Figure 4-25.

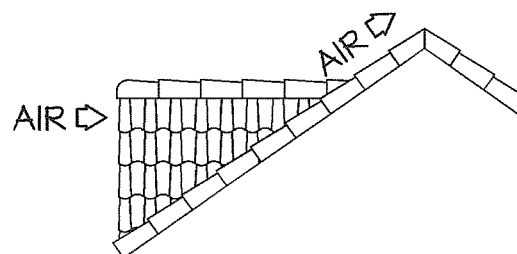


Figure 4-25: Air inlets at the face of a dormer

A.3.2. Consider using a heating system in valley areas or near dormers, since a large portion of the roof drains to a small eave section. See Figure 4-26.

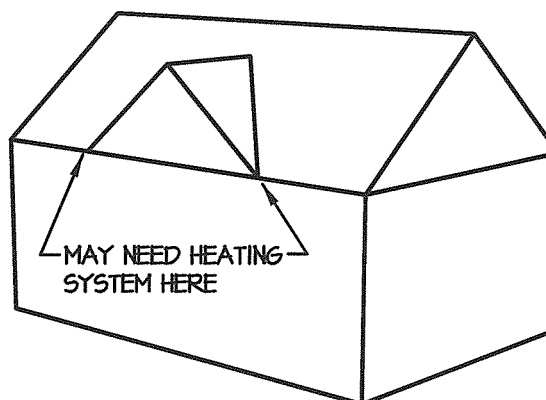


Figure 4-26: Areas which may need heating systems if a large open attic is not used

A.4. A structural engineer responsible for the building design should be consulted for the attachment of batten boards. The engineer may want to use angle brackets on 2 x 4s or 2 x 6s on edge. See Figure 4-27.

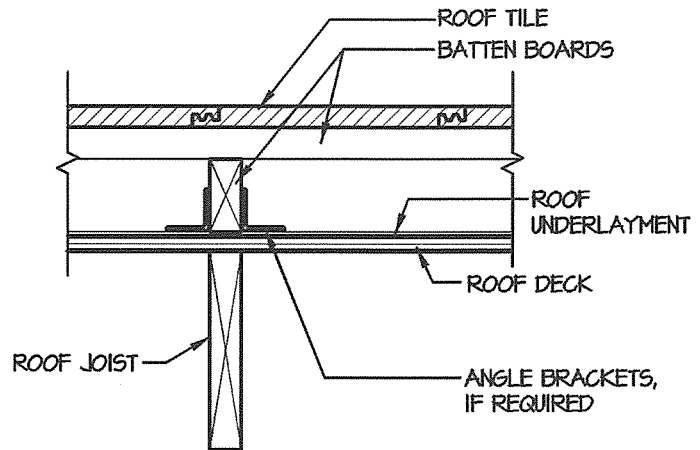


Figure 4-27: Batten board attachment

B.1. Horizontal batten boards should be designed by a structural engineer to support the weight of the tiles and design snow load or live load of the roof. Deflection should be no more than the distance between batten boards divided by 240. This is the typical deflection allowed by code for a roof. Larger deflection can result in tile breakage, generally at the corners of tiles. Figure 4-28 shows allowable loads for horizontal batten boards.

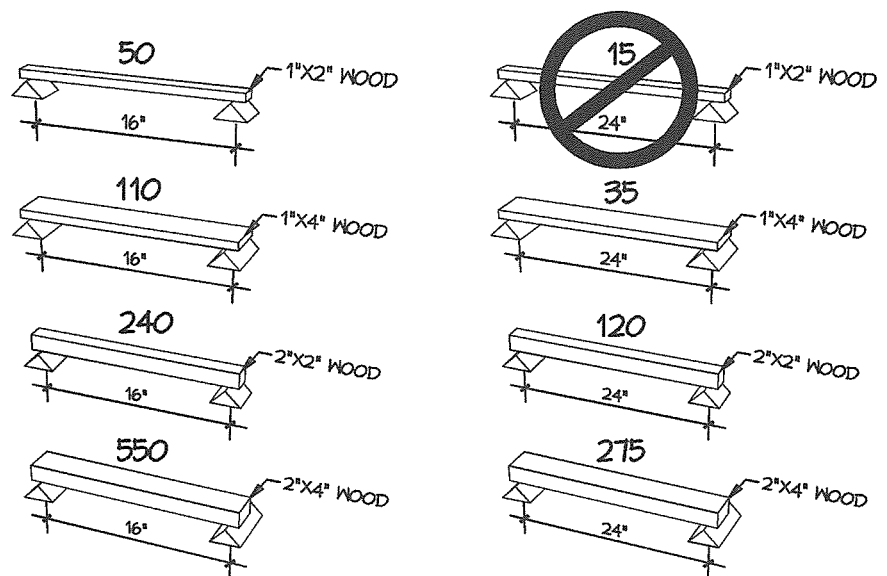


Figure 4-28: Allowable loads in pounds per square foot for No. 2 western cedar horizontal batten boards

B.2. Nailing tables for wind loads and snow loads with respect to roof slope can be found in tile manufacturers' installation recommendations.

C.1. All fasteners must be corrosion resistant.

Section VI. Criteria for Metal Flashing

A.1. Flashing for tile roofs must do more than just keep water out of the building; it must also keep water out from under the tile. At pipe or vent penetrations, a jack should be used at the roof deck and on the roof surface. Along walls, a waterproofing membrane shall be used from the deck up the walls 6 inches. The tile surface shall be flashed to prevent water from getting below the tile. This is critical in snow areas since the tile can be lifted by the collection of ice below the tile.

B.1. Minimum thickness of metal flashing shall be to local code requirements.

C.1. Siding should always be terminated a minimum of 2 inches above the roof or horizontal flashing to prevent it from absorbing water, collecting debris and deteriorating prematurely.

D.1. Lead or other malleable products must be used with profile tiles to direct water onto the tile where the top edge of the tile butts against a wall.

E.1. When installing valley flashing, either open or closed valleys can work well if the snow is prevented from moving. In either case, cut tile must be adequately secured and not allowed to drop down into the valley. Figures 4-29 and 4-30 show a typical European design.

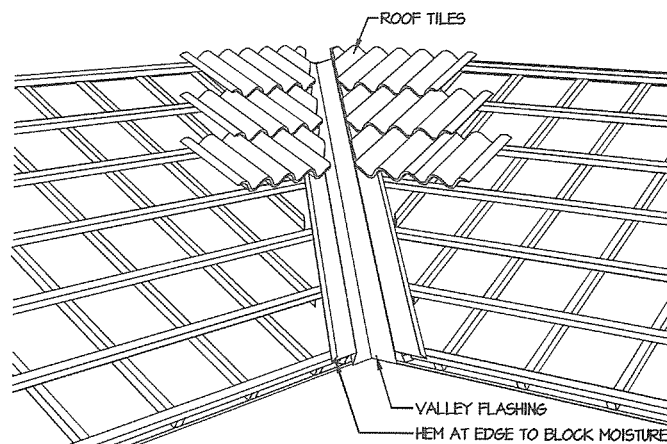


Figure 4-29: View of an open valley, typical European design
See also Chapter 6, CWT 9

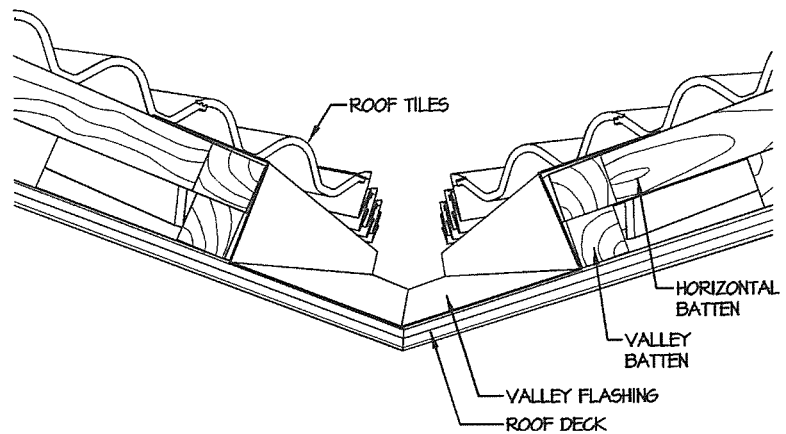


Figure 4-30: View at end of valley, typical European design

E.2. Design and construct open valleys to taper and open as they slope down at 1/8 inch per lineal foot or greater.

E.3. A “W W” valley flashing design is shown in Figures 4-31 and 4-32.

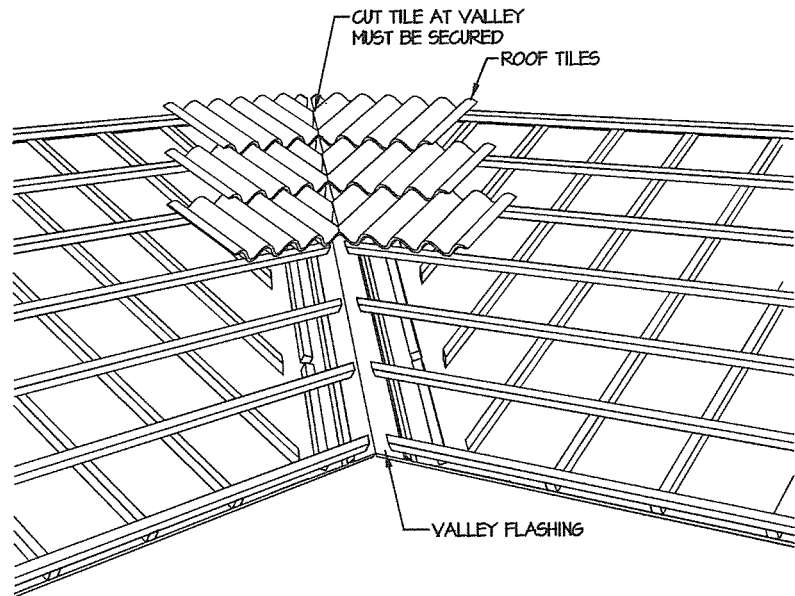


Figure 4-31: View of a closed valley with a “W W” flashing
See also Chapter 6, CWT 4c

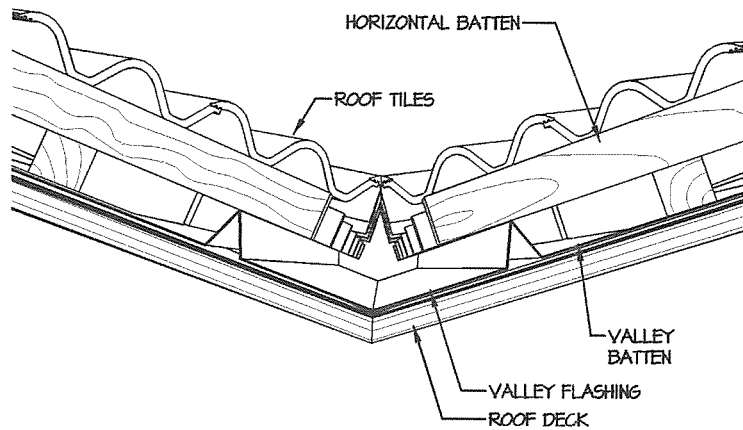


Figure 4-32: View at end of valley with "W W" flashing

E.4. Cut tiles at valleys should be secured with clips or adhesive as recommended by the manufacturer.

E.5. Open valleys can have an electric heating system added if needed in the future. It is much more difficult to heat a closed valley.

Section VII. Criteria for Snow Retention

A.1. Snow retention in Climate Types II and III is essential. If snow brackets are not installed over the entire roof, snow moving into brackets may flatten or break them. Snow brackets are generally designed to only hold the snow in their vicinity.

B.1. Snow guard design is critical. There are many roofs with flattened out snow brackets that were inadequately sized for either strength or quantities for the roof on which they were installed.

B.1.1. Place the weight bearing part of the snow brackets on the tile at the overlap. This way, the batten boards support the weight of the snow on the bracket. See Figure 4-33.

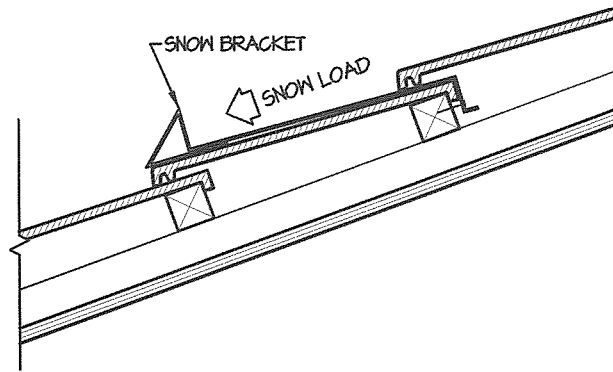


Figure 4-33: Snow bracket placement

B.1.2. Snow brackets should be spaced evenly over the entire roof in a staggered pattern.

B.1.3. Consult with the bracket or fence manufacturer for an adequate design and layout. A structural engineer may be needed if the bracket manufacturer will not accept responsibility for the design.

C.1. Snow fences are generally about 1 foot high. Since they are higher than individual snow brackets, snow fences help to prevent the snow layers from delaminating, and an upper layer from sliding off. This type of snow slide is generally less damaging to the roofing than when the snow slides directly on the tile. However, it can still harm those below. See Figure 4-34.

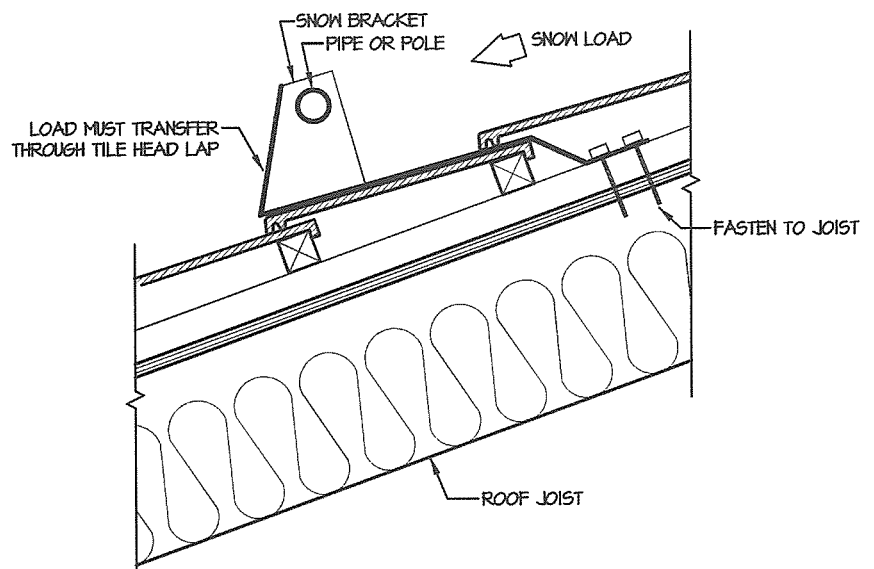


Figure 4-34: Tile specific snow fence design

C.1.1. Snow loads pushing just 1 foot off the roof create high concentrated loads on the roof structure. The structural engineer responsible for the building design should be consulted as the loading can be significant at the fence and result in the collapse of a roof structure.

C.1.2. If enough snow fences are not used, or if they are only located at the eaves on a large roof, they may allow snow movement. Once snow begins to move, loads increase on fences. The chances of the fences failing increases. Tiles can be damaged from this snow movement.

C.1.3. A combination of snow fences and snow brackets may provide an economical alternative to multiple snow fences up a roof.

C.1.4. Snow fences as shown in Figure 4-35 require additional flashing to seal the tile surface where the bracket passes through the tile. Tiles have to be cut to allow the fence to pass through, weakening the tile. Because this type of fence is attached directly to the structure, it can take a much heavier load. Designers then tend to rely on too few fences up the roof. This can result in undesirable snow movement between fences. For these reasons, we do not recommend this type of fence.

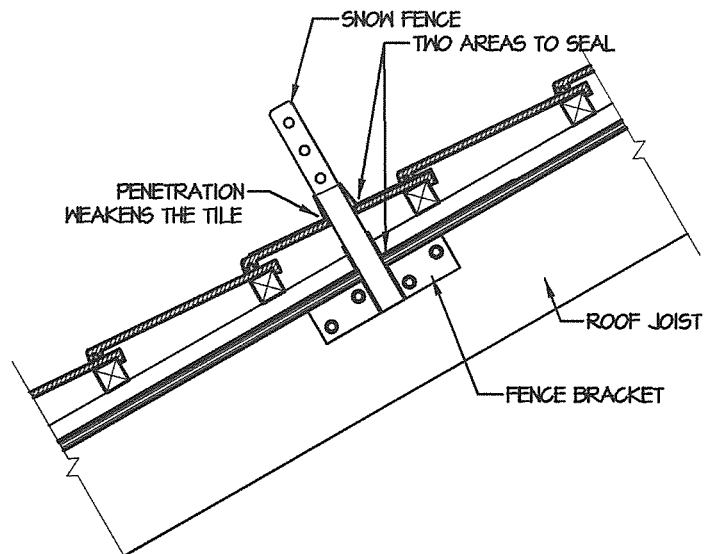


Figure 4-35: Roof joist attachment snow fence design

Note: This design is not preferred. See C.1.4.

D.1. The snow retention device manufacturer will need the following information for proper design:

- ♦ Roof dimensions and slope
- ♦ Tile type
- ♦ Deck information including vertical and horizontal batten boards, deck thickness and material and fasteners used to hold the roof and batten boards together
- ♦ Vertical and horizontal batten board size, layout and fastening
- ♦ Aesthetic look
- ♦ Roof snow load
- ♦ Local code requirements

E.1. Request the following information from the retention bracket manufacturer, fence manufacturer and/or structural engineer:

- ♦ Snow loads used
- ♦ Installation instructions
- ♦ Sizing
- ♦ Load on each bracket or fence
- ♦ Layout
- ♦ Requirements to seal any penetrations

Chapter 5

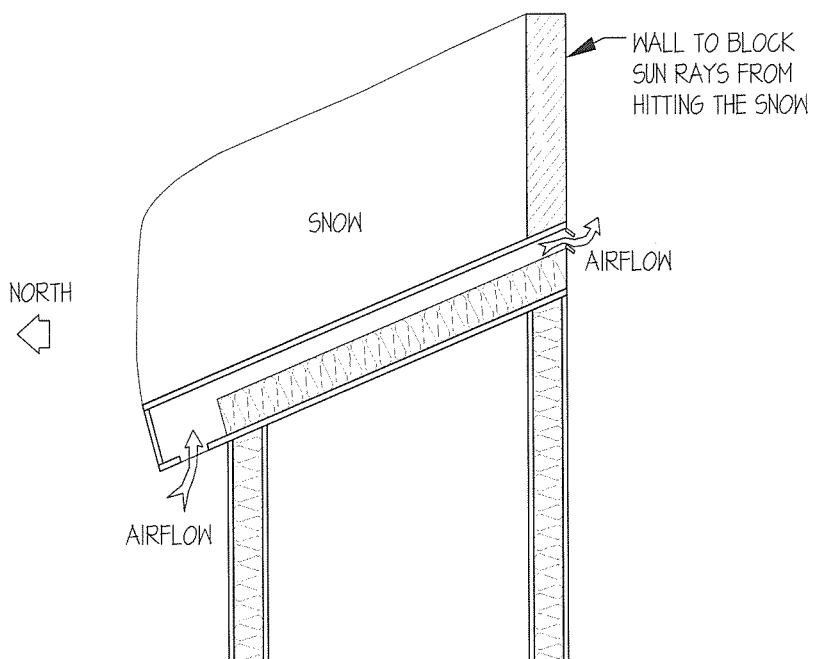
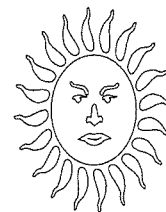
Climate Type III

Section I. General Considerations

- A.1. Climate Type III is a cold and snow region in which ice dams are a recurring problem and are caused by building heat loss and high solar radiation.
- A.2. Climate Type III accounts for the added adverse conditions associated with high mountain areas where the air is thin, the solar radiation is intense, and the sky is often clear. There is rarely a hazy day. In this climate the snow is generally deep and can stay on roofs from October to May.
- A.3. A roof design that may be adequate in Climate Type II may need additional ventilation in this climate.
- A.4. Chapter 4 of this manual contains most considerations to prevent ice damming. A few special considerations for high altitude and high solar gain are mentioned below. The following suggestions should be used with the material in Chapter 4.

Section II. Criteria for Architectural Design

- A.1. Multiple roof elevations can create problems with shading and getting melt water from one roof to another. In some regions the worst problems deal with a south or west facing roof draining onto a shaded area. Melt water refreezes in a shaded area.
- A.2. Ice melting systems or manual ice removal may be required where the roof becomes complicated with dormers, multiple roof elevations and other features that create shaded areas. In some cases, electrical outlets or hydronic heating lines should be installed in possible problem areas during construction. Then if problems occur later, ice melt systems can be more cost effectively installed. This installation cost is much lower during construction than later.
- A.3. The sun's rays will melt snow at a much higher rate when they strike the roof surface at a perpendicular angle. This is most obvious on a north facing shed-type roof where the sun hits the top edge of the snow and melts it. The melt water runs down the roof and forms an ice dam at the eave. Placing a wall at the top edge of the roof to shade the snow from the sun's rays will help reduce ice damming for such roofs. See Figure 5-1.



5

Figure 5-1: Wall placed to minimize ice damming

Chapter 6

Detail Design for Climate Types II and III

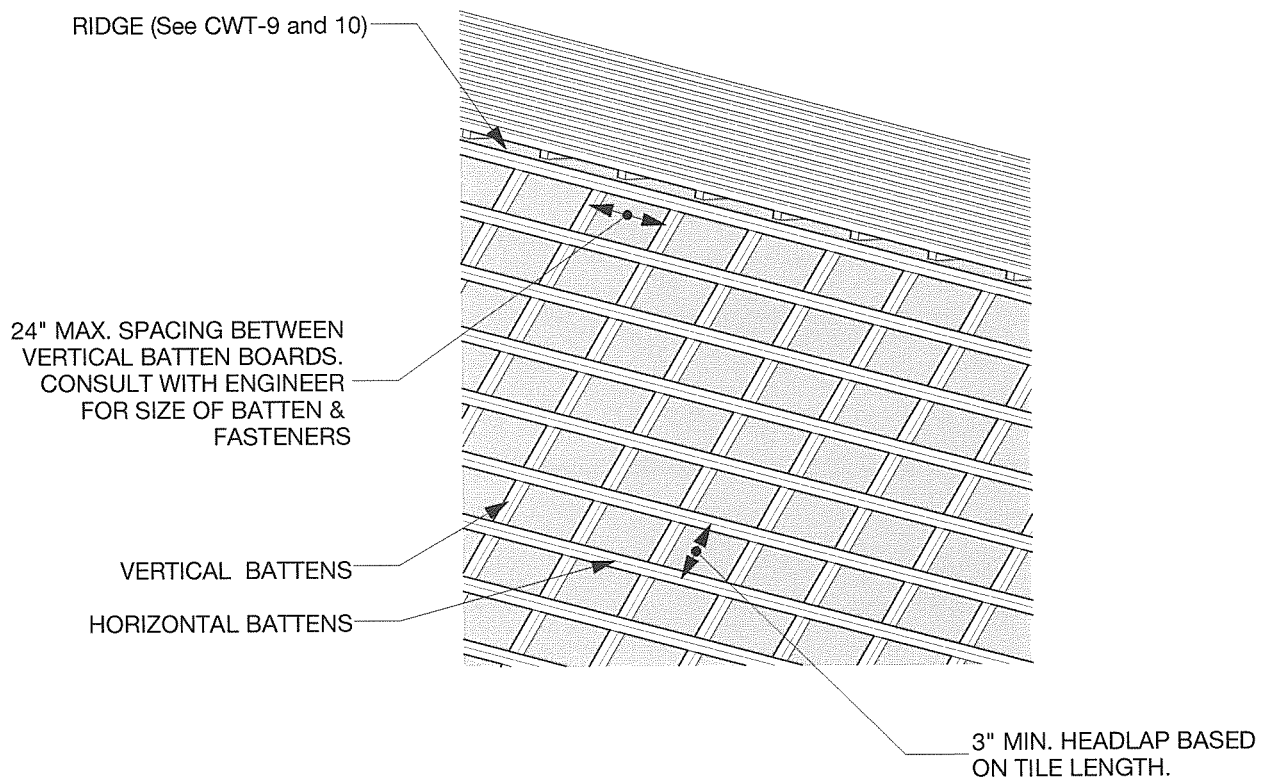
There are many specialty products that may improve upon the details shown or which may be more cost effective. Consult with tile roofing manufacturers for specific detail



BATTEN BOARD INSTALLATION

CWT-1

6

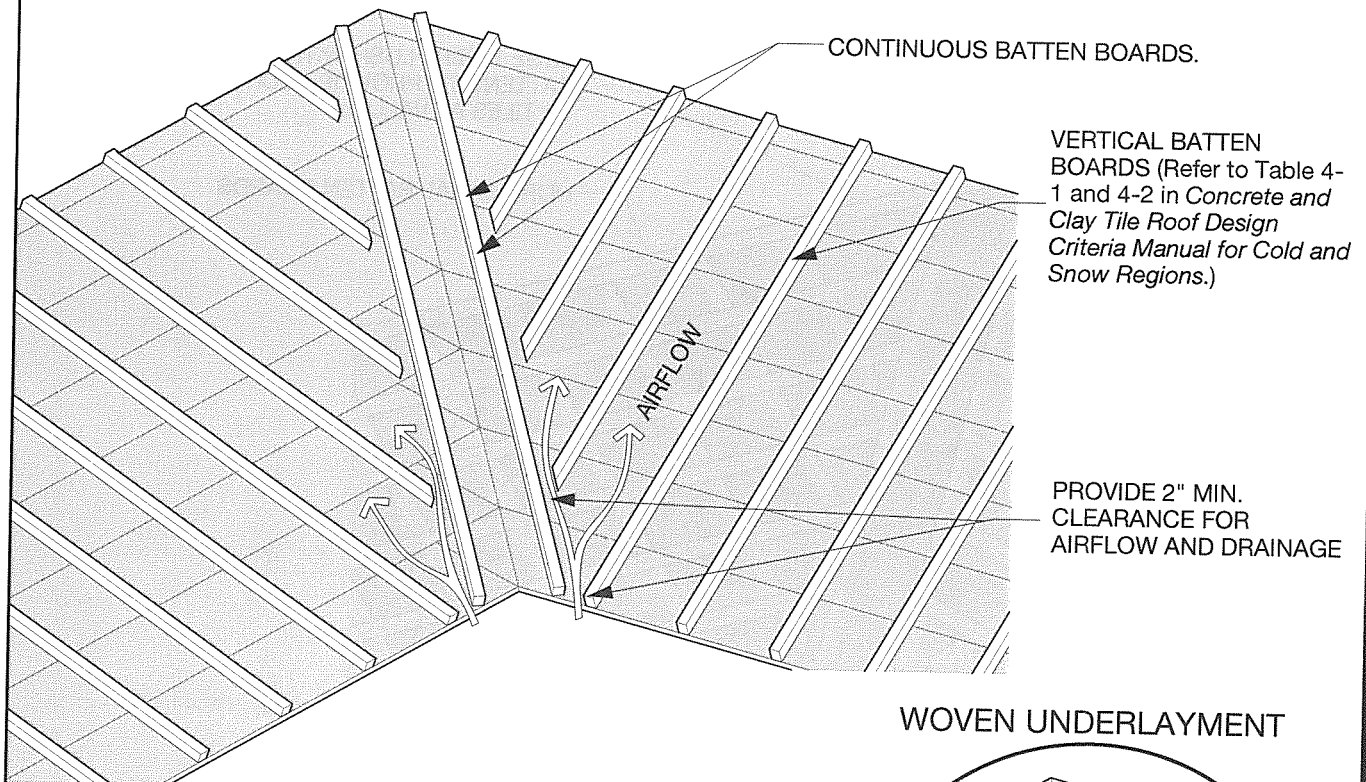


Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. There are many specialty products available that may improve upon the details shown. Please consult with manufacturers for specific details.
4. Securely fasten battens through roof sheathing per manufacturer's recommendations and complying with local code requirements. For general information regarding batten type, sizing, fasteners, and fastening schedules consult the *Concrete and Clay Tile Roof Design Criteria Manual for Cold and Snow Regions*.
5. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

VERTICAL BATTENS - FOR DEEP TROUGH VALLEY

CWT-2a

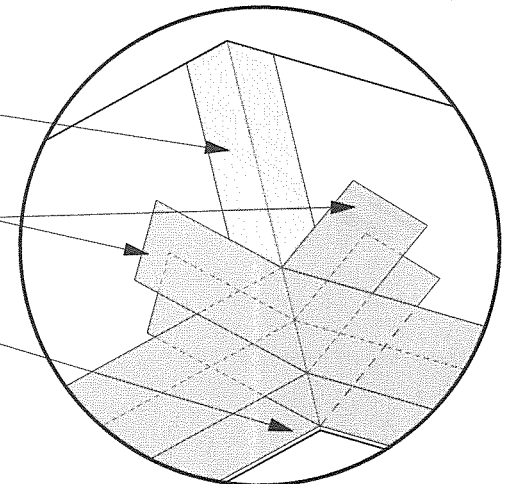


WOVEN UNDERLAYMENT

SELF-ADHERING POLYMER MODIFIED ASPHALT MEMBRANE OVER ROOF DECK (Extend 18" Minimum Up Each Side From Valley)

UNDERLAYMENT WOVEN BETWEEN COURSES

UNDERLAYMENT WOVEN THROUGH VALLEY LINE



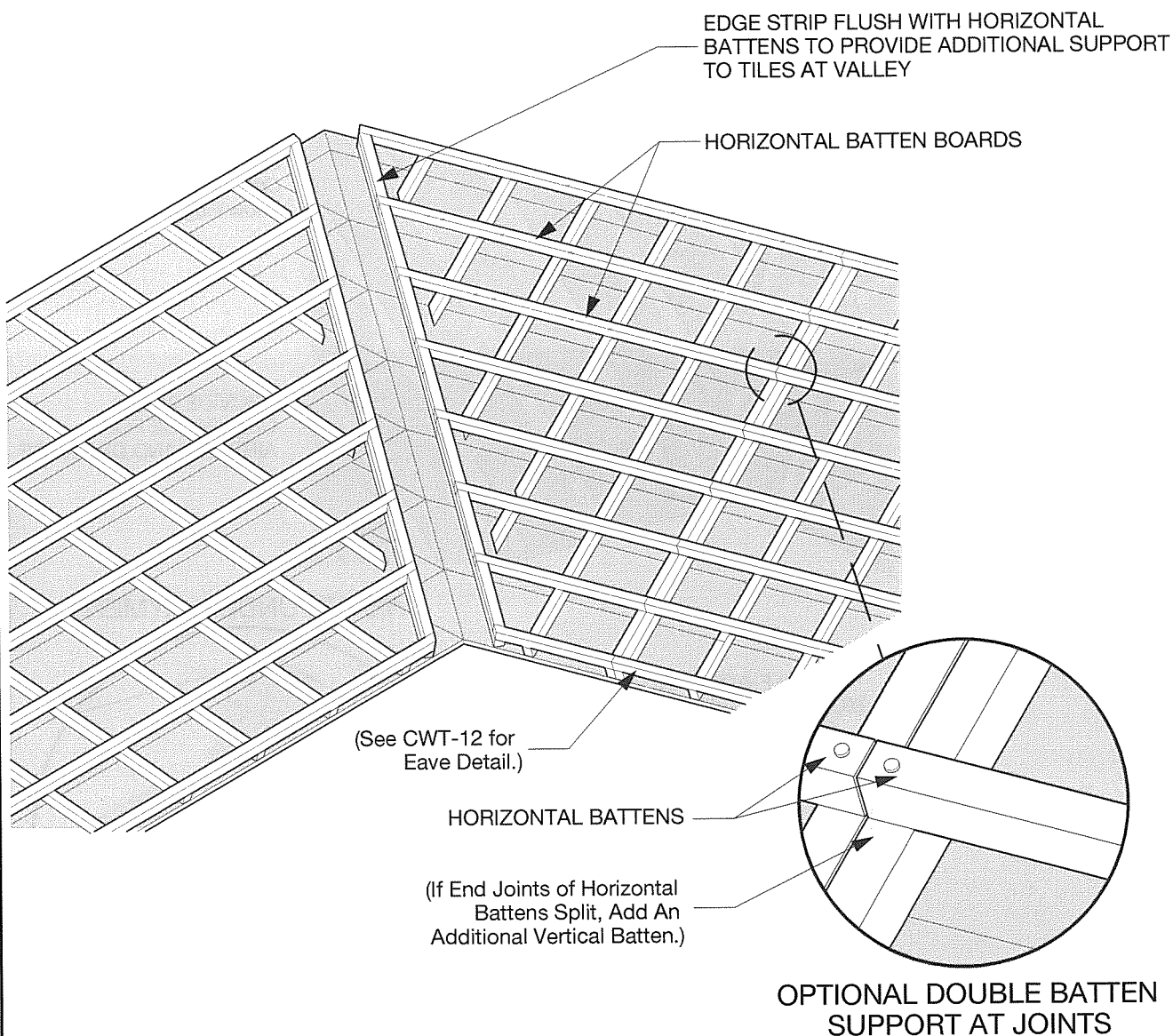
Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. There are many specialty products available that may improve upon the details shown. Please consult with manufacturers for specific details.
4. Securely fasten battens through roof sheathing per manufacturer's recommendations and complying with local code requirements. For general information regarding batten type, sizing, fasteners, and fastening schedules consult the *Concrete and Clay Tile Roof Design Criteria Manual for Cold and Snow Regions*.
5. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

HORIZONTAL BATTENS - FOR DEEP TROUGH VALLEY

CWT-2b

6

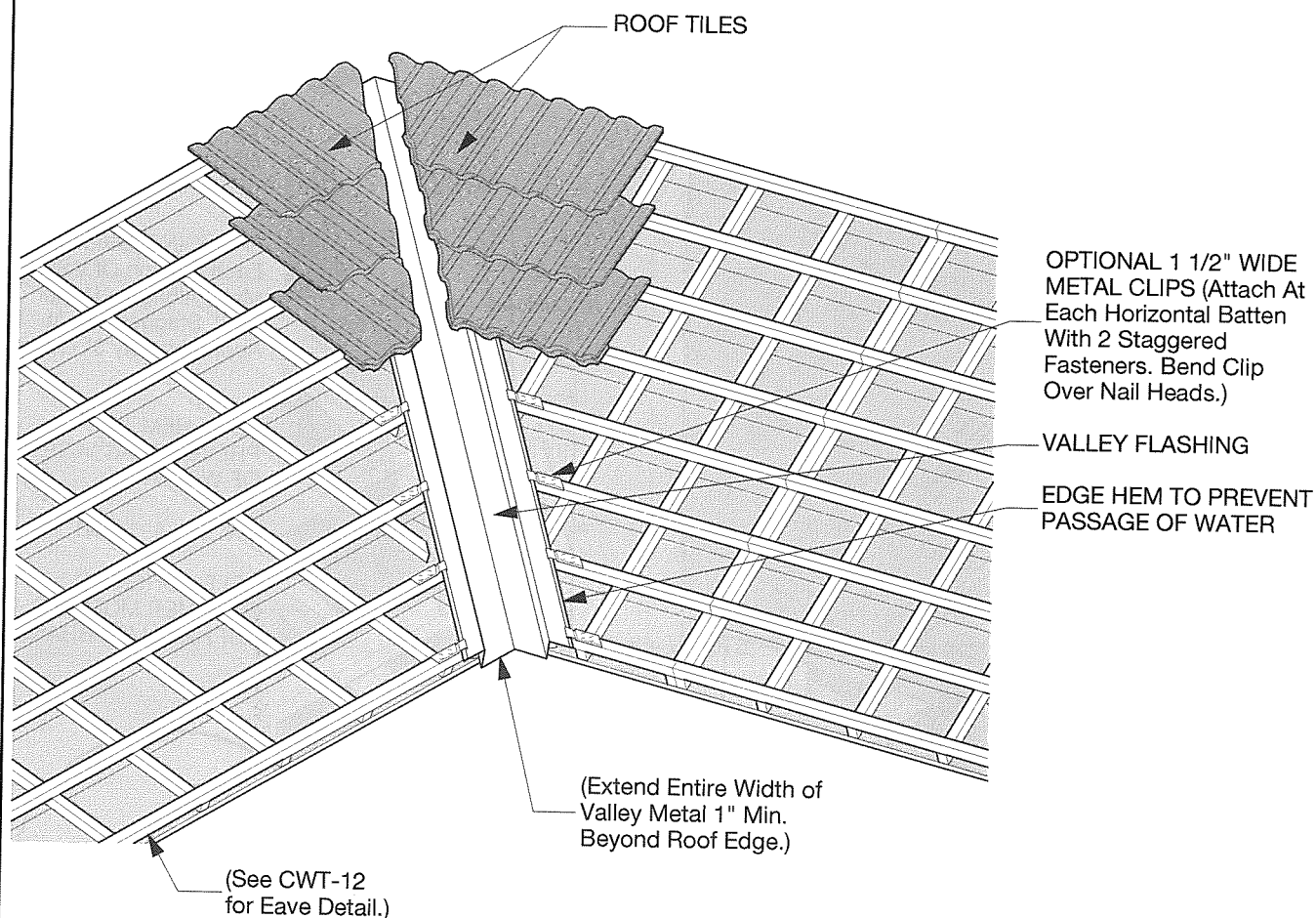


Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. There are many specialty products available that may improve upon the details shown. Please consult with manufacturers for specific details.
4. Securely fasten battens through roof sheathing per manufacturer's recommendations and complying with local code requirements. For general information regarding batten type, sizing, fasteners, and fastening schedules consult the *Concrete and Clay Tile Roof Design Criteria Manual for Cold and Snow Regions*.
5. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

TILE & VALLEY LAYOUT - FOR DEEP TROUGH VALLEY

CWT-2c



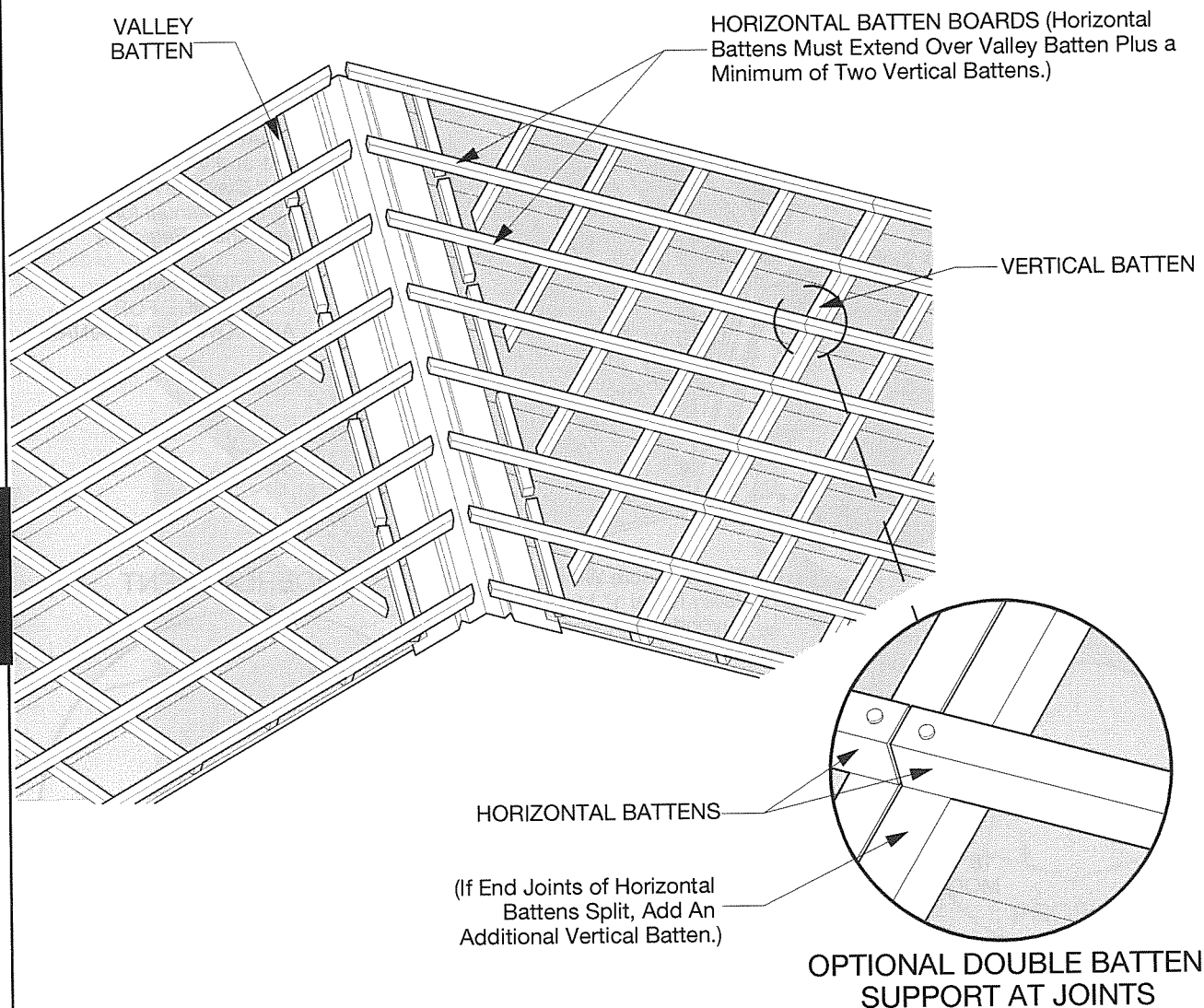
Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. Cut tile pieces should be secured by one or a combination of the following: (a) tile manufacturer approved adhesive; (b) wire tie; or (c) other manufacturer approved fastening device.
4. For deep trough valleys: Metal valley flashing is recommended to be a minimum of 24 gauge pre-finished galvanized steel, 16 oz. copper or an equivalent longevity non-corrosive metal. Valley flashing metal is recommended to be formed from minimum 24" wide stock. On projects with large expansive roof areas and/or long rafter lengths wider valley metal is recommended. Tile should extend over valley metal into valley trough a minimum of 1 1/2 inches.
5. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
6. There are many specialty products available that may improve upon the details shown. Please consult with manufacturers for specific details.
7. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

HORIZONTAL BATTENS - FOR SHALLOW TROUGH VALLEY

CWT-4b

6

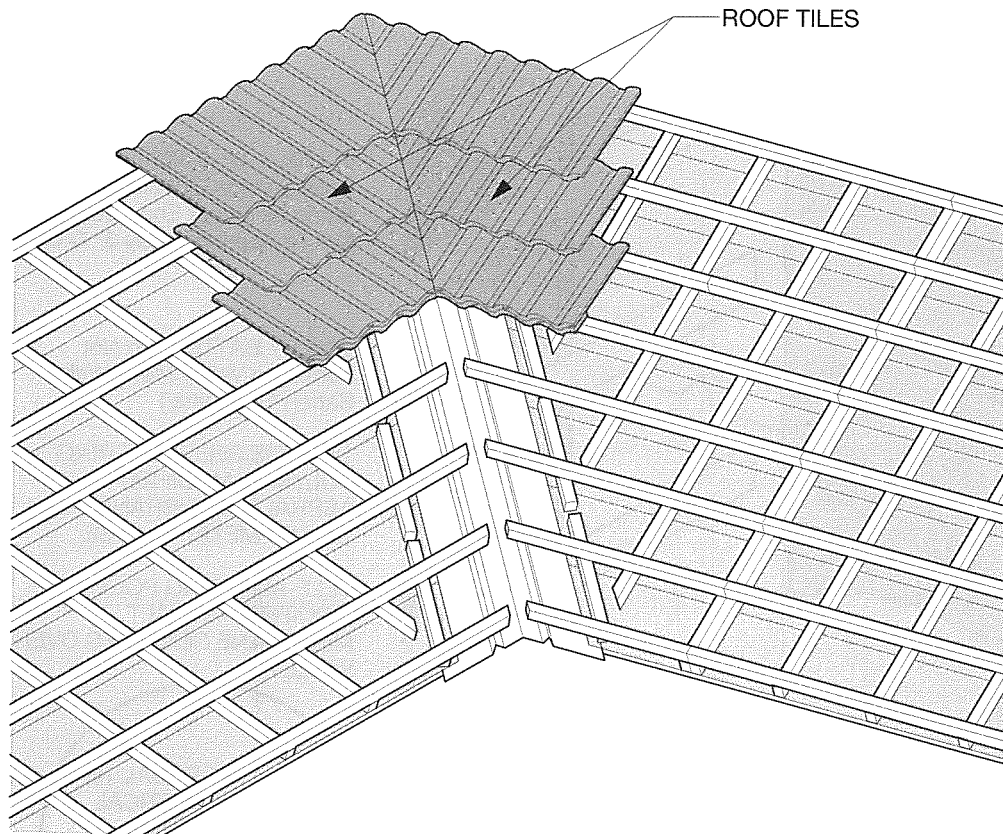


Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. There are many specialty products available that may improve upon the details shown. Please consult with manufacturers for specific details.
4. Securely fasten battens through roof sheathing per manufacturer's recommendations and complying with local code requirements. For general information regarding batten type, sizing, fasteners, and fastening schedules consult the *Concrete and Clay Tile Roof Design Criteria Manual for Cold and Snow Regions*.
5. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

TILE & VALLEY LAYOUT - FOR SHALLOW TROUGH VALLEY

CWT-4c

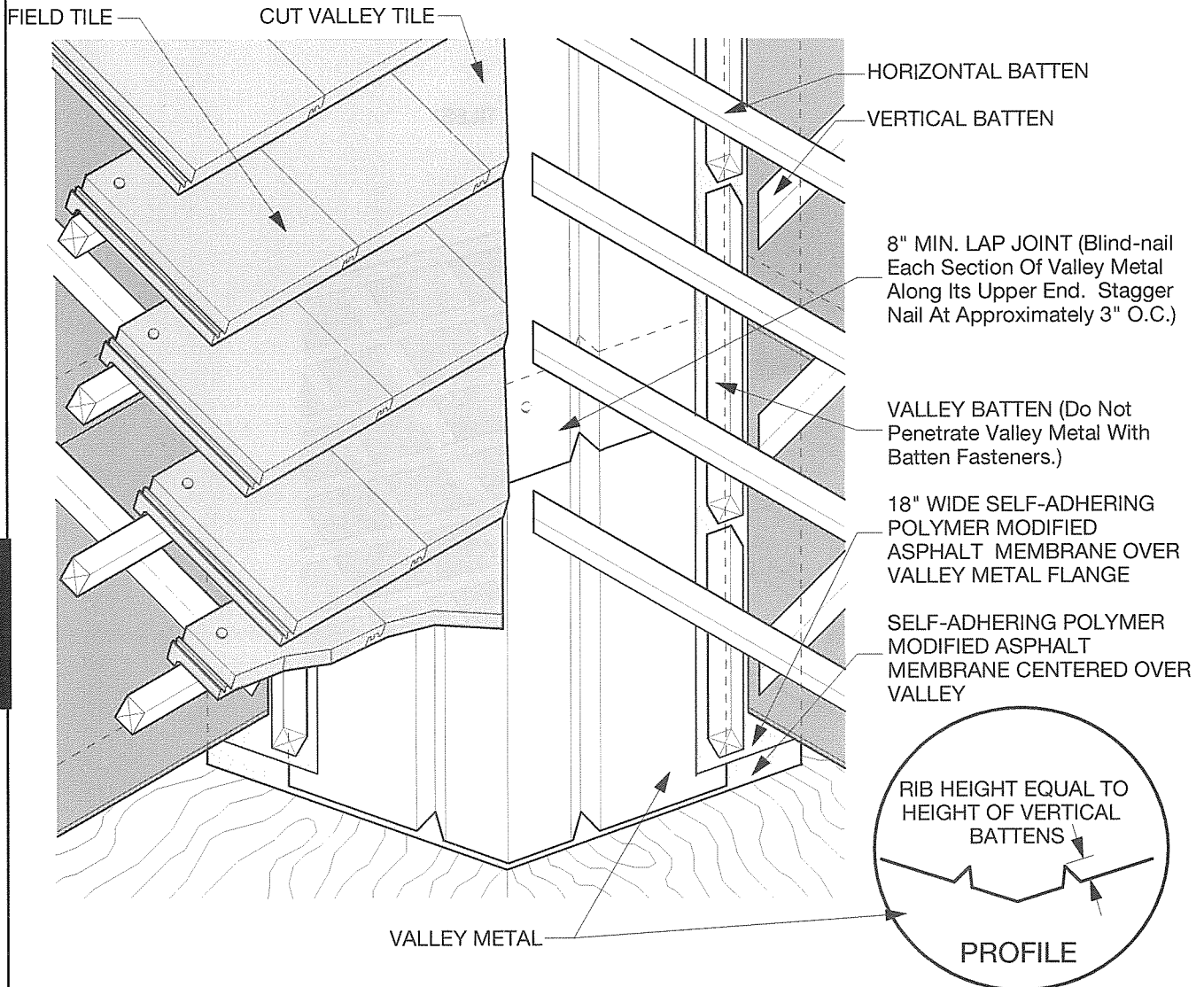


Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. Cut tile pieces should be secured by one or a combination of the following: (a) tile manufacturer approved adhesive; (b) wire tie; or (c) other manufacturer approved fastening device.
4. For shallow trough valleys: Metal valley flashing is recommended to be a minimum of 24 gauge pre-finished galvanized steel, 16 oz. copper or an equivalent longevity non-corrosive metal. Valley flashing metal is recommended to be formed from approximately 36" wide stock.
5. Other valley metal profiles are available, refer to tile manufacturer recommendations.
6. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
7. There are many specialty products available that may improve upon the details shown. Please consult with manufacturers for specific details.
8. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

VALLEY METAL - FOR SHALLOW TROUGH VALLEY

CWT-5

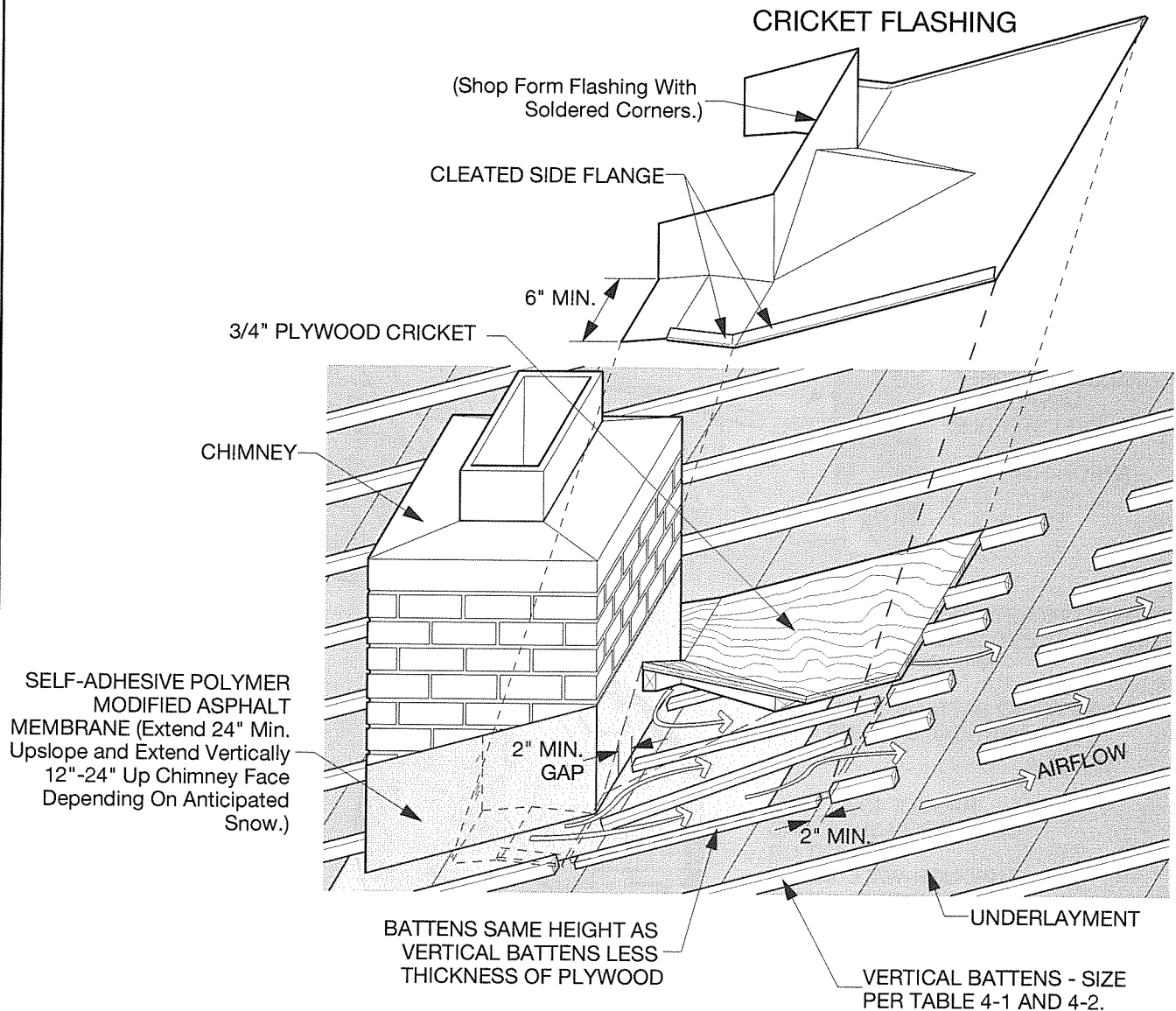


Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. Cut tile pieces should be secured by one or a combination of the following: (a) tile manufacturer approved adhesive; (b) wire tie; or (c) other manufacturer approved fastening device.
4. For shallow trough valleys: Metal valley flashing is recommended to be a minimum of 24 gauge pre-finished galvanized steel, 16 oz. copper or an equivalent longevity non-corrosive metal. Valley flashing metal is recommended to be formed from approximately 36" wide stock.
5. Other valley metal profiles are available, refer to tile manufacturer recommendations.
6. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
7. There are many specialty products available that may improve upon the details shown. Please consult with manufacturers for specific details.
8. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

CHIMNEY SADDLE OR CRICKET FLASHING

CWT-6a

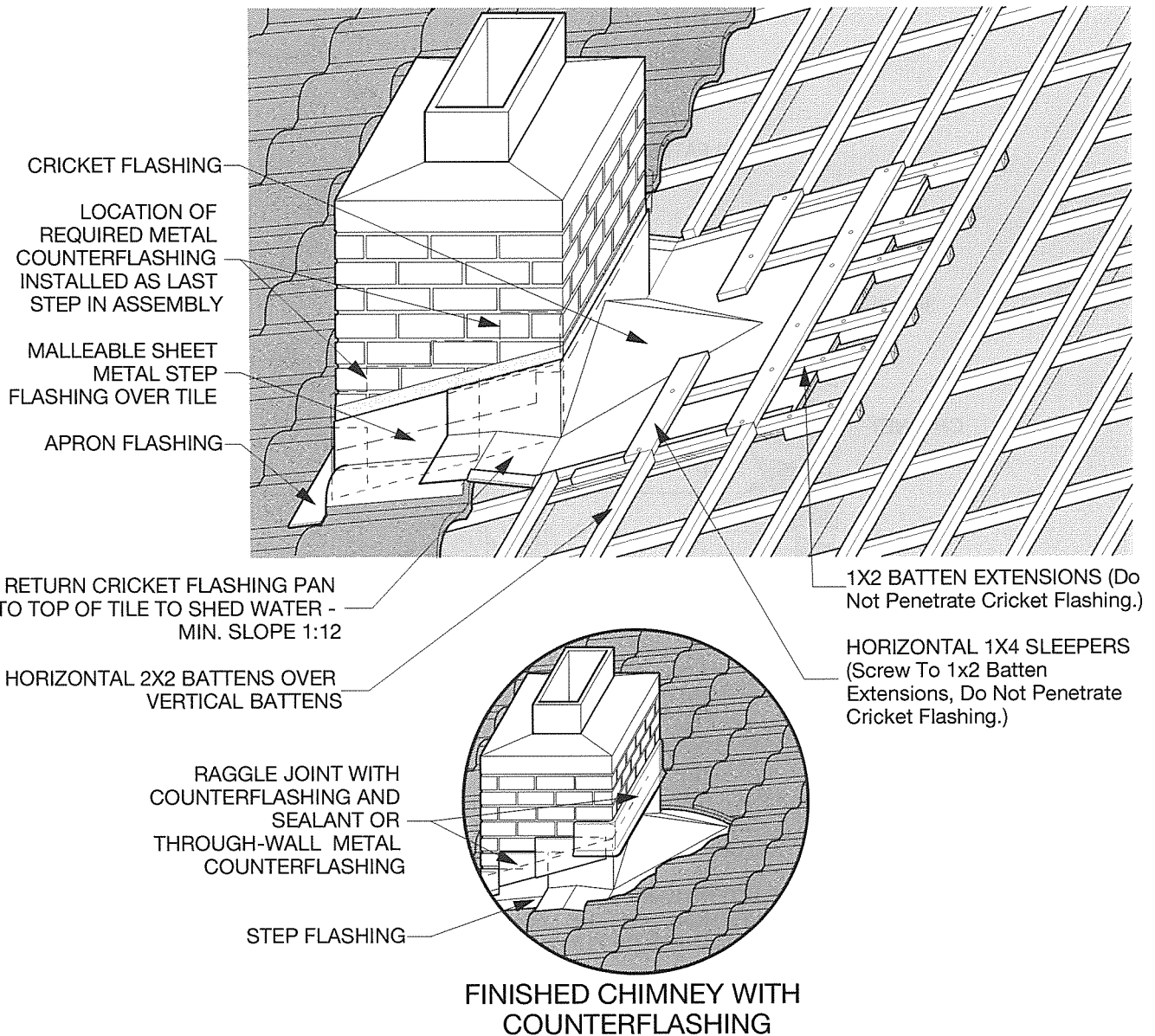


Notes:

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. Chimney flashing dimensions may vary according to local weather conditions, chimney size, chimney location, slope of roof and rafter length behind chimney.
4. A cricket flashing is recommended for chimneys and other penetrations equal to or greater than 24" in width to promote positive runoff.
5. Securely fasten battens through roof sheathing per manufacturer's recommendations and complying with local code requirements.
6. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

CHIMNEY SADDLE OR CRICKET FLASHING

CWT-6b

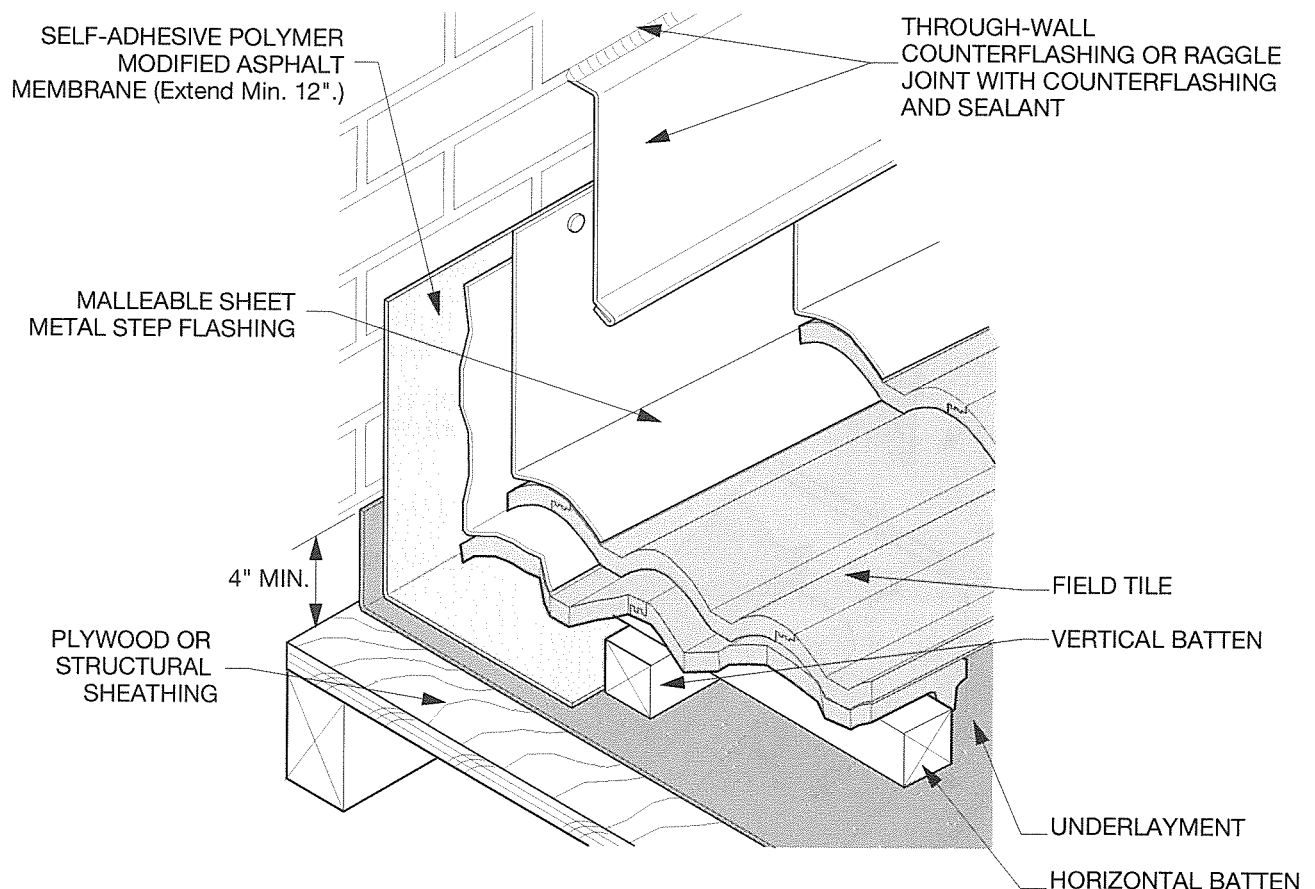


Notes:

1. Alternate sidewall flashing, other than step flashing shown, requires pan or channel flashing installed as secondary flashing at roof deck level. Provide primary flashing made of continuous flashing or step flashing.
2. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

STEP FLASHING AT CHIMNEY

CWT-7

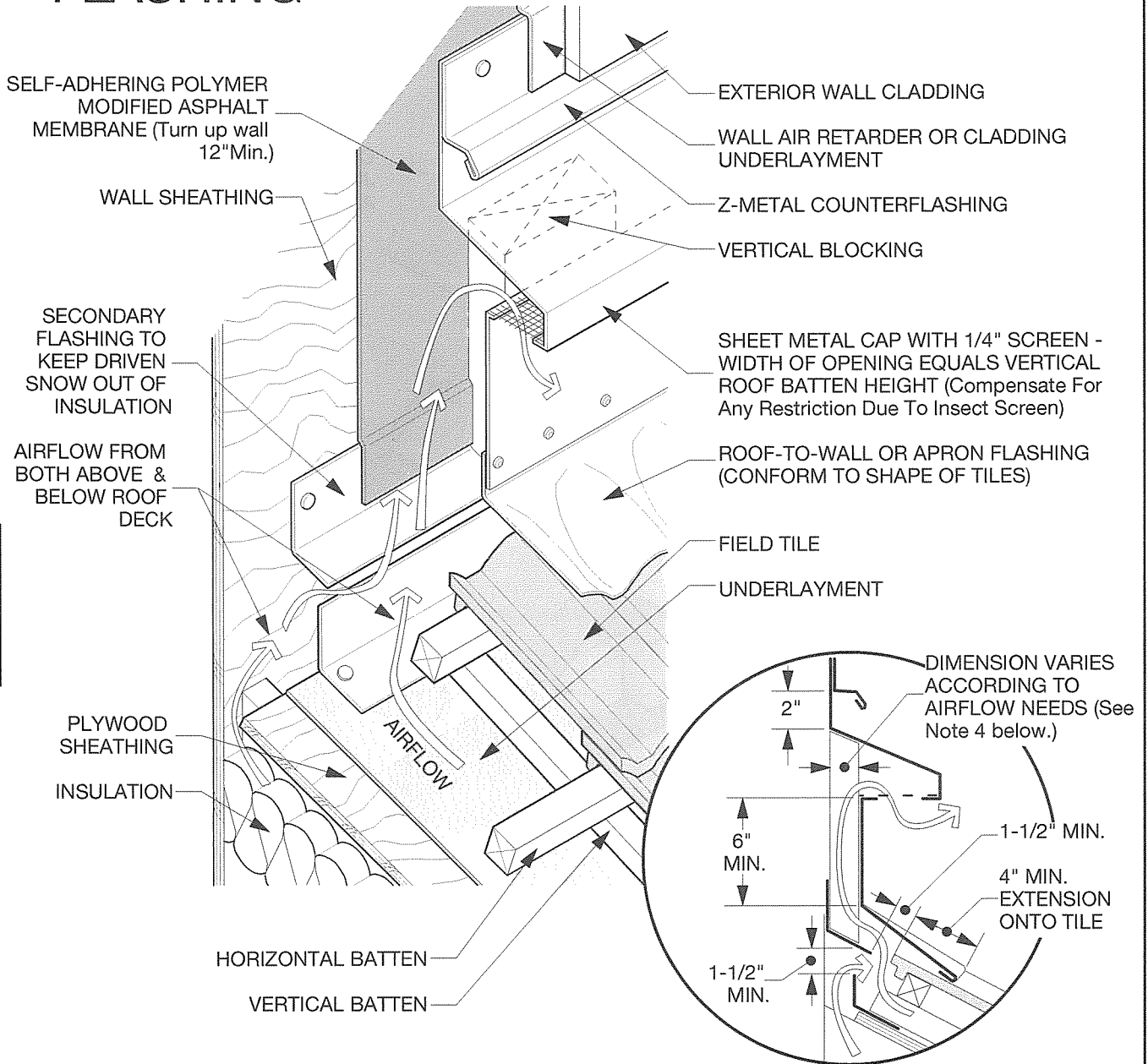


Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. Sheet metal step flashing should be a minimum of 24 ga. pre-finished galvanized steel, 16 oz. copper or an equivalent longevity non-corrosive metal. For profile tile use malleable step flashing.
4. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
5. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

VENTILATED HEADWALL METAL FLASHING

CWT-8



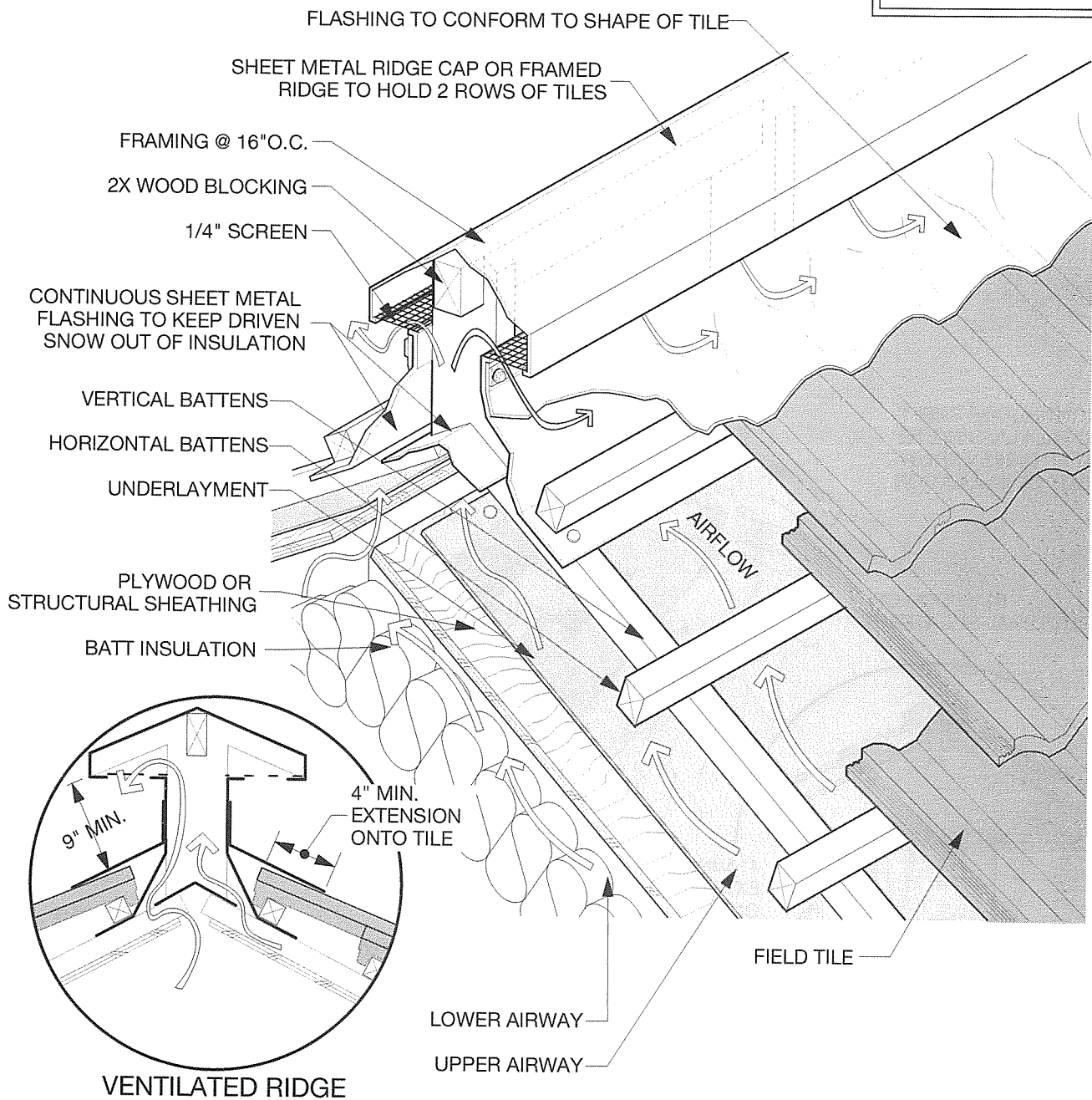
VENTILATED FLASHING

Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves, valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. A closure material is required on all high profile tile to prevent wind-blown moisture intrusion.
4. For determination of airflow needs, refer to Table 4-2; Page 4-16 in the *Concrete and Clay Tile Roof Design Criteria Manual for Cold and Snow Regions*.
5. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
6. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

SHEET METAL RIDGE VENT

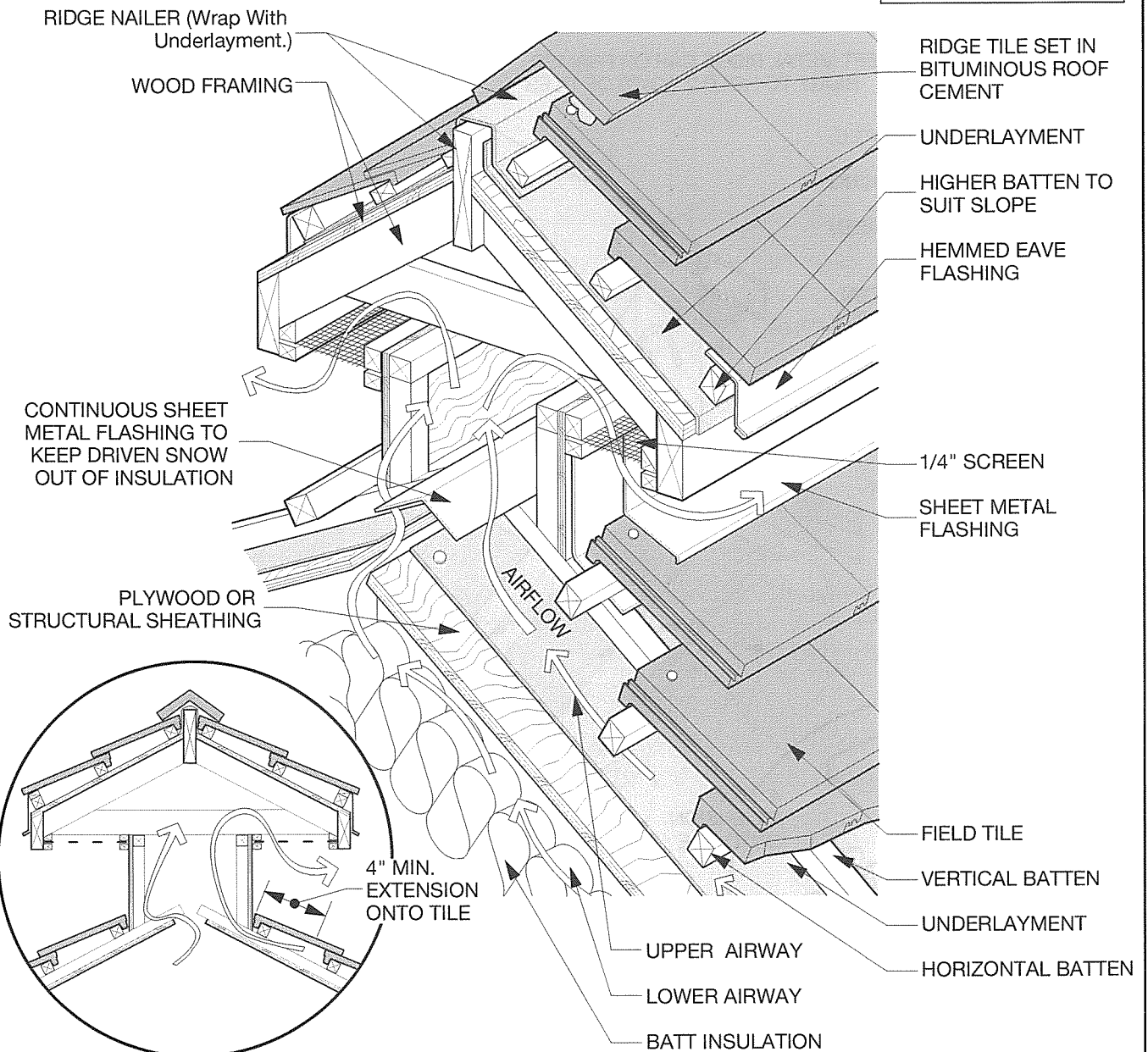
CWT-9



Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. A closure material is required on all high profile tile to prevent wind-blown moisture intrusion.
4. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
5. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

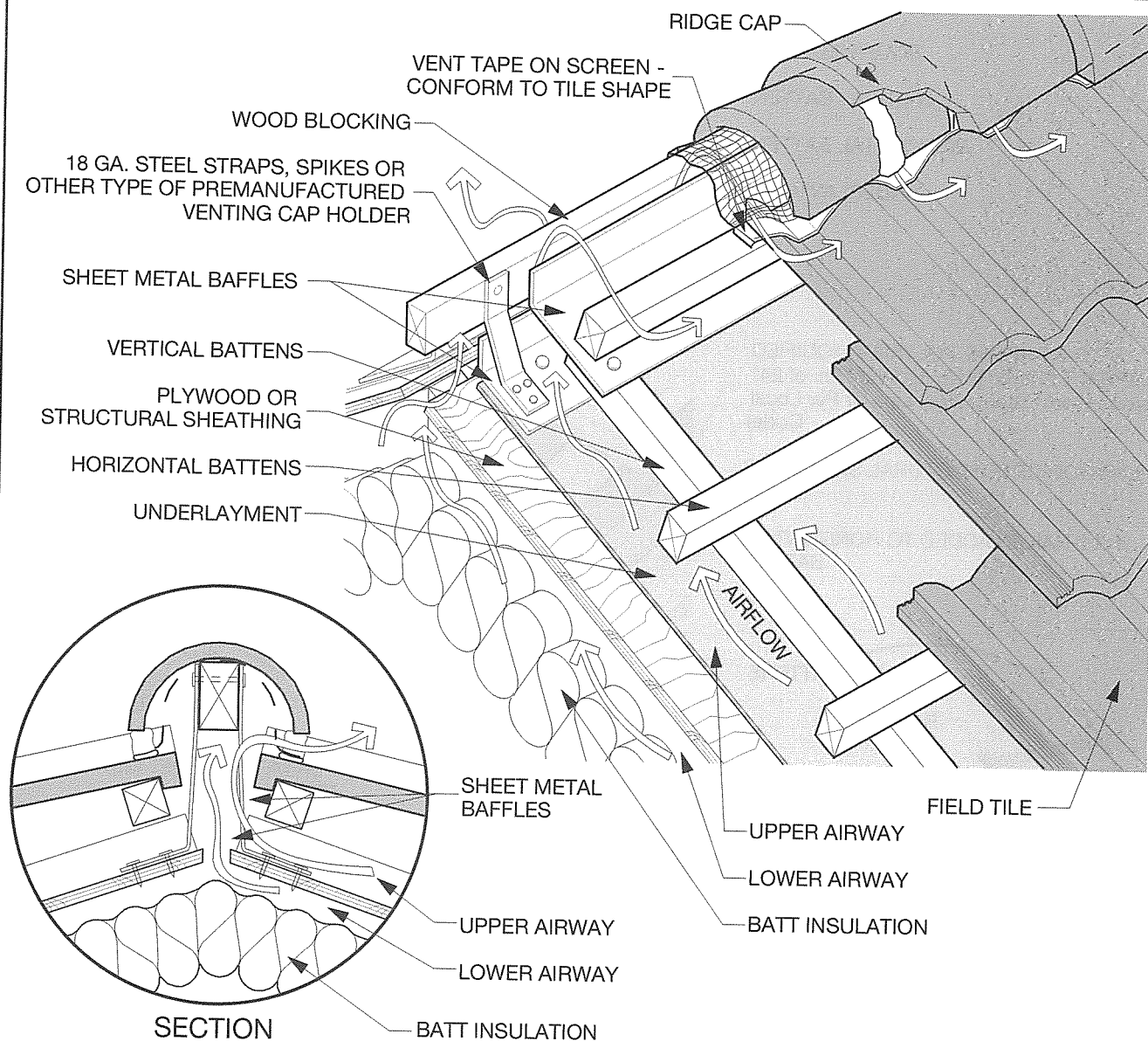
CWT-10



1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves, valleys, and around penetrations). (Consult local authorities for building code requirements.)
3. A closure material is required on all high profile tile to prevent wind-blown moisture intrusion at ridge and/or headwall.
4. All ridge tile are recommended to have a manufacturer's approved adhesive between laps of ridge tile.
5. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
6. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

ALTERNATE RIDGE VENT

CWT-11

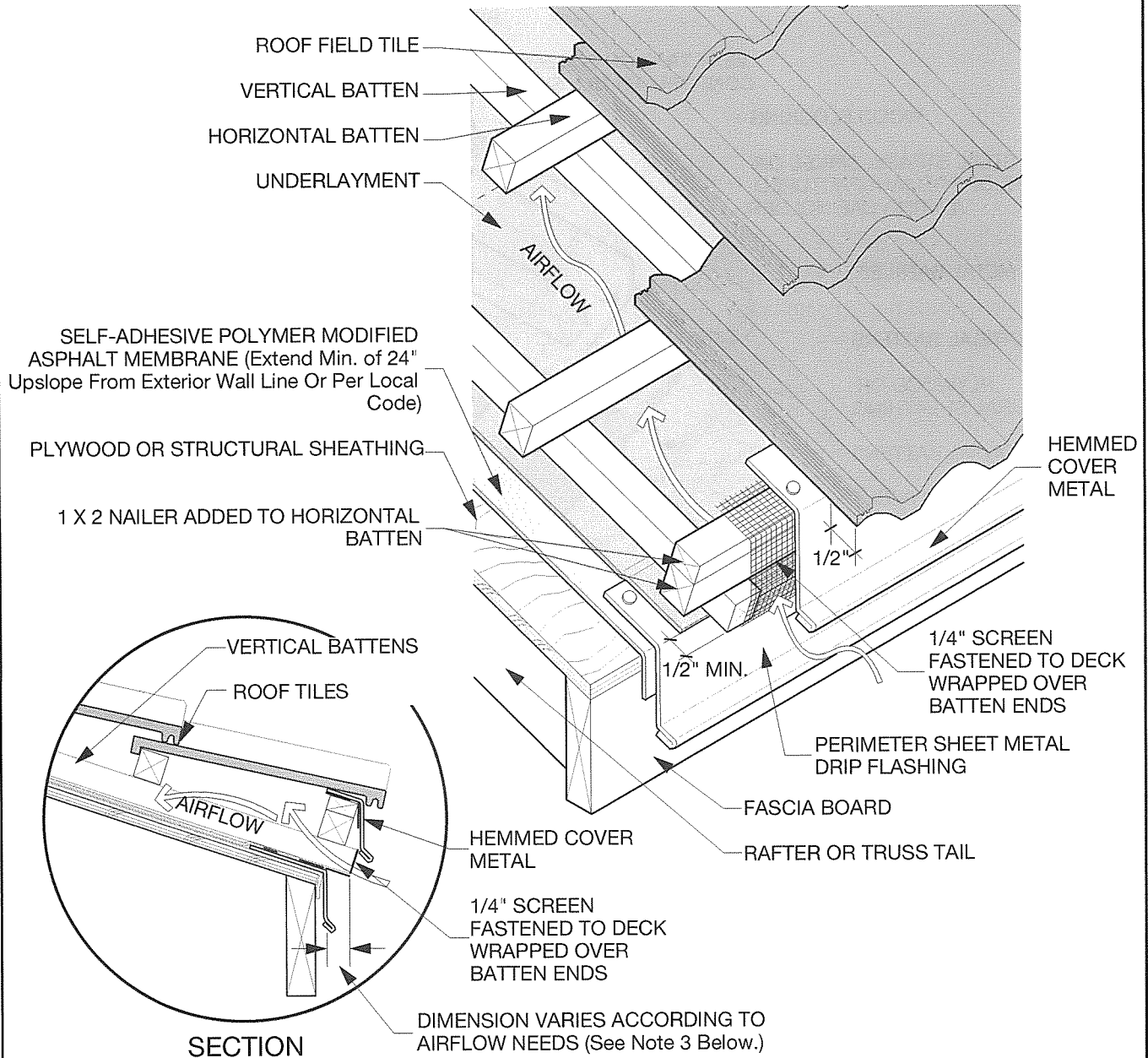


Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. All ridge tile are recommended to have a manufacturer's approved adhesive between laps of ridge tile.
4. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
5. Securely fasten battens through roof sheathing per manufacturer's recommendations and complying with local code requirements.
6. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.
7. NTRMA/WSRCA does not recommend venting hips.

ROOF FLASHING AT EAVE

CWT-12

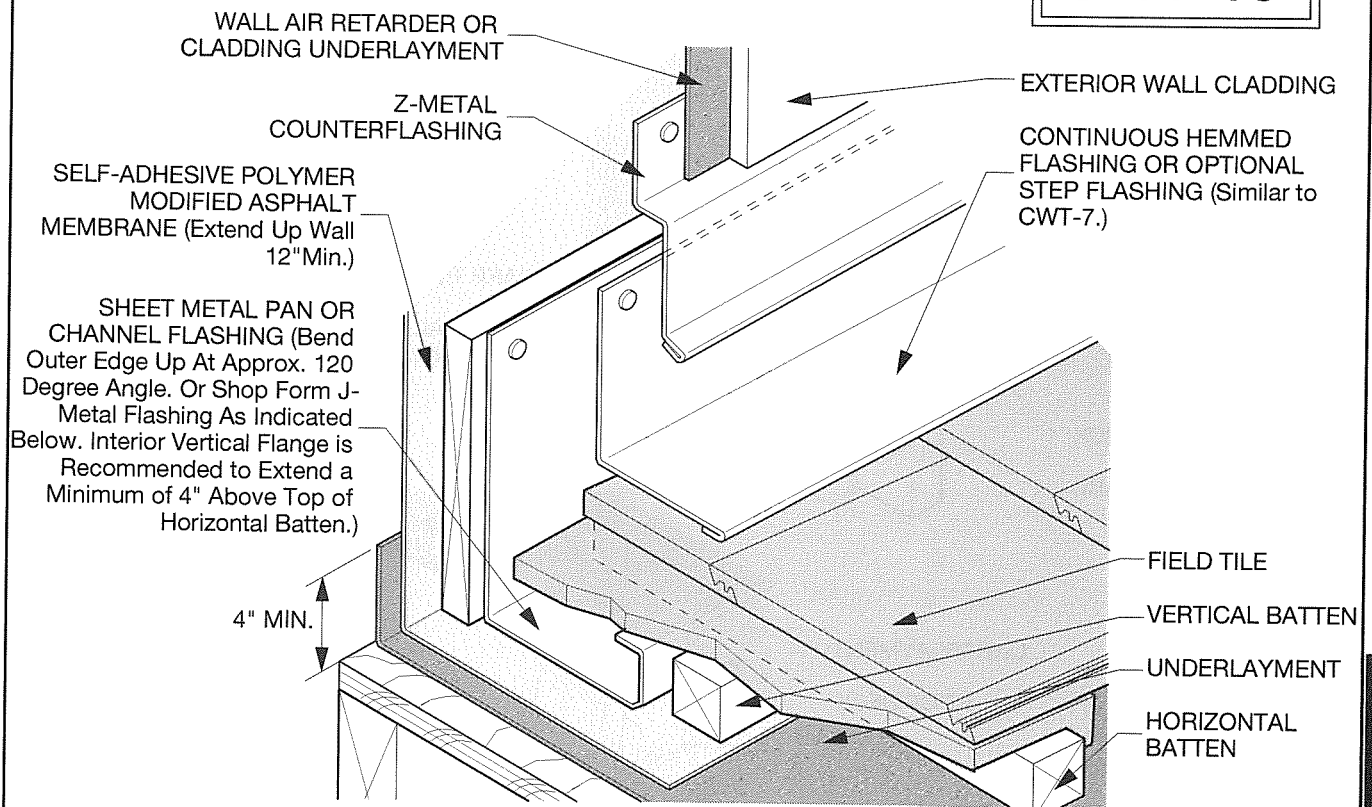


Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. For determination of airflow needs, refer to Table 4-2; Page 4-16 in the *Concrete and Clay Tile Roof Design Criteria Manual for Cold and Snow Regions*.
4. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
5. Securely fasten battens through roof sheathing per manufacturer's recommendations and complying with local code requirements.
6. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

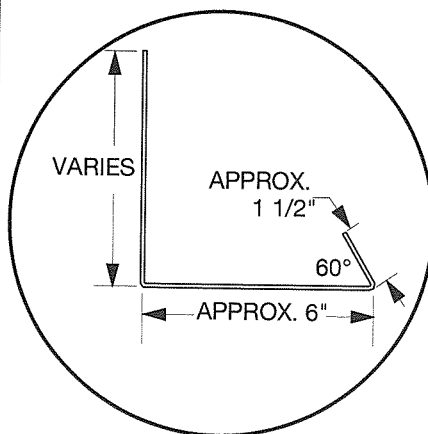
SIDEWALL FLASHING

CWT-13

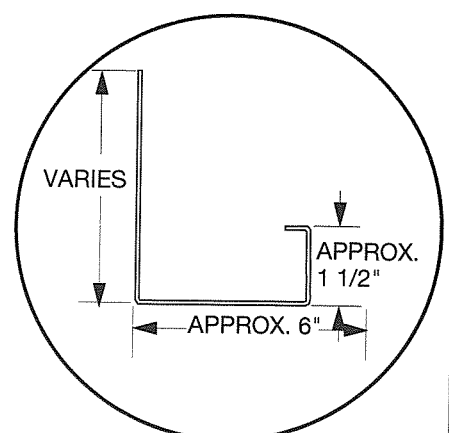
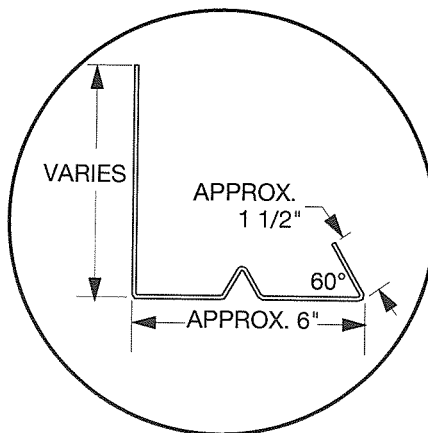


Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves, valleys, and around penetrations). (Consult local authorities for building code requirements.)
3. Sheet metal step or continuous flashing should be a minimum of 24 ga. pre-finished galvanized steel, 16 oz. copper or an equivalent longevity non-corrosive metal.
4. Solid wood blocking is required behind pan flashing and Z-metal counterflashing applications for stucco or cementitious cladding.
5. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
6. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.



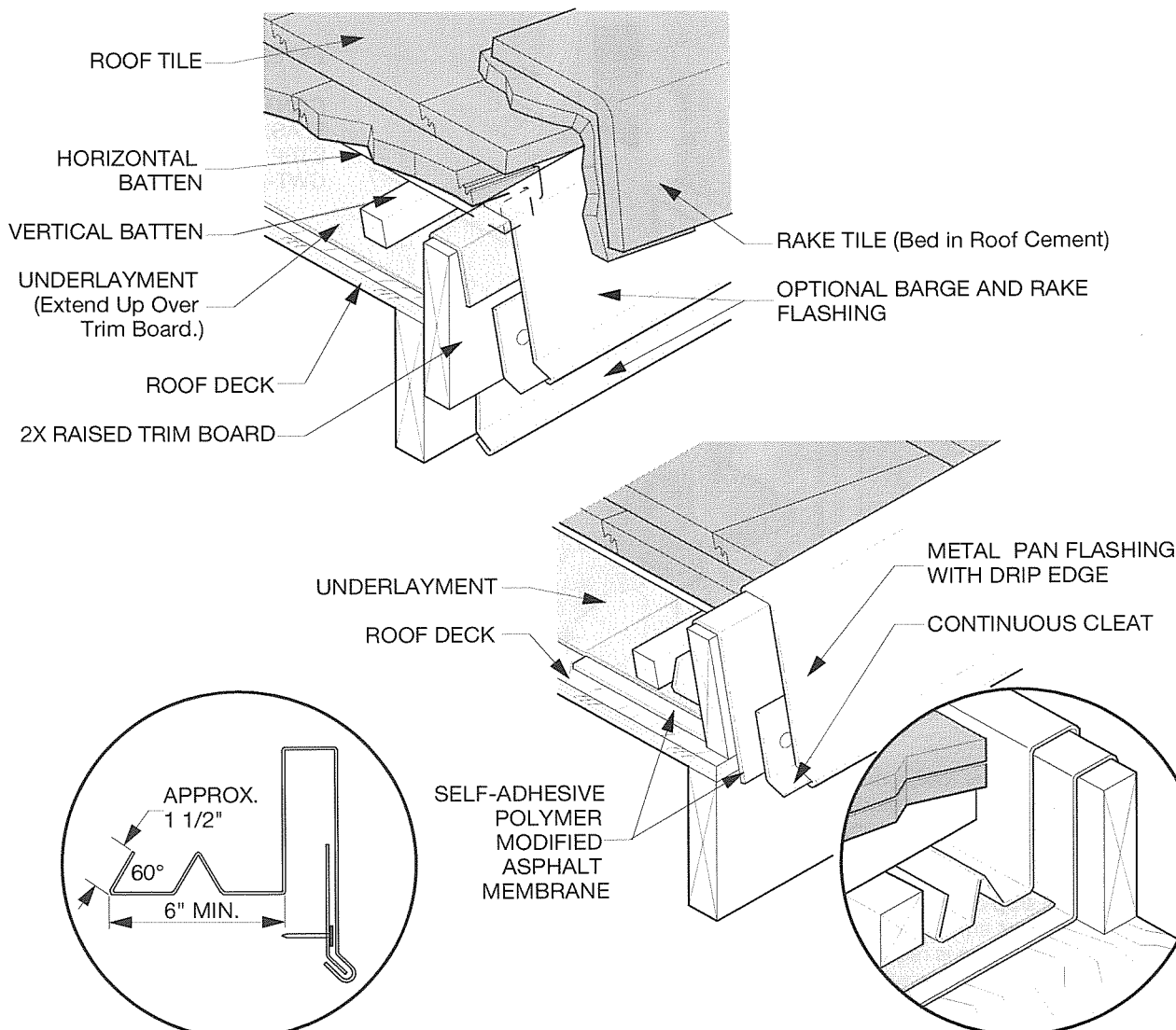
MINIMUM PAN FLASHING



PREFERRED PAN FLASHINGS

RAKE FLASHINGS

CWT-14



PAN FLASHING AT METAL RAKE

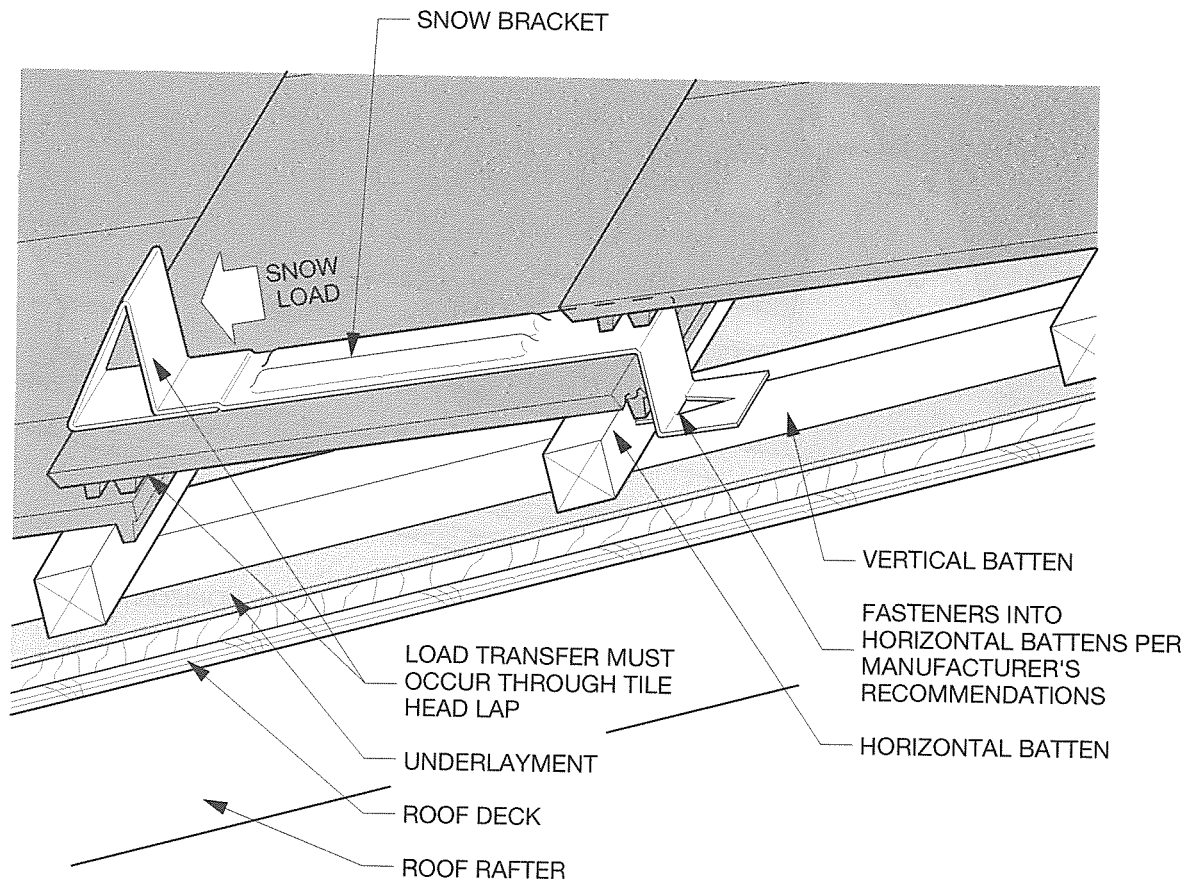
INSIDE VIEW OF PAN FLASHING

Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. Sheet metal flashing should be a minimum of 24 ga. pre-finished galvanized steel, 16 oz. copper or an equivalent longevity non-corrosive metal. For profile tile use malleable step flashing.
4. Continuous cleats are recommended when rake flashing face dimension exceeds 3 inches and in areas where design wind zone is 70 mph or greater.
5. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
6. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.

SNOW BRACKET

CWT-15

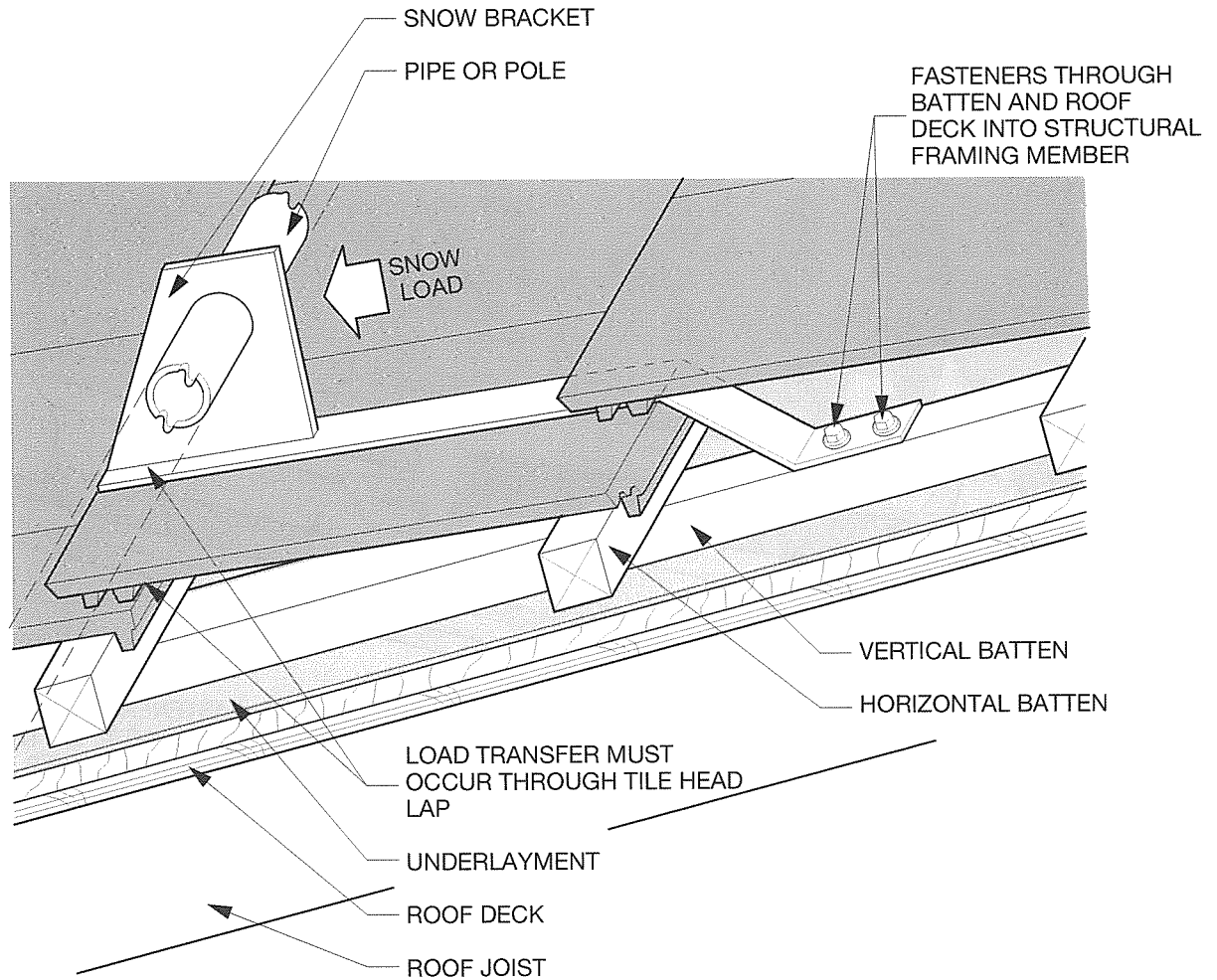


Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
4. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.
5. **Consult bracket manufacturer and/or engineer for number of brackets, layout location, fastening schedule, fastening location, schedule, and other specifics. See Chapter 3, Section VII of *Concrete and Clay Tile Roof Design Criteria Manual for Cold and Snow Regions* for additional information on snow retention.**

TILE SPECIFIC SNOW FENCE BRACKET

CWT-16

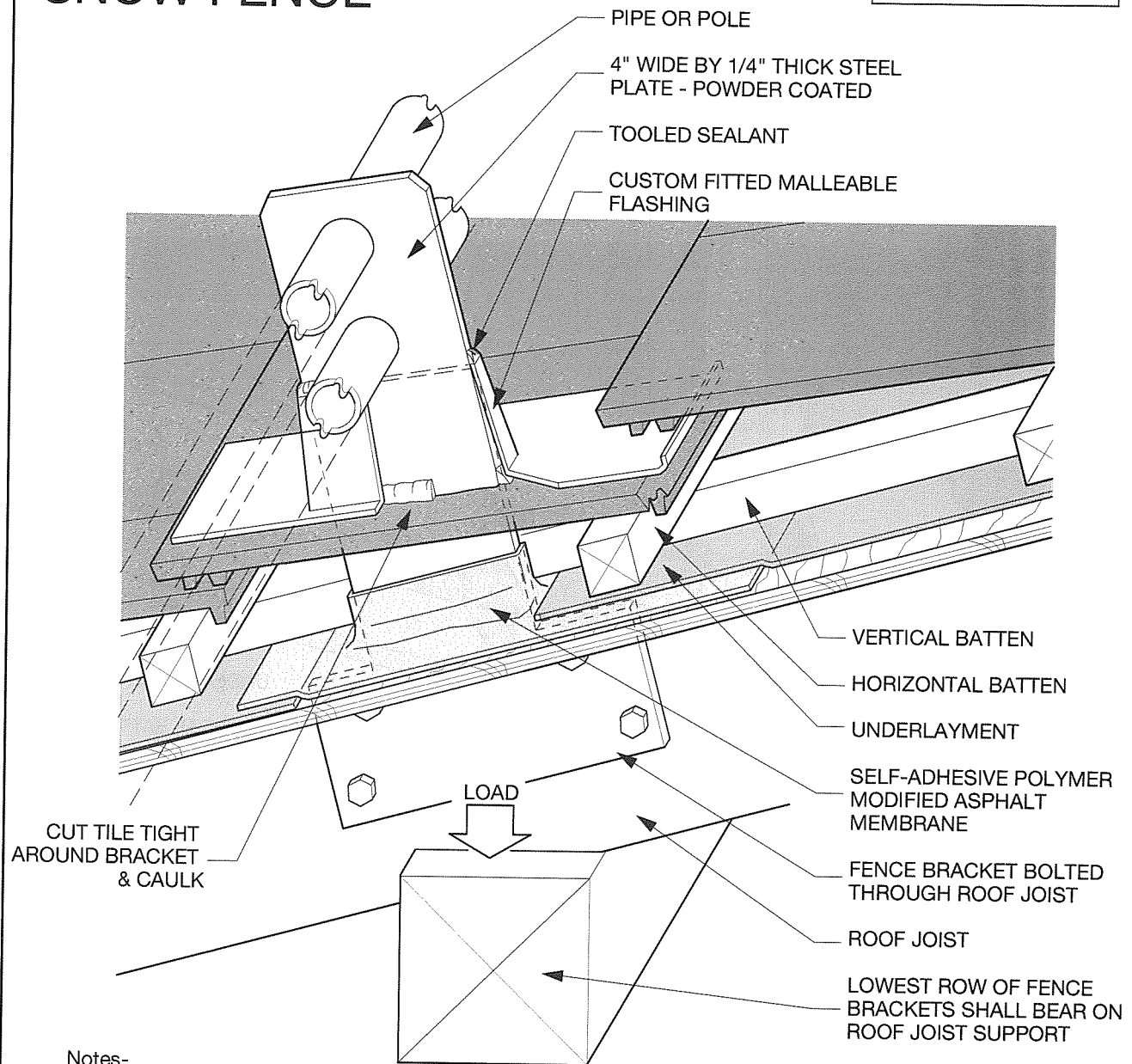


Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
4. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.
5. **Consult bracket manufacturer and/or engineer for number of brackets, layout location, fastening schedule, fastening location, schedule, and other specifics. See Chapter 4, Section VII of Concrete and Clay Tile Roof Design Criteria Manual for Cold and Snow Regions for additional information on snow retention.**
6. Serious consideration must be given to bracket with combined snow and ice loading that is transferred to tile surface, to avoid crushing tile.

ROOF JOIST ATTACHMENT SNOW FENCE

CWT-17

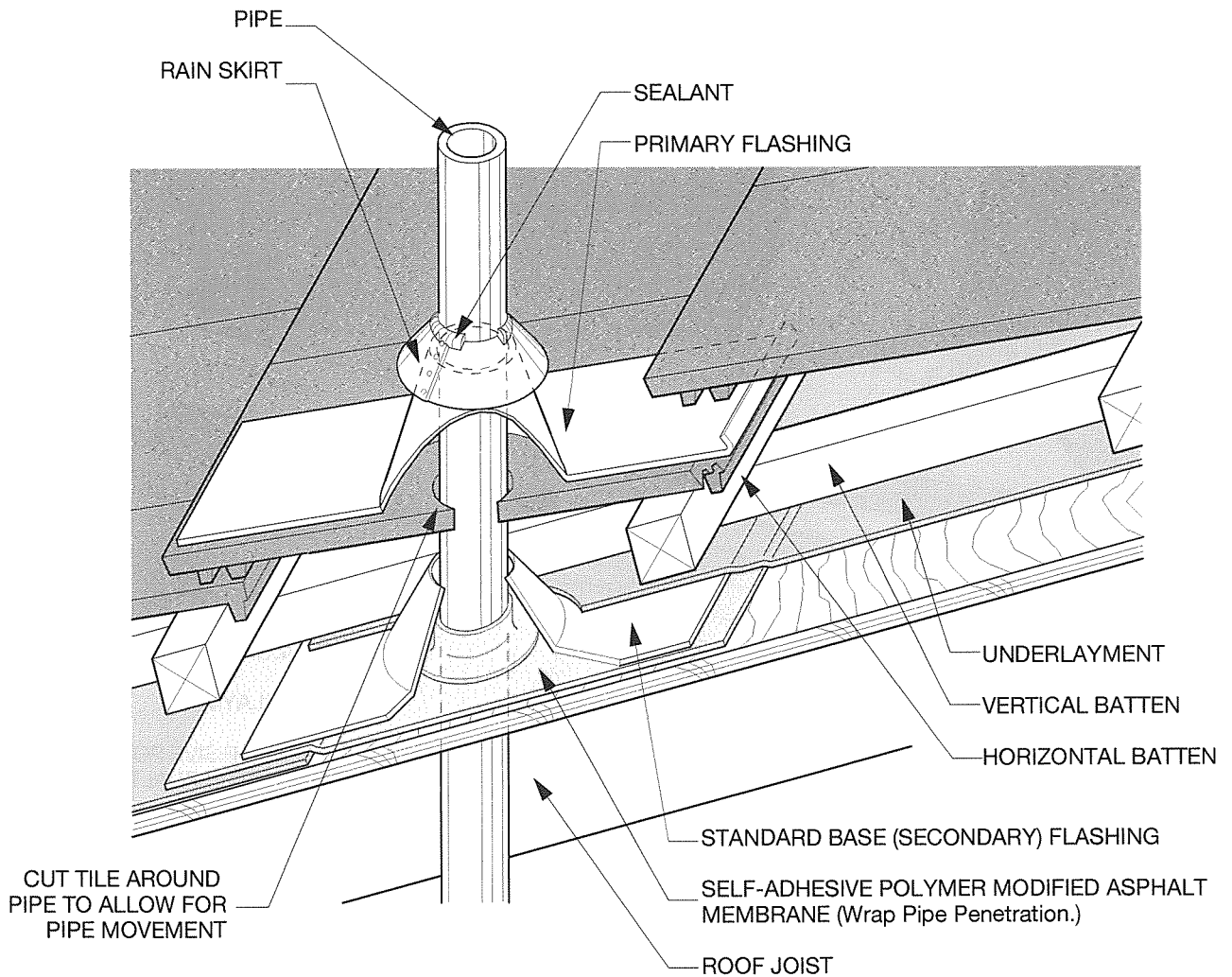


Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
4. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.
5. **Consult bracket manufacturer and/or engineer for number of brackets, layout location, fastening schedule, fastening location, schedule, and other specifics. See Chapter 4, Section VII of *Concrete and Clay Tile Roof Design Criteria Manual for Cold and Snow Regions* for additional information on snow retention.**
6. Serious consideration must be given to bracket with combined snow and ice loading that is transferred to tile surface, to avoid crushing tile.

PIPE PENETRATION FLASHING

CWT-18



Notes-

1. Over the field of the roof, a minimum of one layer of No. 30 asphalt-saturated felt complying with ASTM D-226 is required as underlayment on all tile roof applications. A minimum of two layers of No. 30 asphalt-saturated felt complying with ASTM D-226 are recommended for Climate Types 2 and 3.
2. An ice-dam protection membrane is recommended on all downslope roof perimeters (e.g. eaves), valleys, and around penetrations. (Consult local authorities for building code requirements.)
3. For recommended tile fastening schedule(s) see Fastening Table 1 in Appendix.
4. Dimensions shown are recommended minimums and are intended to be approximate to allow for reasonable tolerances due to field conditions.
5. Flashing base is recommended to be a minimum of 6" from base of cone for flat tile and 9" for profile tile, on all sides.
6. Pipe must be firmly attached to structural system to prevent dislocation.





Appendix A

Climate Condition Examples

A.1. Denver, Colorado is located at 39.7° north latitude and an altitude of 5,280 feet. According to the CRREL map (Figure 2-1), Denver is located in a 20 pounds per square foot ground snow load area. Ice and waterproofing membranes are not required by the building department. Ice dams occur about every 10 years and build up to 6 to 8 inches. There are enough warm days with warm Chinook winds coming off the mountains that the snow generally does not stay on the ground for more than two weeks. This area is Climate Type I.

B.1. Salt Lake City, Utah is located at 40.7° north latitude and an altitude of 4,220 feet. According to the CRREL map, Salt Lake City is located in a CS area and would require a site specific Case Study. We did not do a Case Study for ground snow loads. The area can experience high winds although this is not typical. The building department requires an ice and waterproofing membrane 2 feet up beyond the inside wall of all exterior walls. Ice dams are reported to be a problem. Solar radiation and freeze-thaw cycles contribute a great deal to the ice dams that form each year. This area is probably considered Climate Type II but may be on the edge of Climate Type III.

C.1. Vail, Colorado is at the same latitude as Denver, 39.7° north, but it is at an elevation of over 8,000 feet. According to the CRREL map, Vail is located in a CS area and would require a site specific Case Study. The yearly ground snow load is well over 30 pounds per square foot. Ice and waterproofing membranes are required 8 feet up past the inside of all exterior walls. Large ice dams form in the winter from the intense high altitude sun, and in the spring from quick changing freeze-thaw cycles. A cold roof design may work well if the architectural roof features are simple without dormers or other obstructions to the sun's rays that cause shadows. Trees shading the lower portion of a roof also create ice damming. This area is Climate Type III.

D.1. St. Paul, Minnesota is at 45° north latitude and an elevation of 822 feet. According to the CRREL map, St. Paul is located in a 50 pounds per square foot ground snow load area. Ice and waterproofing membranes are required 2 feet up beyond the inside of the exterior walls. Much of the winter is calm with little wind. The area has ice dam problems, more from building heat than from solar radiation. It is interesting

that the ice dams do not vary much from the north side of the building to the south. Roof ventilation is usually appropriate, but super insulated roofs with R-45 insulation and a vapor retarder on the inside (heated side) can also avoid chronic ice dams if built well. This area is Climate Type II.

E.1. Great Falls, Montana is located at a latitude of 47.5 north and an elevation of 3,664 feet. According to the CRREL map, Great Falls is located in a CS area that would require a site specific Case Study. Ice and waterproofing membranes are required by state law. However, the Great Falls Building Department does not enforce the law since the area does not have problems. Great Falls is located at the base of the mountains and experiences warm Chinook winds that blow in off the mountains and melt the snow. Two weeks is a long time for the snow to be on the ground. The area does not have ice damming problems. It is Climate Type I.

F.1. Bangor, Maine is at an elevation of 162 feet above sea level at a latitude of 44.7° north. According to the CRREL map, Bangor is located in a 70 pounds per square foot ground snow load area. The area does not require ice and waterproofing membrane to be installed at the roof edges; however, most roofers install it. There are ice damming problems if there is inadequate insulation, vapor retarder or possibly venting. It is Climate Type II.

G.1. Casper, Wyoming is at an elevation of 5,723 and a latitude of 43° north. According to the CRREL map, Casper is located in a 15 pounds per square foot ground snow load area. An ice and waterproofing membrane is not required by the building department. The wind blows constantly, creating some snow drifting on roofs but usually blows the snow off the roofs. This area is Climate Type I.

Appendix B-1

Ventilation

Section I. Vapor Drive

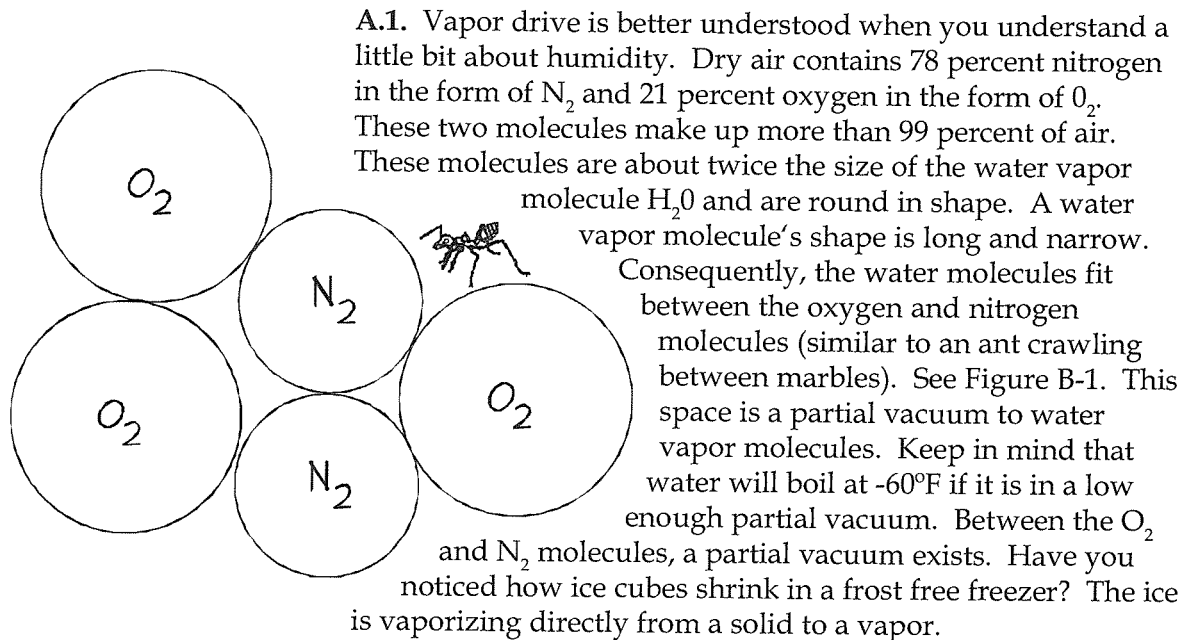


Figure B-1: Example of difference in size between oxygen and nitrogen

A.2. As air is heated, the water molecules move faster, bouncing off each other and creating larger voids between them. The larger the void, the more room there is for water molecules. The air acts much like a sponge; when it warms and expands, it sucks up the water. When it is cooled it "squeezes" the moisture out in the process of condensation. The point at which the air becomes saturated and moisture starts to drop out of the air is called the dew point. See Figure B-2.



Figure B-2: Example of condensation

A.3. The water vapor in the air moves to areas of less moisture or to where there is a greater partial vacuum. This is **Vapor Drive**. A typical example is a glass of ice water sitting on a table. The cold water lowers the temperature of the glass surface below the dew point of the room. As long as you put ice in the glass, water vapor will continue to condense and attract more vapor. The condensation runs down and accumulates on the table. This example assumes the relative humidity of the air around the glass is high enough that moisture will condense on the glass. At 72°F, the relative humidity would need to be above 25 percent for condensation to form on the glass. See Figure B-3.

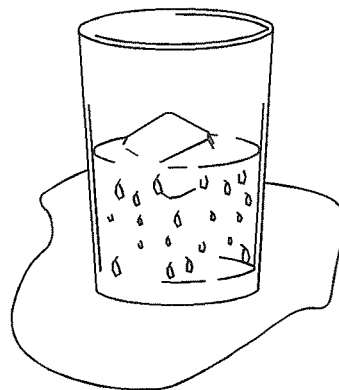


Figure B-3: Example of vapor drive

A.4. In the case of a residential building, moisture is generated by cooking, showers, humidifiers, hot tubs and perspiration. In winter months with cold, dry air outside, the inside moisture is drawn into the walls, ceiling and doors at a rapid rate. This is due to vapor drive, or the movement of moisture from an area of high vapor pressure to an area of low vapor pressure. As the moisture moves through the ceiling and insulation, the air is cooled and squeezes out the moisture condensing within the insulation when it reaches the dew point. The increased moisture in the insulation lessens the effectiveness of the insulation in the ceiling. If the moisture reaches a place in the insulation that is below 32°F, it freezes and builds frost. This frost melts when the weather warms, wetting the ceiling and dripping down into the room below. With tight vapor retarders and outside ventilation, the small amount of moisture involved can be continually drawn off to the outside air, preventing the buildup of moisture within the insulation. See Figure B-4.

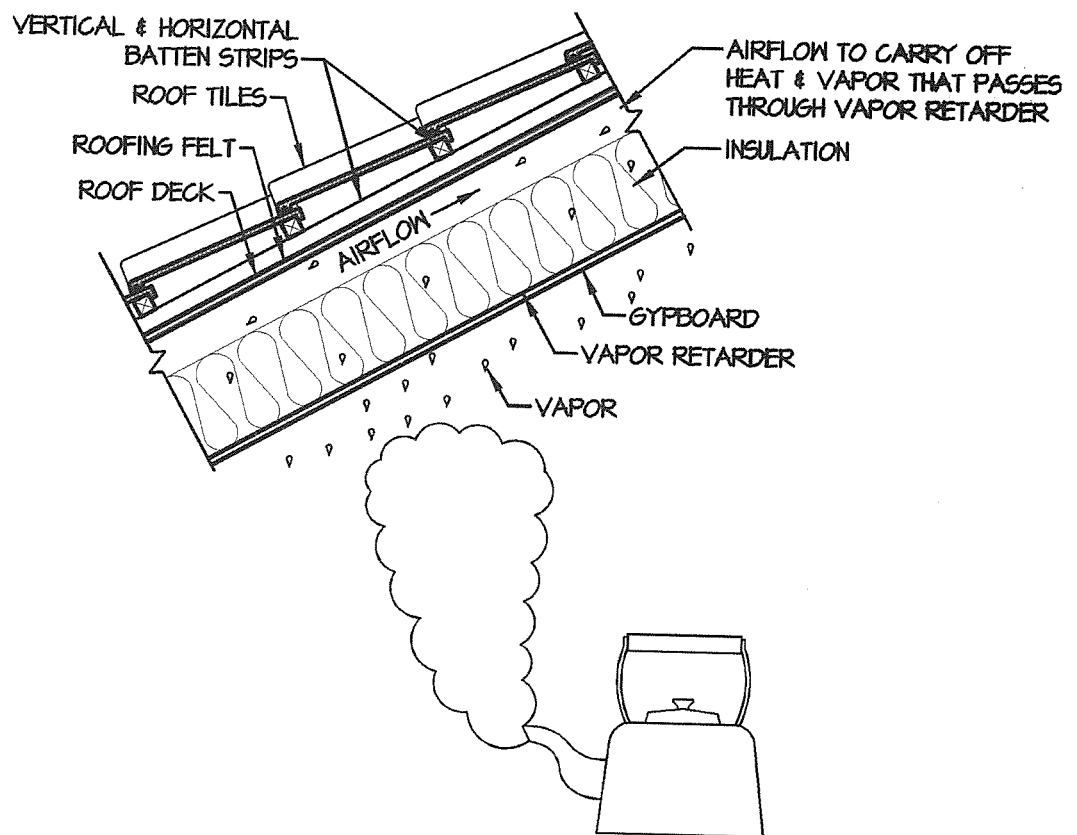


Figure B-4: Vapor drive and ventilation

Section II. Controlling Vapor Drive

A.1. Vapor drive must be controlled so that there is less moisture allowed into a ceiling or wall than can be removed to the outside. Often people refer to a vapor barrier when they are really talking about a vapor retarder; there are very few building systems that create a true vapor barrier. Materials such as gypsum board and most paints used on building interiors provide almost no vapor retardation.

A.1.1. An example of a problem roof seen often in mountain areas is where an ice and waterproofing membrane is used on the roof deck directly above an insulated roof system with no attic, a 4 mil thick polyethylene sheet vapor retarder on the inside or warm side and gypsum board. No ventilation is provided in the joist space. The vapor drive forces moisture through the staple holes, nail holes and screw holes and lap joints of the polyethylene and into the interior ceiling. The moisture is not allowed to move to the outside as fast as it comes in because of the ice and waterproofing membrane placed on top of the roof which seals itself when nails are driven through it. Moisture content in wood of over 20 percent will allow most woods to start rotting. In a few years roof joist can rot to the point of collapsing.

B.1. In all buildings in cold climates the vapor retarder must be better on the inside of the building than on the outside or have sufficient vents.

Appendix B-2

General Field Tile Fastening Guidelines

The fastening requirements depend upon roof slope, deck type, orientation to prevailing winds, design wind speed and local wind uplift code requirements. Where field tile nailing is specified or required, one nail per tile may be used but two nails are recommended and shall be approximately an 11-gauge, corrosion resistant box nail and must penetrate 3/4" into wooden batten strips or through the thickness of the sheathing, whichever is less.

FASTENING - TABLE 1

FIELD TILE NAILING			
Roof Slope ¹	Solid Sheathing With Battens	Solid Sheathing Without Battens	Perimeter Tile & Tile On Cantilever Areas ²
3:12 to less than 5:12	Nailing May Not Be Required - Check Building Code	Fasten Every Tile	Fasten Every Tile
5:12 to less than 12:12	Fasten Every Tile Every Other Row	Fasten Every Tile	Fasten Every Tile
12:12 And Over	Fasten Every Tile	Fasten Every Tile	Fasten Every Tile
NOTE: For slopes of 21:12 (60°) and greater, one nose clip per tile is recommended in addition to specified nailing.			

¹ For roof slopes above 7:12 battens may be required. Check local Building Codes.

² Perimeter may be defined as 10% of minimum building width or 40% of building height, whichever is less but not less than 3 feet. Perimeter areas include all hips, ridges, eaves and rake edges.

³ In snow areas, a minimum of 2 fasteners per tile are required, or battens and 1 fastener.

Appendix C

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Appendix D

About the Editors

Leland E. Gillan has a bachelor of science degree in mechanical engineering from Colorado State University and is a registered professional engineer in the states of Colorado and New Mexico. He is co-owner of Gillans Incorporated, an engineering and architectural firm in Westminster, Colorado offering consulting services in all building disciplines. He became interested in tile roofs during a consultation with Telluride Mountain Village, a community with all tile roofs and a tremendous amount of annual damage. Gillan has since researched and put into practice a more complete explanation of why ice dams form and how to prevent them. In addition, he is involved with numerous organizations including the Roof Consultants Institute, the Construction Specifications Institute, the Roofing Industry Education Institute and the National Roofing Contractors Association. Gillan can be reached at 303-426-1731 or by e-mail at GillansInc@aol.com.

Terry Anderson has been involved in the roofing industry for 22 years and is the owner of Anderson Associates Consulting and TRA in Highland, Utah. His specialty is concrete tile, and he has done research about snow and ice movement on roofs in other countries. This research helps Anderson provide consulting services to the Rocky Mountain area where snow and ice have caused problems for concrete tile. His expertise is known throughout America, and he has written several articles on snow and ice movement on tile roofs for leading trade magazines. Anderson holds a roof contractor's license and is associated with the Western States Roofing Contractors Association, Roof Consultants Institute, National Roofing Contractors Association and Roofing Industry Education Institute. He is also accredited to teach continuing education by the American Institute of Architects. Anderson can be reached at 801-756-8666 or by e-mail at terry@trasnowbrackets.com.

Wayne Tobiasson has a bachelor of science degree in civil engineering from Northeastern University and a masters of engineering from Dartmouth College. Before his retirement, he was a research civil engineer with the U.S. Army Corps of Engineers' Cold Regions Research and Engineering Laboratory (CRREL). Tobiasson is a member of the American Society of Civil Engineers, an honorary member of the Roof Consultants Institute and has taught at the Roofing Industry Education Institute. He can be reached at 603-643-5490 or by e-mail at weworkshop@aol.com.

Index

A

Air flow

Inlet and outlet losses: 4-5, Glossary-1

Maximizing: 4-7

Screens: 4-5

Altitude. *See* Elevation

Architectural design, criteria: 3-2, 4-3

Asphalt felt. *See* Underlayment

Avalanche: Glossary-1

B

Batten boards: 3-4, 4-2, 4-13, 4-14, 4-20, CWT-2, Glossary-1

Chimneys: CWT-11, CWT-12, CWT-13

Horizontal: CWT-4, CWT-8

Vertical: 3-3, CWT-3, CWT-7

BTU: Glossary-1

C

Cathedral ceilings: 1-6, 3-2, 4-3

Chimneys: 4-8, CWT-11, CWT-12, CWT-13

Chinook winds: Glossary-1

Climate

Considerations: 2-2

Examples: A-1

Identification: 2-1

Related questions: 2-2

Type I: 2-1, 3-1

Type II: 2-1, 4-1, 4-14

Type III: 2-1, 4-14, 5-1

Cold roofs: 1-4, 1-6, 1-8, 4-9, Glossary-1

Condensation: 1-11, 4-13, B-1, Glossary-1

Construction adhesive: 3-2, 4-2

Crickets: 4-8

D

Detail design: CWT-1

Dew point: B-1

Disclaimer: ix

E

Eave overhang: 1-4, 3-2, 4-8

Elevation: 1-2, 1-3, 1-4, 1-6, 1-8, 1-9, 2-1, 2-2, 5-1

Exfiltration: 1-9, 3-3, 4-4, 4-17, Glossary-1

F

Flashing

Barge board rake: CWT-20
 Continuous at wall: CWT-19
 Criteria: 3-4, 4-21
 Double: Glossary-1
 Eave: CWT-18
 Pipe penetration: CWT-24
 Roof rake: CWT-20
 Roof ridge: CWT-15, CWT-16, CWT-17
 Snow fences: 4-25
 Step at chimneys: CWT-13
 Thickness: 3-4, 4-21
 Trimming siding away from: 3-5, 4-21
 Valley: 4-21, 4-22, CWT-5, CWT-6, CWT-7, CWT-10
 Wall: 3-4, CWT-19

G

Gable vents: 4-7
 Ground snow loads: 2-2, 2-3, A-1

H

Head lap: 4-2, Glossary-1
 Heat loss: 1-2, 1-4, 1-9, 2-1, 4-1, 5-1
 Heat tracing: 4-10
 Disadvantages: 4-11
 Heated drain pipes: 1-10
 Heating panels: 4-11

I

Ice and waterproofing membrane: 2-2, 3-3, 3-4, 4-11, 4-12, 4-13, 4-21, Glossary-1
 Problematic installation: B-4
 Ice dams: 1-1, 1-2, 1-3, 3-1, 4-1, 5-1, Glossary-1
 Insulation: 1-6, 1-11, 3-1, B-3

L

Latent heat: Glossary-1
 Latitude: 1-6, Glossary-2
 Low-slope roofs: 1-10, 1-11, 4-9, Glossary-2

N

Nailing tables: 3-4, 4-21
 Non-passive design: 4-9

P

Parapet walls: 1-11, 4-9

Passive design: 4-8

R

Ridge extension: 4-6

Roof

Elevations: 5-1

Leaks, apparent: 4-13

Penetrations: 1-9, 3-4, 4-4, 4-5, 4-18, 4-21, Glossary-2

Shaded areas: 5-1

Slope: 3-2, 4-3

S

Snow

Brackets: 1-10, 3-5, 4-23, CWT-21, Glossary-2

Fences: 1-10, 4-24, 4-25, CWT-22, CWT-23, Glossary-2

Load: 3-4, 4-20, 4-25, Glossary-2

Melting systems: 4-8, 4-19, 4-23, 5-1, Glossary-2

Movement: 1-10

Retention: 1-11, 3-2, 3-5, 4-3, 4-23, Glossary-2

Information for manufacturer: 3-6, 4-26

Information from manufacturer: 3-6, 4-26

Sliding: 1-10

Solar radiation: 1-2, 1-4, 1-6, 1-8, 1-9, 2-1, 2-2, 5-1,
Glossary-2

Steep roofs: 1-10, Glossary-3

Super insulated roofs: 1-4, 4-1, 4-4, Glossary-3

T

Temperature fluctuations: 1-2, 1-6, 2-2

Tile

Clay: 3-1, 4-1

Concrete: 3-1, 4-1

Criteria: 3-1

Fasteners: 3-2, 4-2

Installation: 3-1, 4-1, Glossary-3

Integral color: 3-1, 4-1

Snow and ice weight: 4-2

U

Underlayment: 3-3, 4-11, 4-12, CWT-3, CWT-7

V

Valley flashing. *See* Flashing: Valley

Valleys: 4-22

 Closed: CWT-7, CWT-10

 Open: CWT-5, CWT-6

Vapor drive: B-1, B-2, B-3, B-4

Vapor retarder: 1-6, 3-3, 4-1, 4-4, 4-15, B-3, B-4,

 Glossary-3

Ventilation: 1-2, 1-4, 1-6, 1-8, 1-9, 3-2, 4-3, 4-5, 4-6,

 4-14, 4-18, B-3, Glossary-3

W

Waterproofing membrane. *See* Ice and waterproofing membrane

Wind: 2-2

Glossary

Avalanche: A mass of snow or ice suddenly moving down a sloped surface.

Batten boards (single, double, horizontal, vertical): Strips of lumber between the roof deck and the roof tiles. Vertical battens run up-slope; horizontal battens run cross slope.

BTU: British Thermal Unit. It is the amount of heat required to raise 1 pound of water 1 degree Fahrenheit.

Chinook wind: A wind that blows down off the mountains, warming as it descends.

Cold roof: A roofing system which contains a ventilated air way above its insulation to cool the roof deck and remove moisture.

Condensation: Water's change in state from a vapor to liquid.

Doubled flashed: Layers of flashing both over and under tiles.

Entrance and exit losses: Reduction in air flow at the vent inlets or outlets.

Exfiltration: Air movement from a building's interior to the exterior. The air filters through building components (i.e., drywall, rafters, siding).

Head lap/overlap: The amount of up-slope overlap of tiles placed on a roof.

Ice and waterproofing membrane: Self-adhering, rubberized asphaltic membrane placed on portions of roofs to waterproof them. This membrane needs the ability to remain watertight when nails are driven through it.

Ice dam: Ice that forms on a roof, often at eaves, damming up water behind it.

Latent heat: Heat released by water vapor into its surroundings as it condenses, or heat absorbed when water is vaporized.

Latitude: The system of parallel line measurements extending in an east-west direction on the globe representing the angular

distance north or south of the equator.

Low-slope roof: A roof with a slope of less than 3 inches vertical to 12 inches horizontal (3:12). Most low-slope roofs have a slope of 1/4 inch per foot to 1/2 inch per foot and require waterproof membranes rather than water-shedding systems like tiles.

Rafter space: Space between rafters containing insulation and, in the case of a ventilated cathedral ceiling, an airway.

Roof penetration: Openings made in the roof for items such as vents, flues, chimneys or skylights. Penetrations must be flashed and sealed to prevent roof leaks. Penetrations complicate roof ventilation.

Snow and ice melt systems – heat tape, heat panels, heat trace: Systems used to melt snow and ice on the roof. These systems are often used at eaves where melt water from other areas refreezes, creating ice dams.

Snow bracket: A small snow retention device mounted on the tile's surface. Brackets should be spaced through the system from eave to ridge.

Snow fence: A snow retention system in the form of a cross-slope fence usually less than 1 foot high. The height of a snow fence helps to prevent an upper layer of snow from delaminating from a lower layer and sliding off the roof. Snow fences are often used for whole roof snow retention. This is not a recommended application of a snow fence.

Snow load: The weight of snow in pounds per square foot on a roof.

Snow retention system: see snow fence and snow bracket

Snow, ripened: Snow that has warmed and frozen; it contains ice in various forms. This snow is more dense and stronger than fresh snow. It can more easily damage tiles if it slides down a roof's slope.

Solar radiation: A measure of the amount of solar energy a site receives. High altitude and low north latitude combine to increase solar radiation.

Steep roof: A sloping roof designed to shed water rapidly

rather than resist water pressure as a roof membrane does on a low-slope roof. Tile roofs are steep roofs.

Super insulated roof: Insulation system with a thermal resistance rating of R-45 or greater combined with the installation of a vapor retarder on the warm side of the insulation. Generally these systems are not vented or are vented only enough to prevent vapor collection and condensation in the attic or roof space.

Tile installation, broken bond or staggered: Tiles are laid so that the side laps do not line up from one row to the next.

Tile installation, full bond or straight bond: Tile installation method in which the tiles are laid in straight lines rather than staggered.

Vapor retarder: Barrier or membrane intended to reduce the amount of moisture that passes through ceilings into roofing systems. It is important that a vapor retarder have a low permeability to reduce diffusion of moisture through it. As well, it is essential that a vapor retarder does not contain gaps that allow moist indoor air to bypass it.

Ventilation: A means of providing for fresh (outdoor) air to enter and escape from an attic, cathedral ceiling or airways between tiles and a roof deck below.

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