We hope that the information provided in this chapter will help determine whether architectural or structural, standing-seam, or through-fastened roofing is appropriate.

6.11.1 Avoid Penetrations

Do not compromise the advantages of metal roofing by cluttering it with a forest of pipes, ducts, openings, and rooftop-mounted equipment. Every roof penetration or opening results in field-cut panels that can restrict temperature expansion, expose metal to corrosion, and invite future leaks. It is better to make penetrations through the walls; these are is much easier to protect from leakage. It is also better to combine several potential roof openings into one by manifolding vent pipes together.[21] Where impossible to avoid, the penetrations and openings should be carefully detailed to allow for panel movement and to resist water intrusion. One of the product selection criteria should be clarity of the manufacturer's details for difficult conditions.

For architectural panels with felt underlayment, any penetrations through the felt should be detailed at least as carefully as through the metal. Also, underlayment must be allowed to drain at the eaves, which is impossible if the eave trim blocks it. To drain properly, the felt should run on top of the trim and into the gutter, not behind it.[42] Where the roofing details make that impractical, at the very least the edge of the underlayment should be turned down over the wall siding and protected with eave flashing, as in Fig. 6.46.

6.11.2 Select Proper Products

When standing-seam roofing is called for, carefully review the seam details offered by various manufacturers. As Stephenson[43] observes: "Some so-called weather-sealed designs are more weather-resistant than others, and some may prove to be not weather-sealed at all." Clearly, the Pittsburgh-style seam (Fig. 6.2*d*) is superior to the snap-on types. Structural roofing recommended for low slopes ($^1/_4$:12) is likely to be more water-resistant than most architectural products designed for a 3:12 or steeper slope. From the standpoint of hurricane resistance, all seam designs are somewhat vulnerable, but the snap-on types seem to perform the worst.

As for the roof coating, we recommend using Galvalume panels, either clear-coated for industrial, warehouse, and similar utilitarian applications, or PVDF-finished for all others, except for minor and temporary structures where acrylic or polyester will suffice. Galvalume roofing should be accompanied by flashing made of the same stock (and of the same color line, if the roof has color), or of aluminum. Galvanized, copper, or lead flashing common in other types of construction should not be used in metal building systems. Galvanized flashing does not provide the same high level of corrosion resistance as Galvalume, while copper and lead flashing may cause galvanic corrosion when placed in contact with zinc-aluminum coated steel.

We recommend that gutters and downspouts be provided in most large metal buildings. The manufacturers carry these essential means of removing rainwater as an additional-cost item, and some owners are tempted to save money by omitting them. Without gutters, such as those shown in Fig. 6.46, water can cling to the underside of the roofing and find its way back into the building, especially in the absence of properly installed roofing closures and sealants.

And finally, thin metal tends to get damaged by hail, as many car owners have discovered. In areas where hail is frequent, heavier-gage panels should be used—or perhaps even nonmetal roofing.

6.11.3 Special Consideration for Roofs in Cold Regions

Snow and ice accumulation can severely test the structural capacity of a metal roof. Drifting and sliding snow can overstress some areas of the roofing and produce local depressions in others, where standing water could collect. This water could leak into the building through the seams of water-

shedding panels or even through the supposedly waterproof roofing with some minor breaches in its defenses. A classic source of leaks in metal and other roofs is ice dams.

Ice dams begin to form when rising building heat melts the roof snow in some areas. The water trickles down under the snow until it reaches a cold eave, where it freezes. The freshly melted water collects behind this ice dam and eventually backs up into the unprotected seams or sealant gaps of the roofing. The key to ice dam and icicle formation is a combination of warm roofs and cold eaves, so it is important to avoid both.

As house builders in snow country have long realized, overhanging eaves and cathedral ceilings should not be combined. Roof insulation helps keep the roof cooler and reduces snow melting. In some areas of the United States it is common to heat the eaves with special heating cables. The risk of leakage can be further mitigated by using "waterproof" instead of "water-shedding" panel design and increasing roof slope (to even as high as 2 to 12, according to Tobiasson and Buska[3]).

If water-shedding roofs are used in snow country, at the very least they should be equipped with added waterproofing layers at the eaves and valleys. As Hardy and Crosbie[21] suggest, the valleys should be made of flat metal stock and widen toward the bottom of the roof, to promote snow movement away from these difficult-to-waterproof areas. The vertical roof seams terminating at the valleys tend to interfere with the sliding valley snow and can be bent or torn by it. Similarly, vent stacks should be located away from the eaves so as not to become the unintended snow guards that can be damaged by sliding snow. But what about snow guards in general?

Architectural roofing, even when used on the steep slope, does not work very well with snow guards. The snow and ice trapped by the guards may melt and seep through the joints, resulting in ice damming. When the snow guards are required, it is best to specify high-quality Pittsburgh-style seams.

In any case, it is not clear how effective snow guards are on metal roofs. Sometime they can hold too much snow and lead to a roof overload, or can get torn off by a large snow accumulation, causing roof damage and leakage. Building codes often require that the roofs with snow guards be designed for the flat-roof snow load, rather than for a potentially lower sloped-roof load. It is important to realize that snow guards are intended to keep the roof snow in place until it melts, but they cannot stop the snow already sliding down the roof.

Snow collected on a steep roof tends to pull the roofing downward. While snow load is vertical in nature, on sloped roofs it can be resolved into the components acting parallel and perpendicular to the roof, similarly to the forces illustrated in Fig. 5.14*a* in Chap. 5. The steeper the roof, the larger the parallel-to-the-roof component known as the drag force. The roofing fasteners must be able to resist this drag force, and the panel manufacturer should demonstrate that the fasteners are adequate for the task.

6.11.4 The Importance of Proper Construction

Throughout this chapter, we have emphasized the importance of proper design and selection of roofing, but even the best-designed system will fail if installed incorrectly. This is why warranties and the manufacturer's and installer's reputation are important. A wealth of information about various metal roofing manufacturers can be found in NRCA's *Commercial Low-Slope Roofing Materials Guide*.[44] For projects with any nontypical features, details for which are not included in the manufacturer's standard assortment, shop drawing submittal should be required. The shop drawings should clearly indicate the installation details for all trim, fasteners, and sealants.

Still, the installer's qualifications are even more important. Despite the commonality of design errors, most wind-related roof losses can be traced to improper roofing attachment to the structure.[20] The general issues of avoiding bad apples in contractor selection are discussed in Chap. 9, but it is also essential to gain a measure of confidence in the contractor's workmanship during roofing installation.

How to tell if the roofing is being installed in accordance with the best construction practices? Here are a few signs of poor workmanship (and of poor system design) in roofing installation:

1. All panel endlap splices line up, meaning that four panel corners overlap and must be sealed at one place, which is difficult to do properly. Quality manufacturers often require that erectors stagger the roofing splices. Preferably, the splices should occur over the purlins rather than between them.