## SUMMARY OF DESIGN GUIDELINES FOR METAL WALL AND ROOF SYSTEMS

a. Sheet metal wall and roof systems offer virtually unlimited, cost-effective choices to meet job requirements. Early consultation with qualified sheet metal contractors about specific job details, technical advice and good general practice is highly recommended to take advantage of their knowledge and extensive previous experience. Use the Metal Roof Plan drawing on page RP.3 to obtain a complete and coordinated system and design.

b. There are two general categories of metal systems: those that require continuously backed (architectural) support and those that are structurally adequate with intermittent support (structural). The examples on Figure 6–19 represent typical design concepts. There are many systems the sheet metal contractor can provide.

c. Long-length sections should be considered for reasons of least cost, visual effect, and greater potential for water tightness.

d. Prefinished metals should not be required to have soldered joints because of expense and possible warranty violations of removing the coating system at the joint. Other joint designs and high quality sealants, gaskets and tapes are available and are recommended for prefinished metals.

e. Prefinished systems should have minimum exposure of sealants and touch-up paint because of differential coloring or fading relative to the main surface.

f. Provide appropriate temperature resistant waterproof membrane as recommended under wall and roof systems. *See* Section F.3 Underlayment Commentary.

1. Asphalt-saturated organic roofing felt (non-perforated) that is covered with rosin-sized paper (often called a slip sheet) immediately preceding the application of the copper roofing has historically been used as the underlayment method for copper-metal roofing systems. The rosin-sized paper acts as a separator sheet to keep the copper roofing metal from adhering to the roofing felt. The separator sheet helps reduce oil canning of the copper metal while protecting the underlayment from being damaged by thermally-induced movements of the metal. Also, where metal seams are soldered, rosin-sized paper helps protect the underlayment from the heat of soldering.

2. Membranes are now commercially available that do not require the use of a rosin-sized separator sheet because the membrane material and the metal roofing materials will not adhere to one another. Slip sheets should be used over the membrane in areas where the metal is to be soldered to protect the membrane from excessive heat.

3. Where moisture under the metal is a potential problem, rosin-sized separator sheets should not be used under metal roofing materials that are subject to rusting. Some types of geotectic fabrics may reduce under-metal condensation. Check with the metal and underlayment manufacturer for specific recommendations.

g. Wind, live- and dead-structural loads and fastener/clip size and spacing conditions must be reviewed for local conditions and code requirements.

h. Factors to consider in designing eave to ridge runs of standing seam and batten seam roofing are:

1. Whether expansion will be controlled by anchoring the roof at the ridge, at midpoint of a rise, at the eave or in the transverse seams of pans that are limited to 8 or 10 ft (2.5 to 3.0 m).

2. Depending on type of metal, roof design, and location of fixed points expansion must be considered and accommodated with expansion clips and loose lock joints.

3. Structural metal panel roof systems are typically hydrostatic, that is water-barrier, roof systems. They are designed to resist the passage of water at joints, laps and junctures under hydrostatic pressure. These roof systems have the strength and capability of spanning structural members, such as joists or purlins, without being supported by continu-

ous or closely spaced decking. A structural metal panel roof system's capacity is influenced by metal type, gage/thickness, panel width, seam height, use of stiffening or intermediate ribs in the pan of the panel, and purlin spacing. Nonstructural metal panel roof systems are absent of intermediate ribs or large side ribs which provides the panels with a clean appearance, but these panels typically do not have adequate strength to be used without a continuous or closely spaced substrate.

4. For custom sheet metal panels cleats typically should be installed at the rate of a minimum of 1 cleat per 2 square feet (0.186 $m^2$) of metal pan. Local codes or conditions or designers may require closer cleat spacing at 12 in. (300 mm) on center. Two fasteners per cleat are used. Expansion cleats should be used for standing seam pans of 30 ft (9.1 m) or more of continuous run. Fixed cleats can be placed at midspan with 5 to 10 ft (1.5 to 3.0 m) spacing, with expansion cleats elsewhere to allow movement in two directions.

5. Alignment of panels is critical at transitions and where flexibility of movement is needed at transitions. Expense is an important variable for these conditions.

i. Evaluate the potential for condensation occurrence within roofs and walls. Consult ASTM Standard E241, Standard Guide for Limiting Water-Induced Damage to Buildings, and ASHRAE Fundamentals Handbook.

j. Design penetration locations to avoid roof panel joint locations. Limit penetrations.

k. Evaluate patterns of roof seams and ribs to see prospects of nonalignment at hips and valleys, lower planes of roofs with higher planes, roof versus wall panels, mullions, etc. Criteria for acceptance with acknowledgement of practical limitations should be indicated. Wedge shaped panels may be more expensive than those with parallel edges.

l. Require a uniform, true, warp, and deflection controlled non-corrosive substrate of a continuous or grid contact support nature for metal roofing. The waterproofing and visual effect of metal systems can be compromised by irregular support systems.

m. Oil canning is defined as a perceived waviness across the flat areas of metal panels. It is a naturally-occurring phenomenon that is inherent in all light-gage sheet metal. Oil canning is more apparent under shallow cross lighting so its presence is more discernable during certain seasons or times of the day. Also, differing thermal forces can create waviness, either temporary or sustained, as the sun moves across the sky. Oil canning is an aesthetic issue, not a structural problem or a defect. It is unrealistic to expect any architectural roof or similar wide-metal element to be totally free of some degree of oil canning.

While oil canning cannot be totally eliminated, adherence to industry-accepted and –recognized methods of design, metal specification, handling, fabrication, and installation can minimize its occurrence. Recommended procedures are listed below:

- Design – Panel gages and widths scheduled in this manual were selected to minimize oil canning with proper installation but they should be considered minimum gages and maximum widths. Specifiers should use metal gages and limit panel widths that experience, either their own or that of experienced local sheet metal contractors, has shown as appropriate for a particular application. The most current ASTM standards should also be reviewed to gain insight into the standard tolerances. Wide, shiny, dark-colored, light-gage sheet metal panels will exhibit a degree of oil canning that is directly proportional to the width and inversely proportional to the thickness. Darker colors simply accentuate any oil canning that is present; it can be made less obvious by the use of lighter, more neutral colors. Also, reflective surfaces will be more unforgiving in revealing oil canning while the use of nonreflective or textured finishes aids in masking waviness. Movement of the primary support system or the structure itself can cause waviness that may become permanent or temporary during certain weather conditions. The fastener system should be designed so that the panels can "float" in response to thermal changes, the perimeter design is especially impor-

tant. Ultimately, the magnitude of thermal stresses transferred from the structure to metal panels is carried through the fastener system. Stiffening ribs can be specified within wide panels to break up the panel and make oil canning less apparent.

- Metal Specifications – Generally, the heavier the gage the less oil canning will be visible. Oil canning can also be reduced by ordering tension-leveled coils and re-squared sheet stock. Tension leveling involves stretching the metal on coils past its yield strength which provides a flatter surface less subject to oil canning. Resquared metal simply assures that the metal's shape will be more amenable to roll or brake forming without generating unwanted surface tensions due to warped raw material or metal edges that are not truly parallel.

- Refer to Table 6–1 for minimum thicknesses of fully supported metal. This table is based on metal roof panel widths. Handling – Proper handling needs to be addressed in every step of the process from production to final installation. For example, panels should not be carried "flat" or lifted by a single corner to remove one panel from a bundle. In some cases, especially with custom finishes, it may be beneficial to use gloves to handle and position metal panels.

- Fabrication – Slitting panels from a coil releases and creates residual stress within the metal. Typically, slitting from wider coil stock is unavoidable due to the economic benefits of using wider coil stock. Residual stresses are also created by any forming operations required to develop flat metal into the desired shape. Metal forming equipment should be well adjusted, operated within its design limits, and operated by experienced sheet metal crafters to minimize stresses induced by fabrication.

- Installation – The sheet metal's foundation—the substrate—is a very important element of any architectural metal system. For non-structural panels the substrate must be flat with any required felt or paper closely conforming to the supporting system. For structural panels, the resulting bearing surfaces must be properly aligned with the structure and one another or the metal will "telegraph" the location of each structural support. Otherwise, stresses induced when the metal conforms to any contouring of the bearing system can create oil canning. Placing panels too closely will not allow sufficient room for expansion and can generate waviness as daily and seasonally thermal stresses vary. Fasteners that are over driven or are of incorrect height, severely restrict movement—especially for long or wide panels—stress the panels through the daily and seasonal thermal variations and can create visible deformations. Allowances must be made for thermal expansion in all directions; rigid retention methods that are too restrictive can cause oil canning and create stress cracks and tears in the metal, especially along the perimeter. The substrate must be of a material, or set of materials, that will not adhere to the underside of the metal and restrict its normal thermally-driven movements. Handling should be done with care and, for some types of metals, clean gloves and appropriate shoes should be used to avoid scuffing the finish.

  Oil canning is typically more visible on a new roof before the natural patina of raw metals or the paint weathers to its normal gloss. Metals that weather to a natural finish as oxidation develops should be considered as a method to reduce the visual effects of oil canning.

n. The selection of a sealant is dependent on many factors including service temperature range, cohesion, adhesion to the contact surfaces, movement at the joint, cleanliness of surfaces, tack-free time, cure time, reaction to sunlight, ozone and ultraviolet radiation, modulus (load per unit of crossectional area to produce a given elongation), service life expectancy, hardness, shrinkage, air pressure differential, paintability, sag, cracking and water resistance. Selection by generic type, brand name or conformance to ASTM or Federal specifications does not necessarily insure satisfactory performance. Sealants that were developed for curtain walls and glazing may not be suitable for roofing and surface-mounted flashing use. Acrylic, neoprene, and

nitrile based sealants have reportedly corroded copper. Butyl, polysufide, and polyurethane sealants are in general use. Low-modulus silicone formulations are recommended when sealing flashing and roofing applications. Where surface runoff may create streaking, advanced, non-staining formulations should be used. Oil or resin based sealants have low UV resistance. Oil, resin, bituminous, and polybutene based sealants tend to be lower in performance and service life. The shelf life of sealants is relatively short. Sealants with expired shelf life should not be used. Consult local contractors about their experience with particular sealants. If in doubt, metal samples can be sent to a sealant manufacturer for specific recommendations. It is preferable to design metal systems with adequate pitch and drainability than to rely on sealants in low pitch, exposed fastener, and caulked edge flashing terminations.

o. Review the metals application data and design references in the Appendices.

p. Review the pressure uplift and water penetration test reports on SMACNA's standing seam and batten seam metal roof systems in Appendix D.

q. Edit and use the model project specifications for custom fabricated metal roofing in Appendix E.

## METAL SIDING AND ROOFING COMMENTARY

Metal siding and roofing can be formed by two different methods called roll-forming and press-brake forming. Roll-forming is the method of passing a sheet of metal progressively through a machine having powered, circular roller dies. Each station of roller dies consists of an upper and lower matched profile die section. As the metal progresses straight through the machine from roll stand to roll stand, the profile shape changes from flat to final form. The advantage of high-speed production is that lengths up to 40 ft (12.2 m) or more can be quickly processed. The disadvantage is the high capital cost of machinery. With fixed profiles there is no flexibility of shape change without changing dies, which are expensive.

Brake forming is the method of forming sheet metal by pressing it between male and female dies. The machine has a fixed length of working surface with the top section moving up and down to press the shape along the length of the matched dies. The machine lengths normally range from 4 to 20 ft (1.2 to 6.1 m) The advantage is virtually unlimited flexibility of shapes since the dies are relatively inexpensive for various bend combinations. The disadvantages are slower production speed and limited piece length. Piece lengths are only as long as a machine's working surface length.

Roll-formed sections are high production items of limited configurations providing the most surface coverage for the least cost. There is both a performance and price advantage for long lengths, 40 ft (12.2 m) per piece is typical. For greater lengths shipping or handling problems are a factor. Longer lengths can mean fewer or no end laps and less leak potential. Panel lengths 300 ft (90 m) and longer have been installed. Panel type and slope should be considered in panel length.

## MECHANICAL VERSUS HAND SEAMING AND METAL THICKNESS

Before specifying thick metal for double lock seams the formability and whether the seaming can be done with a mechanical seamer should be determined. While 24 gage (0.607 mm) steel can be hand formed it is very difficult and is generally only done for short distances ––like a standing seam across the top of a coping. Hand seaming such thick steel would be impractical for the long seams of a double lock standing seam roof, this would be done by a mechanical seamer.

Typically, the maximum thickness for double lock seams by metal type are 24 ga (0.607 mm) steel, 20 oz copper (0.685 mm), 0.040 in. (1.023 mm) aluminum, and 26 ga (0.381 mm) stainless steel. Thicker metals are more difficult to form and designers should consult the architectural sheet metal contractor regarding the limitations of field forming thicker materials. Also, details for thicker metals are not the same as for lighter metals. For example, alignment of individual elements may be more difficult as metal thickness increases.

## PORTABLE ROLL FORMERS

Power roll formers for standing and batten seams and power seam closers are available for on-site use. Seam spacing can be from 6 to 24 inches (152 to 610 mm). Various seam heights are possible. Rafter length pans can be installed with such equipment. This expedites installation and eliminates transverse seams. However, machine-closed seams may be so tight that expansion cannot be accommodated in the seam.

## PREPAINTED METALS COMMENTARY

Prepainted galvanized steel and aluminum sheet metal has a long history of use in the industry and millions

of pounds are used annually. Paint films are applied to the coil in a continuous process at various coil coaters located throughout the country. The usual coil coat system includes mechanical cleaning, a surface chemical treatment, prime coat and baking, finish coat and baking, application of light wax for handling and recoiling. Material may be slit or cut to length before shipment or shipped direct in coil form. A stripable film may be applied if requested to help with handling to minimize scratches. Paint may also be applied to bare metal after fabrication. This is known as post painting. The procedures are basically the same except the paint film is sprayed on instead of coil coating's roller application. Both the coil coat and the post-painting systems utilize thermal setting paints that cure at temperatures up to 425°F (218°C). These films have far superior film characteristics with much better resistance to chalk and fade than ordinary air dried spray or brush paints.

Many classes of paints are used but the most common liquid paints are acrylics, polyesters, silicon-modified polyesters and the kynars, in approximate ascending order of price. There is also platisol for highly corrosive atmospheres. All these coatings can be applied as either pre-painted or post-painted. Dry paints called powder coats are thermal setting also but presently can only be post-painted but have the advantage of a wide variety of vivid colors and high performance characteristics. There is acrylic laminating film in the market for coil application only.

Designers must be aware of the characteristics of the various paint systems. Prefinished coil will ordinarily cut and form with only minor common sense extra care. It is not necessary to post-coat the cut edge of prefinished galvanized steel. Post-painted metal can be welded prior to painting but cannot be soldered because the 400°F (204°C) bake temperature will ruin soldered joints and can cause serious distortion to work which has extensive welding. Important factors in the choice are:

a. available colors

b. paint system cost

c. amount of exposure to sun

d. compass orientation (worst case)

e. horizontal to vertical slope

f. corrosive atmospheres

g. expected film life

h. certain colors will fade more than others

Medium quality paints are often very satisfactory for ceilings or soffits. To over-specify is expensive.

All paints will deteriorate in time but good detailing and maintenance will extend life. Design flat, small valleys, gutters and re-entrants not to hold water or dirt. Emphasize the importance of regular rinsing and cleaning off debris. Today's paints are excellent, but it is worth the owner's time to understand the maintenance of the paints, which can result in many added years to the service life.