ACCESSORY METAL FOR USE WITH MEMBRANE ROOFING ASSEMBLIES

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Accessory metal is used with virtually all currently available types of membrane roofing systems. Deterioration of metal, inattention to detail, and poor installation techniques for accessory metal used with roofing assemblies cause frequent problems. One problem is damage to the membrane roofing material, which allows water to enter the roofing system or interior of the structure behind membrane components. In other cases metal becomes dislodged because of poor fastening, making it incapable of performing its designed function. To make membrane roofing assemblies less troublesome during their expected service life, more attention to selecting metal types, securing procedures, joining techniques, and selecting fasteners for accessory metal is required. This paper will formulate some guidelines for selecting metal types, joining metal sections, waterproofing, and securing methods which will result in more satisfactory performance from accessory metal used with membrane roofing assemblies and, therefore, improved performance from membrane roofing systems.

SELECTION OF ACCESSORY METAL TYPE

The metal types most commonly used with roofing assemblies are as follows.

- Galvanized Metal—26, 24, 22, 20, 18 gage
  G-60, G-90 standard galvanized steel
  "Paint-Grip"-type prepared galvanized metal
  Pre-finished galvanized metal
- Aluminum Sheet—.032, .040, .050, .064
  Mill Finish
  Anodized
  Pre-finished (painted)
  Extrusions (may be mill finish, anodized or pre-finished)
- Copper—16 ounces per square foot or 20 ounces per square foot, cold-rolled
- Stainless Steel (soft)— 26, 24, 22, 20 gage
- Lead—3 pounds per square foot, 4 pounds per square foot, sheet or pre-formed units
  (primarily for drain vent stack flashing)

Coefficients of expansion, corrosion resistance, cost, aesthetics and requirements for joining or sealing must be considered in the selection of metal for use with membrane roofing systems.

Accessory metal usually can be categorized into two types: watershed metal, and system component metal attached or sealed (stripped) to the roofing membrane. Watershed-type metal may be categorized as counterflashing, expansion-joint covers, perimeter-curb metal, wall closures, weathercaps (storm collars) and coping. Provision should be made for positive slope on all watershed metal to insure immediate runoff of water. Gravel stops, eave strips, metal base flashings for chimneys, stacks, etc., and drain metal must, of necessity, be stripped or sealed onto the roofing membrane and thus become a component of the roofing membrane.

Watershed metal need not be waterproof, nor joints sealed. This type of metal need only be able to shed water over raw edges of membrane flashings, from wall tops and surfaces, and over expansion joint curbs or metal base flashings. Adequate slope must be provided so that water will immediately drain from all such metal surfaces. Since watershed metal sections should never be sealed or attached to the roofing assembly, provision for movement of (or between) metal sections may be provided by lapped or interlocking vertical sections or by mechanical joints. Component metal must be sealed to the roofing membrane and solidly anchored to wood nailers or to the roof substrate, in order to keep its movement under thermal load from damaging the membrane roofing assembly.

Several basic questions must be answered when selecting accessory metal for use with membrane roofing assemblies.

- What function is the metal expected to perform? Must it be sealed or can it be mechanically joined?
- What kind of environment is anticipated? Must the metal exist in coastal areas or in areas of heavy pollution?
- Is the metal rigid enough to resist deformation in straight runs, or is a softer metal necessary to conform to irregular surfaces?
- How is the metal to be secured in place? Is a metal with a low coefficient of expansion required to minimize movement and potential displacement of the metal sections and fasteners?
- Must the metal coexist with different metal types? Is provision for separation between metal types necessary?
- Can the selected metal be easily formed and handled by field installers at the site, or is shop fabrication necessary?
- Are protective coatings required to minimize corrosion? What type of preparation may be necessary prior to application of the coating? Must a preservative be applied prior to installation?

Selection of the proper type of metal and the most acceptable method of metal securing, should be given careful consideration. Consideration of proprietary metal systems may be warranted when these types of systems solve particular problems which cannot be solved by typical shop-fabricated accessory metal sections, or when special systems lend themselves to the particular construction. Most of the available accessory metal systems have special components for securing, but may not be inherently watertight. Each system should be evaluated on its own merit for ease of installation and waterproofing properties.

MOVEMENT OF METAL

The greater the coefficient of expansion of a given metal, the more compensation must be made during installation for controlling movement. Metal used as a component in membrane roofing systems must be either restrained to the point where it cannot damage the membrane assembly to which it is attached or the metal must be divorced completely from the membrane roofing assembly and allowed to move. The effects of metal movement under wind or thermal loading must be compensated for by use of control, mechanical or expansion joints. Aluminum and lead require much more attention to the control of metal movement than does galvanized steel. The following chart from the Architectural Sheet Metal Manual form the Sheet Metal and Air Conditioning Contractors National Association (SMACNA) shows the relative coefficients of expansion of metals commonly used with membrane roofing assemblies.

Restraint of accessory metal normally is accomplished by the use of mechanical fasteners such as nails, screws, expansion or special securing devices. If metal incorporated into the roofing assembly must be restrained (as in gravel stop closures), the use of light-gauge sheet metal will make its restraint easier and will minimize backing out of fasteners used to restrict the movement of accessory metal. A common misconception in the roofing industry is that more is always better. More is not necessarily better when selecting accessory metal, especially component metal, for roofing assemblies. Aluminum extrusions and thick (in excess of .040 inches) aluminum sheets are difficult if not impossible to control by securing. Unless these aluminum sheets are divorced completely from the roofing assembly, they will almost invariably cause significant damage to the roofing membrane or stripping plies at metal junctures adjacent to roof membrane surfaces. Since heavy aluminum extrusions are, in a practical sense, non-restrainable with most available fasteners over time, use of heavy-gauge accessory metal or extrusions should be limited to closures installed on top of the waterproofing assembly assembly with provisions made to allow the heavy metal sections to move without destroying the waterproofing integrity of adjacent roof membrane areas *(Figure L)*. Light-gauge metal exerts much less strain on fasteners than heavy metal does because the overall mass of the metal is significantly less, although the coefficient of expansion is the same. When accessory metal is to be restrained, treated wood nailers must be provided beneath metal flanges and should extend a minimum of ½ inch beyond the outside edge of the metal flange. Fasteners long enough to penetrate the wood nailer by at least one inch, spaced not more than four inches on center and staggered front-to-rear on the flange, should be installed to hold metal flanges tightly to the roofing membrane and to restrict metal movement so that damage to adjacent membrane surfaces is minimized.

The effects of movement of accesssory metal may be controlled by the use of mechanical joints at metal junctures, the use of short metal sections (for example, 5-foot-long sections instead of 10-foot-long ones, interlocking laps or expansion/control joints in the accessory metal sections *(Figure C)*.

The use of mechanical joints (standing seam or drive) on closure metal joints (such as metal coping or expansion joint covers) stiffens the metal in the cross direction at regular intervals, minizing "dishing" of the metal section and creating an effective expansion/control joint at each metal joint. The mechanical joint maintains its watertight integrity indefinitely, unless it is significantly damaged. There are no fasteners at the joints to become dislodged by normal movement of the metal sections, and there is only a slight possibility of water infiltration at metal joint junctures.

Provision for metal securing and movement of the metal sections should be made on the face side by the use of continuous concealed cleats or hook strips *(Figure D and Table 1)*. Securing the metal sections on the back side may be done by installing fasteners through elongated holes (to minimize damage to the accessory metal caused by its movement around fasteners or backing out of fasteners) or by installing a clip on the back side of the metal section, with the clips hand-formed around the drip flanges on the main metal sections. Because of irregularities in the wall or curbs over which closure metal is installed, use of the above methods provides the most secure fastening for the back sides of these types of closures.

In some details, continuous cleats or hook strips are specified for installation on the front and back sides of wall-closure metal. Irregularities in wall width dimensions and straightness make securing the back side of closure metal with continuous cleats or hook strips difficult, if not impossible. If heavy-gauge aluminum closures are required by specific conditions, the effects of the high coefficient of expansion may be countered by decreasing the length of metal sections. If a 10-foot section of metal will move ⅛ inch under normal thermal loading, a 5-foot section of metal under the same conditions will move only 1/16 inch. The less total movement anticipated in the metal section, the easier long-term fastening becomes. Fasteners installed in the middle of a metal section require no special treatment, but fasteners at other locations should always be installed through elongated holes in the vertical metal sections. Screws used for this purpose should have inherent metal and neoprene washers at least ¼ inch larger larger in diameter than the holes in the metal.

Watershed metal used for counterflashings installed over membrane base flashings in membrane roofing assemblies may be lapped 3 inches, or installed with interlocking joints. This insures the longitudinal integrity of the counterflashing while allowing for the movement of metal at the ends of sections. Installation of any type of fastener at the metal overlap will invariably result in the fastener backing out, or being sheared off if heavy metal sections are joined in this manner. Corner sections should be formed and installed, with legs not exceeding 18 inches, prior to installation of full-length sections of metal. Allowing for movement of long metal sections in areas away from corners minimizes buckling in corners where the ends of the sections abut.

Expansion joints in long metal runs, such as perimeter gutters, will eliminate rupturing of joints caused by movement of the metal during thermal loading *(Figure G)*. A control joint should interrupt the section to insure free movement of adjacent sections of metal. Some guidelines for inclusion of expansion joints for gutter sections are available from the Sheet Metal and Air Conditioning Contractors National Association (SMACNA) as follows.

Metal counterflashings, gravel stop, eave strips, and perimeter curb metal extending over or across structural expansion joints must be broken next to the joints in order to allow individual structural sections to move without displacing the accessory metal. Slip-joints must be created to allow a continuous flow of water over the metal sections without letting water penetrate the waterproofing assembly.

The use of "short legs" at the corners of accessory metal will minimize the effects of movement of long sections at critical corner junctures *(Figure A)*. Corners and termination sections for coping, expansion joint covers, gravel stop, perimeter curb metal, and counterflashing should be field-fabricated and installed prior to commencing runs of full-length material. Providing mechanical or lapped and interlocked joints near corners allows movement of adjacent full-length metal sections without buckling at anchor points, and minimizes displacement and rupturing of the joints at corner sections. A 12- to 18-inch horizontal "leg" on metal sections at corners and termination junctures preserves the integrity of corner joints and fastening points by allowing minor movement to occur at less stressful areas in the metal section.

CORROSION RESISTANCE

Accessory metal should be selected which will provide a life expenctancy commensurate with that of the membrane roofing assembly. The chief cause of accessory metal failure is corrosion, which occurs when metals inappropriate for environmental conditions have been used. Galvanized metal is perhaps the most susceptible to corrosion caused by external environmental conditions; however, lead and copper may also deteriorate long before the membrane roofing assembly has reached the end of its life. In areas of heavy industry or environmental pollution, unprotected lead and copper have deteriorated in less than 10 years. Unprotected lead around drains and copper gravel stops are particularly subject to degradation from heavy acid conditions. Metal surfaces which are constantly subjected to water moving over or from the roofing membrane are the most likely to degrade.

In some instances, combinations of metal are desirable for different conditions on the same project. For example, a corrosion-resistant metal may be used in watershed areas or at perimeter drains, while a less expensive but less corrosion-resistant metal may be used in areas such as expansion joint covers and metal counterflashings that are not exposed to water. Galvanized metal is the least expensive of all the accessory metals; however, its life expectancy as a gravel stop or gutter in a heavily polluted area is very limited. Stainless steel offers the most resistance to corrosive environments. Soft stainless steel typically used as accessory metal in roofing assemblies has a relatively high coefficient of expansion, and compensation must be made for movement or restraint of the steel in areas where it will be attached to the roofing membrane. Stainless steel also is effective for metal base flashings around chimney stacks, where effluents discharged from the chimney are likely to accumulate. Galvanized metal base flashings around chimneys typically degrade well before the end of the service life of the roofing membrane, and deteriorated metal flashings may allow water into the building or the insulated roofing assemblies, thus accelerating the degradation of the roofing system. In coastal areas, galvanized metal and aluminum may be attacked by the salty coastal environment. "Galvalume" metal also is subject to rapid deterioration in coastal areas. Copper or stainless steel are the preferred accessory metals to use on exposed surfaces in corrosive coastal environments.

Another less obvious corrosive condition occurs when "paint-grip" type galvanized metal is used for gravel stops and gutters. Etching of the zinc surfacing on the galvanized metal to prepare it to receive paint typically weakens (thins) the weather protective zinc surfacing and makes this metal particularly susceptible to rust deterioration. Commonly, the face of the gravel stop and the outside surfaces of the gutter get painted; however, the inside surfaces of the gutter and the vertical section on the gravel stop remain unprotected and rust deterioration begins to occur almost immediately after installation. If prepared galvanized metals are to be incorporated into perimeter drain systems, the inside surfaces must be protected with a bituminous or alkyd based paint to minimize the effects of rust deterioration on inside gutter surfaces. All prepared galvanized metal must be protected with a paint coating almost immediately following installation to eliminate potential rust damage.

Aluminum metal may be anodized or prefinished with a baked-on paint finish to protect it from oxidation, attack by salts and ultimate degradation. This type of protective surfacing minimizes the corrosion which is likely to occur on mill-finish aluminum metal in salty environments. Mill-finish aluminum is an economical metal which lends itself to most roof system installations. In general, the lighter the gauge the aluminum, the less damage will be done to the metal during the fabrication process. Similarly, thin sheet material is much easier to "restrain" as a roof system component than heavy aluminum sections. Heavy gauge aluminum sheet metals (in excess of .040 inch) typically "break" or suffer surface fractures at "hard" angles when fabricated in typical metal working equipment. Breaking or rupturing of the surface of the aluminum invariably results in accelerated oxidation caused by salts or moist environments and ultimate degradation of the aluminum section.

FASTENING AND SEALING METAL SECTIONS

Since accessory metal commonly used with membrane roofing assemblies generally is furnished in sheets eight or 10 feet in length, joints in the metal must be considered if a watertight assembly is to be constructed *(Figure C)*. Many specifications call for "continuous" metal, which is an erroneous concept. The metal may run completely along a roof perimeter, but the metal will not be "continuous" in most common installations. In most specifications, no reference is made to the type joint to be used to join accessory metal sections together to form a watertight closure.

If accessory metal components must be waterproof or watertight, a metal must be selected which can be effectively sealed under field conditions. Stainless steel, copper, and galvanized metal can be field soldered and made waterproof under field conditons. Aluminum can be made waterproof by heliarc welding, but this type joining usually must take place in a fabrication shop and is not easily accomplished under field conditions. The most common means of sealing aluminum sections in the field is by the use of an apoxy sealant and some type of mechanical fastener. Spacing of mechanical fasteners will be critical to the creation of an effective and permanent seal since any buckling at the contact surfaces of the two metal sections may break the seal. For epoxy type sealant to be more than marginally effective at aluminum metal junctures, mechanical fasteners should be installed a maximum of 1 inch on center to insure uniform contact of the two adjoined metal surfaces. Metal should lap a minimum of 2 inches at a sealed or soldered joint.

Mechanical fasteners typically used with roofing assemblies with common accessory metals include pop rivets, screws, bolts, expansion fasteners with lead or nylon anchor bases and nails (common or hardened). Fasteners used with accessory metal should be compatible with the base metal to eliminate galvanic response when water is present. An exception to this rule may be made when the metal flanges (gravel stops, etc.) are to be covered with roofing materials so that there can be no flow of water over the surfaces of the dissimilar metals.

Aluminum may be secured using aluminum pop rivets or stainless steel screws. Copper may be secured using copper pop rivets or brass screws. Galvanized metal may be secured with steel pop rivets or with either cadmium plated or stainless steel screws. Stainless steel may be secured by using stainless steel pop rivets or stainless steel screws. All components—screws, nuts, washers, etc.—must be of the same base metal. Stainless steel may be affected by rust deterioration occurring on immediately adjacent steel washers or nuts. Since lead is not commonly mechanically fastened and is too soft to have mechanical fasteners fabricated of a lead base metal cadmium plated or stainless steel screws or galvanized nails should be used, if securement of lead flanges are required.

Galvanic (electrolytic) response occurs when water is able to run continuously over two dissimilar metals. Galvanic response will degrade one of the exposed metals rapidly when no provision for separation or protection is made. If two dissimilar metals must be in contact with each other, the metals may be coated with a bituminous material, the metal sections may be painted or a layer of asphalt coated felt may be used to break the conductivity between metal surfaces. If fasteners of dissimilar metals are exposed, the exposed portion of the fastener and immediately adjacent metal may be protected from galvanic action by covering the area with silicone or urethane caulking.

It is common to specify that the fasteners (nails) used for securement of gravel stop be of the same base metal as the gravel stop closure. Copper and aluminum nails are limited in length by the soft nature of the metals, and fasteners of these metals may not be available in lengths to allow sufficient penetration into the wood nailers to hold or restrain the perimeter metal. If a copper gravel stop is installed as a closure at the perimeter of a built-up roofing system, the thickness of the enveloped roofing membrane may approximate ¾ inch. If the copper metal is set (as it should be) into a ⅛-inch-thick layer of plastic roofing cement, the total thickness of the metal, sealant and roofing membrane may approach one inch. Since copper nails are commonly available in lengths not much in excess of 1¼ inch, there simply is not enough fastener to penetrate the wood nailer and provide positive securement of the perimenter component metal.

Copper nails are very soft, and if they do penetrate to the wood, chances are very good that a significant percentage of the nails will be bent over during installation instead of reaching into the wood nailer. The resulting marginal securement of the gravel stop flange generally results in separation or splitting of stripping plies as the metal moves in response to normal thermal loading, or in severe cases, the perimeter metal is displaced under high wind loads. In this situation, it would appear prudent to specify galvanized nails with a minimum length of 2 inches to insure reasonable securement of perimeter metal. No galvanic response is possible since the fasteners and the copper flanges are covered and sealed with bituminous materials.

Soldered and mechanically attached metal joints are relatively secure; however, fastened or soldered joints are very likely to be ruptured by movement of the metal under thermal loading if continuous sections are too long. Provision for expansion and contraction should be made in metal sections constructed with aluminum, copper, or stainless steel in excess of 30 feet. Under most environmental conditions, galvanized metal sections may be safely joined to maximum lengths of 40 feet. Heavy aluminum metal (.050 inch and thicker) fastened at joints with mechanical fasteners in continuous sections will shear off fasteners ¼ inch in diameter.

Expansion fasteners with lead or nylon anchor bases should be used to secure metal cleats or surface mounted accessory metal units to concrete surfaces. Powder actuated fastening devices generally are unsatisfactory for securing accessory metal since powder charges of the same number rarely result in "setting" the fastener to a uniform depth into the concrete. The result is fasteners which do not tightly secure the metal to the surfaces or make severe indentations in the metal surfaces. Spalling of concrete surfaces caused by powder actuated fasteners usually is detected only when the metal separates from the concrete surfaces.

Galvanized or resin coated nails always should be used when the fasteners are driven into salt-treated lumber. Since the recommended preservative for nailers in most roofing systems is Chromated Copper Arsenate (CCA), and since the salts are present in the lumber along with residual moisture, the potential corrosive conditions in the wood are significant. Untreated common steel nails are subject to severe and rapid deterioration when in contact with salt impregnated lumber. Nails should be of sufficient length to penetrate the wood a minimum of 1 inch.

METAL JUNCTURES

Since the description "continuous" is inappropriate in the majority of roofing assemblies, metal sections must be joined every eight or 10 feet depending on the length of metal to be furnished by the contractor. Wide metal joints at lapped metal sections are difficult to keep tight without some mechanical assistance. Using screw fasteners or pop rivets at lapped metal sections generally is unsatisfactory because of movement of the metal sections and the eventual displacement of fasteners. Mechanical or interlocking joints are preferred to insure that wide metal sections stay in contact and do not admit significant quantities of water through open laps at metal joints.

If waterproofing integrity is critical in any given area, a bituminous waterproofing membrane should be employed beneath any metal closures since complex configurations of metal are difficult to make "waterproof" and multiple soldered sections generally break loose after moderate exposure to thermal loading. Standing seam joints sometimes may be used in joining closure metal on sloped surfaces or beneath counterflashing. These joints are made by forming the standing seam and flattening the top part of the seam to form a watershed from underneath the top piece of closure metal onto the lower joined section.

Even the best available sealants and caulking generally are ineffective in maintaining long-term seals at metal laps or junctures. Mechanical metal junctures are almost always preferable to sealants except when no other alternatives are available; provision for waterproofing then should be made by inclusion of waterproofing membrane material with the metal sections serving only a "closure" function *(Figure B)*.

The "S" metal section can be effectively incorporated into lapped metal joints of any dimension and width to insure close contact of the adjoining metal sections (*Figure F*). Cover plates are desirable on gravel stop joints on level roof sections; however, they are less than desirable on gravel stop joints on rake edges or slopes. The metal closure over the joint effectively divides in half the amount of movement anticipated at the end of metal sections, resulting in less stress on the stripping plies required to seal the gravel stop flanges to the roofing membrane.

On rake edges, any breaking loose of the stripping plies at the upper edge of the metal cover plate would allow water to enter underneath the cover plate and perhaps beneath the metal, resulting in moisture infiltration at the roof perimeter. Lapping of the metal gravel stops with the flow of water on rake edges and the use of a bituminous sealant between the metal sections at the lap results in a continuous water flow down the slope and over the metal joint. If some rupturing does occur in the stripping plies, there still is a lapped section of metal to effectively deter water from entering

ACCESSORY METAL DESIGN

The design of accessory metal for all roofing assemblies should be thought out and depicted in drawings in as large a scale as possible. Drawings should include graphic depictions of all metal junctures, closures, and joints to insure that the contractor understands exactly what is required in the installation and to allow equitable assessment of the work after installation (*Figure H*). Isometric drawings should be provided for all complex junctures where accessory metal is incorporated: i.e., terminal points of expansion joints, wall or curb junctures, etc.

It cannot be assumed that the sheet metal contractor or the sheet metal mechanic will necessarily work out difficult details or provide the type metal work expected. Methods for handling metal closures and junctures must be specfified and preferably depicted in graphic detail to allow proper interpretation by contractors bidding on each project and mechanics responsible for installation. Inexperienced sheet metal mechanics and competitive pressures during the bidding process have resulted in generally poor metal details on many roof installations. The specifier or designer can do much to eliminate misunderstandings and inappropriate final details on roof assemblies by assuming responsibility for understanding requirements for metal and specifying methods and materials required to complete the project in an appropriate fashion. Reference to an accepted source, eg: SMACNA Plate #, is not enough to insure proper or appropriate metal details. Conditions requiring installation of accessory metal are too varied to allow the effective use of "typical" details or reference to a single plate from a guidebook.

In general, good metal details are appropriate and essential to the installation of all membrane roofing assemblies—bituminous built-up, sheet membranes, modified bituminous membranes, or liquid-applied systems. It cannot be assumed that simply because sheet membrane roofing materials are more elastic that securement of accessory metal is not as important as with a bituminous built-up roofing assembly. It is true that the more flexible and elastic materials may not rupture as easily because of metal movement; however, disbonding may occur between the sheet membrane and accessory metal which is marginally restrained and subject to significant movement under thermal loading. Counterflashings and closures are as important to one roofing assembly as to another. Tops of *all* membrane base flashing should be mechanically attached to their substrate and closed with metal counterflashings to provide an effective watershed off vertical surfaces. The type metal selected and specified must perform similar functions under similar environmental conditions for all roof systems.

Penetrations through the roofing assembly should be provided with a means to deflect water over the openings in the roofing membrane (*Figure K*). Pitch pans have long been the source of leakage, repeated maintenance, and designer derision because of the nature of the assembly. The pitch pan becomes a funnel for water under normal exposure conditions. The average pitch pan installed around a penetration through the roof need not be the source of leakage and need not require constant maintenance to insure a seal at the penetration. Weathercaps (storm collars) or other top closures may be installed to the penetration to protect the bituminous sealant from degradation and to shed water over the top of the pitch pan.

If the penetration is of tubular configuration, installation of weathercaps is relatively simple and easy. If the penetration takes the form of an "I", an angle iron or a channel, closures can still be effectively formed, but the task becomes more complex *(Figure J)*. Light gauge metal form closures may be required to fill section areas. A modified bituminous membrane or a non-vulcanized neoprene sheet installed over the form metal may be used to provide the waterproofing function.

Minimum height for a pitch pan to be utilized essentially as a metal curb should be four inches to allow for an adequate quantity of sealant and sufficient clearance from the roof surface to eliminate the possibility of surface water flowing into the pitch pan top opening. Multiple penetrations in close proximity to each other should be avoided whenever possible. If existing conditions do not allow the installation of metal closures, a synthetic sealer should be used as the sealant instead of thermoplastic bitumen.

Basic physical principles do not change with the type of roofing membrane specified, and the prudent designer will account for conditions of nature with any or all membrane roofing assemblies.

The following principles apply to selection and use of accessory metal for membrane roofing assemblies:

- ■If metal must be anchored or face-fastened in some way, select a metal with the lowest possible coefficient of expansion commensurate with environmental conditions.
- ■If heavy metal is required, shorten the long dimension of the metal sections to minimize the total movement anticipated under thermal loading.
- ■Use mechanical joints on all metal closures to insure stiffening of wide metal sections and provision for expansion and contraction of each individual section without displacement.
- ■Use concealed metal cleats on all exposed metal faces: i.e., coping, gravel stop, perimeter curb metal.
- ■If exposed horizontal metal sections exceed 6 inches, consider horizontal breaks for stiffening or multiple metal sections to eliminate "oil canning" of light gauge metal with wide exposed surfaces (*Figure D*).
- ■Use fasteners of a composition compatible with the base metal being secured.
- ■Avoid long continuous runs of accessory metal without provision for expansion and contraction.
- ■Avoid face fastening of accessory metal.
- ■Use lead or nylon-based expansion fasteners to secure accessory metal in lieu of powder-actuated fastening devices (*Figure F*).
- ■Specify and use mechanical closures at all wide metal joints over open spans to insure watertight integrity of the metal assembly (*Figure B*).
- ■Use a bituminous waterproofing membrane under all complex metal junctures or in areas where waterproofing integrity is imperative.

REFERENCES

1 Sheet Metal and Air Conditioning Contractors National Association, Inc., "Architectural Sheet Metal Manual," Third Edition, 1979.

2 Factory Mutual System, Factory Mutual Loss Prevention Data Bulletin 1-49, October 1979.

TYPE OF METAL		**MAXIMUM FACE DIMENSION**						**HOOK STRIP**	
		VELOCITY PRESSURE (pounds per square foot)							
		ZONE 1				**ZONE 2**			
		10-20		**21-30**		**31-45**			
Galv. Iron or Soft Stainless Steel		(0.48-0.95 kPa)		(1.0-1.44 kPa)		(1.48-2.15 kPa)			
Ga.	(mm)	In.	(mm)	In.	(mm)	In.	(mm)	Ga.	(mm)
26	(0.45)	6	(150)	6	(150)			24	(0.61)
24	(0.61)	8	(200)	8	(200)	6	(150)	22	(0.76)
22	(0.76)	10	(250)	10	(250)	8	(200)	20	(0.91)
20	(0.91)	12	(300)	12	(300)	10	(250)	18	(1.06)
Aluminum*									
In.	(mm)	In.	(mm)	In.	(mm)	In.	(mm)	In.	(mm)
0.040	(1.02)	6	(150)	6	(150)			0.050	(1.27)
0.050	(1.27)	8	(200)	8	(200)	6	(150)	0.060	(1.62)
0.060	(1.62)	10	(250)	10	(250)	8	(200)	0.070	(1.78)
0.070	(1.78)					10	(250)	0.080	(1.93)
Copper									
oz	(mm)	In.	(mm)	In.	(mm)	In.	(mm)	oz	(mm)
16	(0.55)	8	(200)	6	(150)			20	(0.69)
20	(0.69)	10	(250)	8	(200)	6	(150)	24	(0.82)
24	(0.82)			10	(250)	8	(200)	32	(1.10)
32	(1.10)					10	(250)	48	(1.64)

NOTES: *Temper "O" aluminum, although easily formed, has a low bending strength. High tempers are advised when using aluminum.

Table 1 *Selection of appropriate cleat (hook strip)*

Building Material	Coefficient of Thermal Expansion	Increase in 10 ft length in 64th of an inch due to an increase of 100 degrees F. (1 2 3 4 5 6 7 8 9 10 11 12 13)
GALVANIZED STEEL	.0000067	
TERNE	.0000067	
COPPER	.0000094	
STAINLESS STEEL	.0000096	
ALUMINUM	.0000129	
LEAD	.0000161	

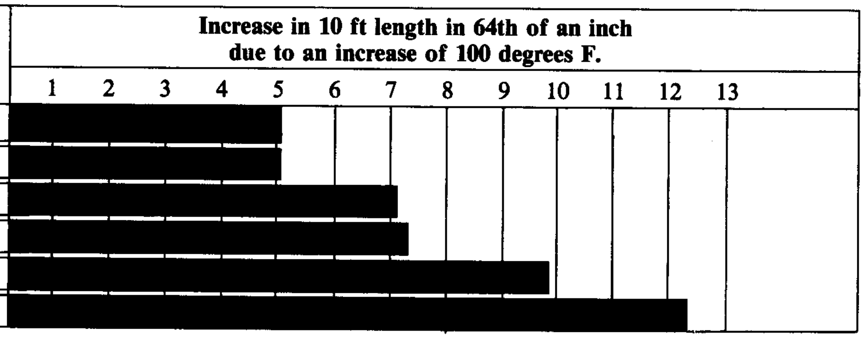

Table 2

SIDE ANGLES OF GUTTER (DEGREES)		A* WIDTH OF GUTTER BOTTOM (INCHES)			B** WIDTH OF GUTTER BOTTOM (INCHES)					C*** WIDTH OF GUTTER BOTTOM (INCHES)						
		4	6	8	4	6	8	10	12	4	6	8	10	12	14	16
90	135	22	18	16	28	24	21	18	17	36	31	26	23	21	20	18
A 90	B 120	23	19	17	31	26	22	20	18	39	33	28	25	23	21	19
90	90	26	21	19	34	29	25	22	20	42	36	31	27	25	23	21

* For column A use 16 oz copper, 26 ga stainless steel, or 40 lb terne.
** For column B use 20 oz copper, 24 ga stainless steel, or 40 lb terne.
*** For column C use 24 oz copper, 22 ga stainless steel, or 40 lb terne.

Table 3 Maximum distance between expansion joint and downspout in feet for built-in gutter

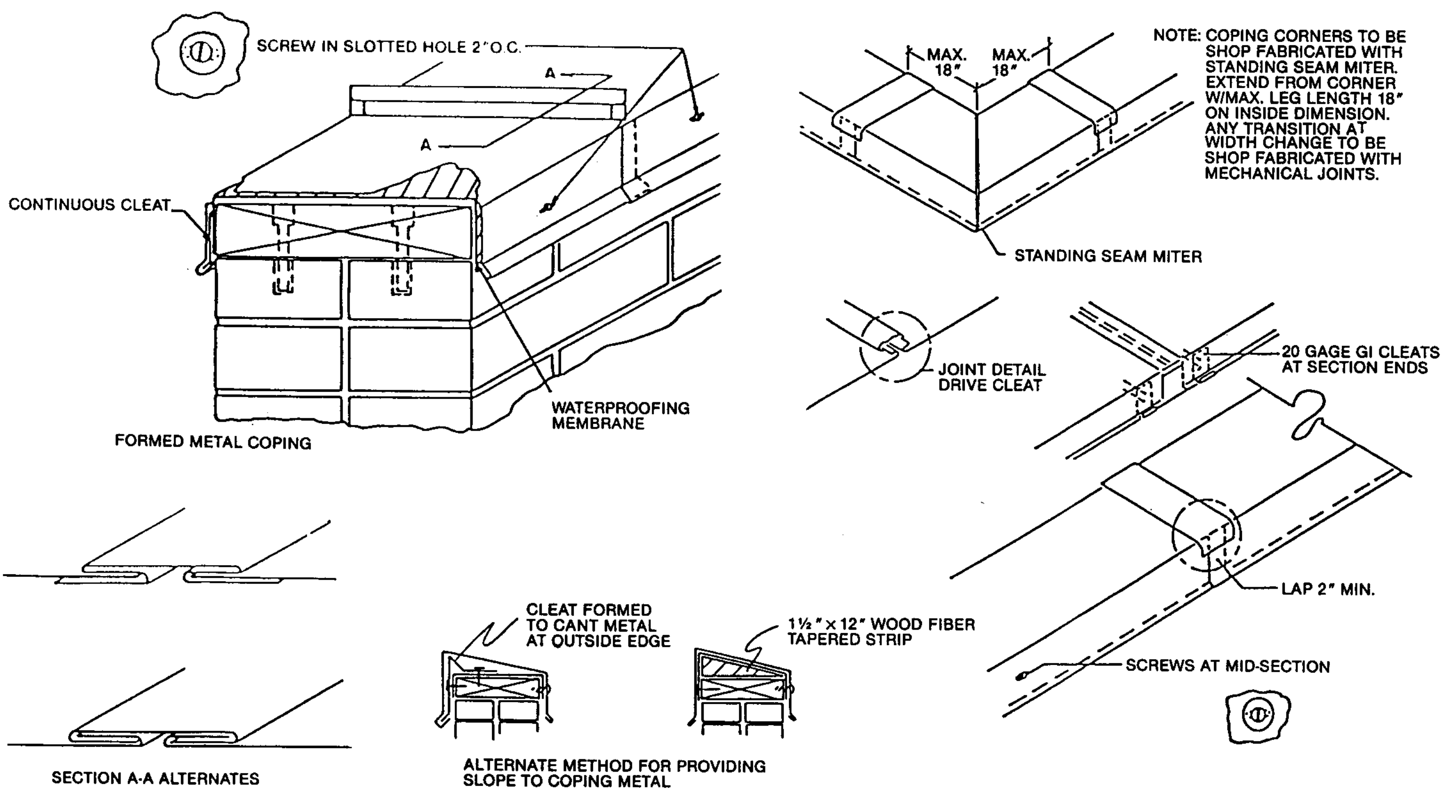

Figure A

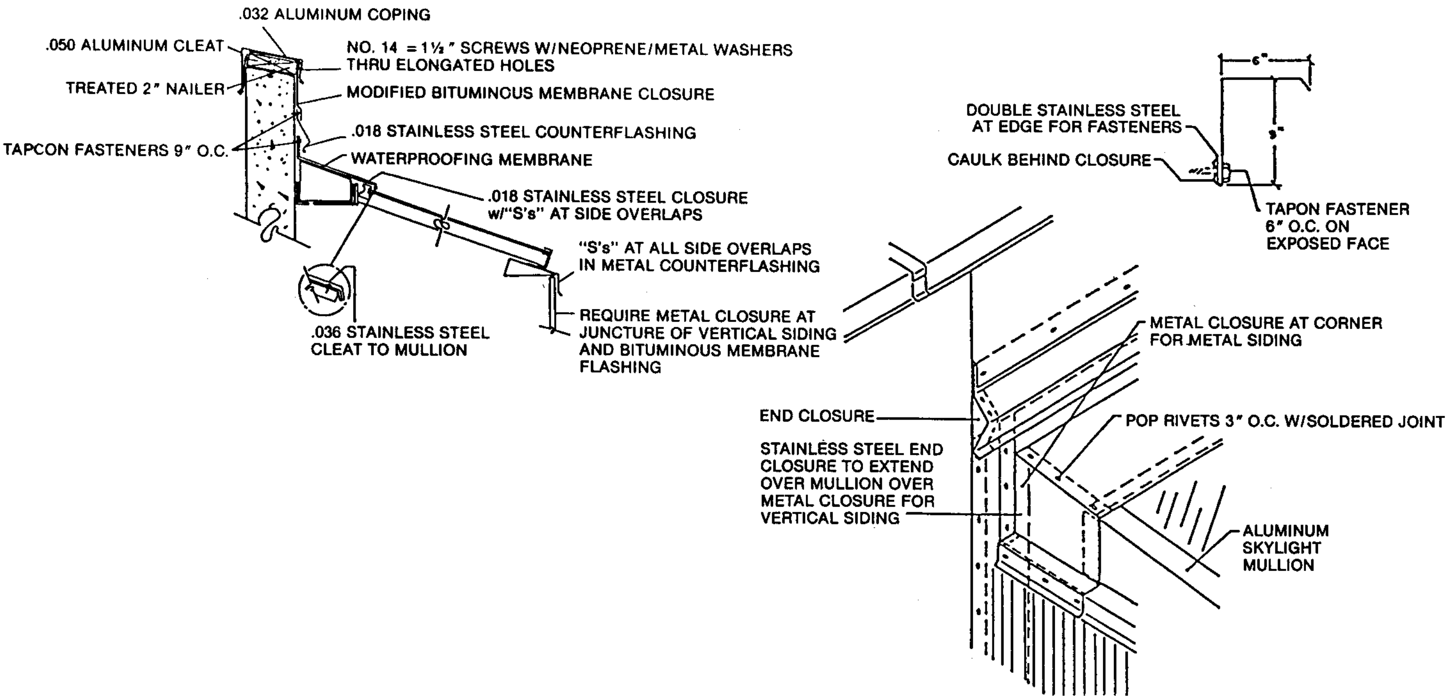

Figure B

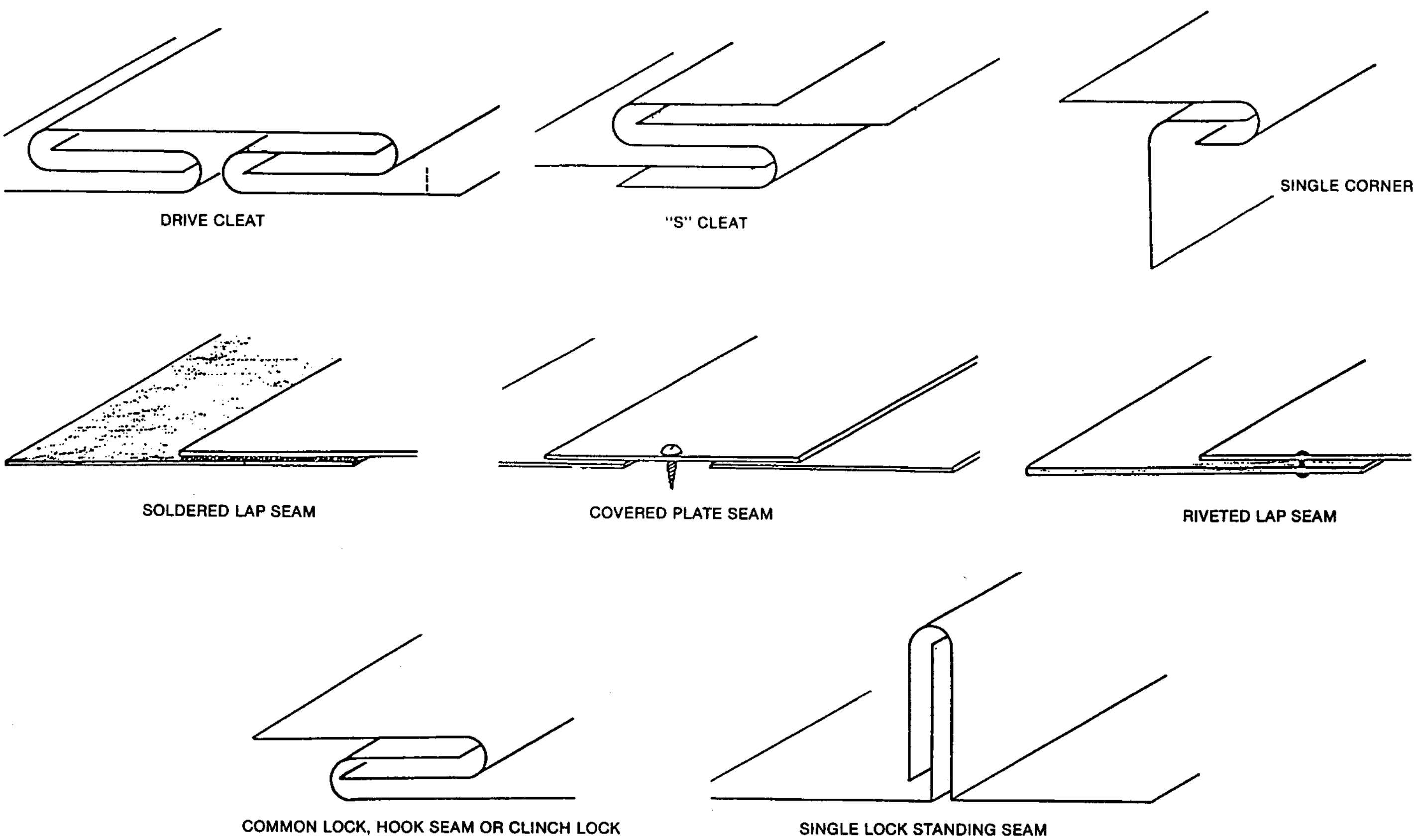

Figure C

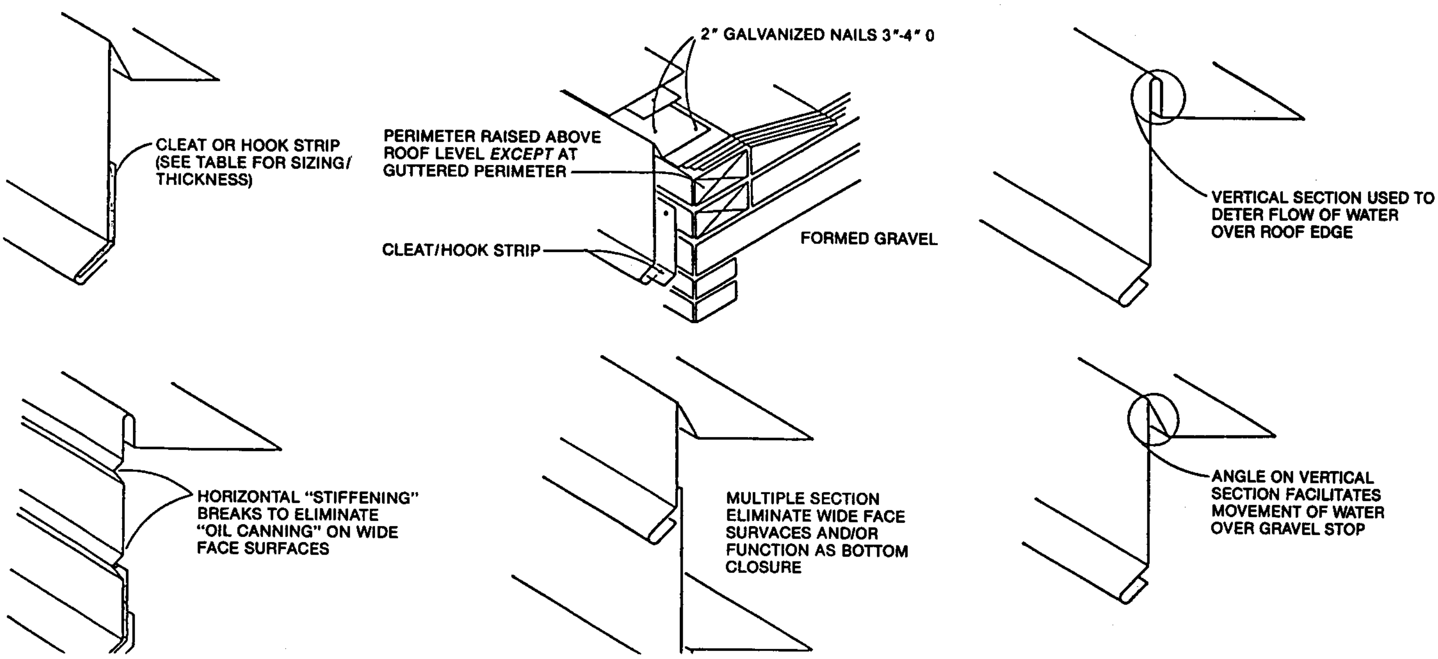

Figure D

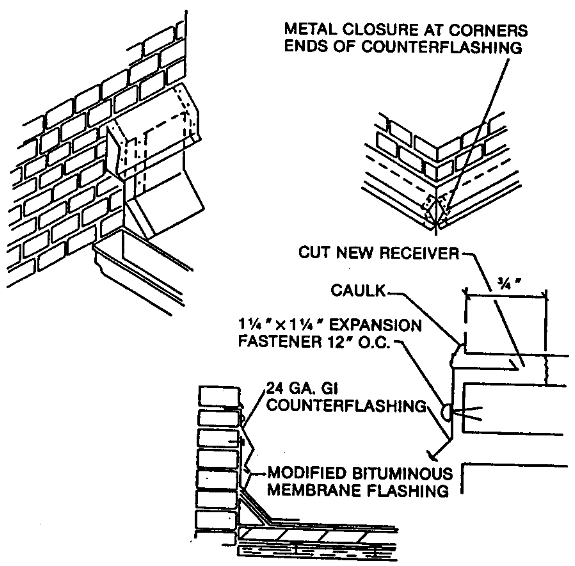

Figure E

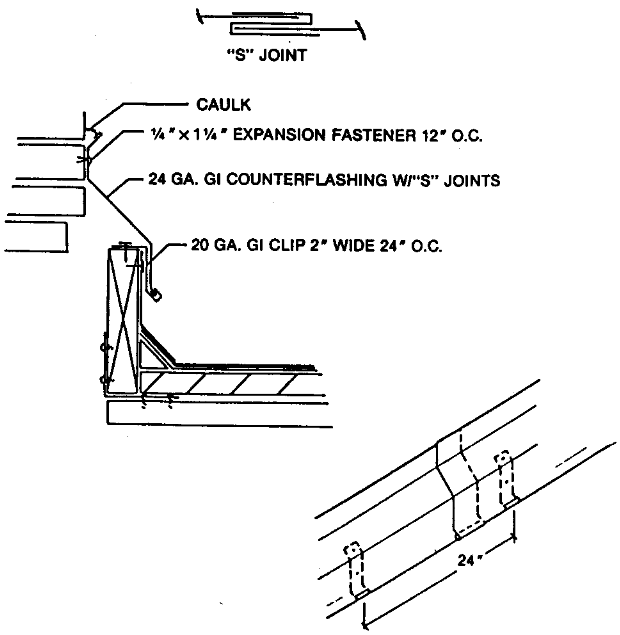

Figure F

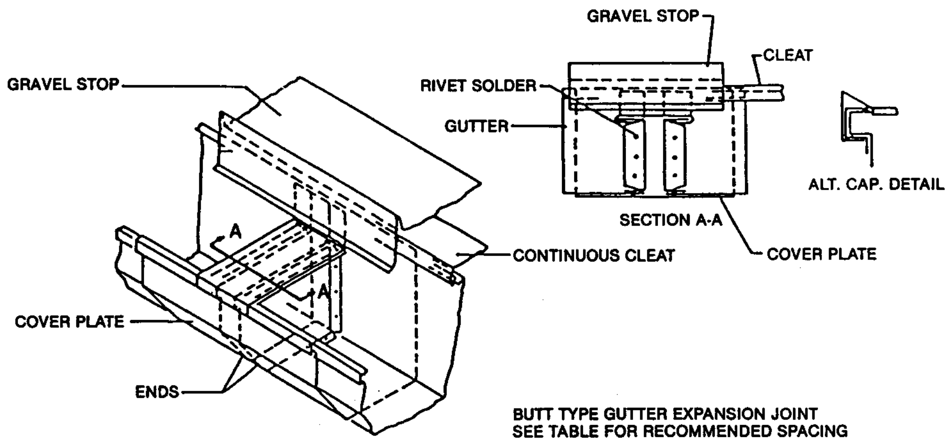

Figure G

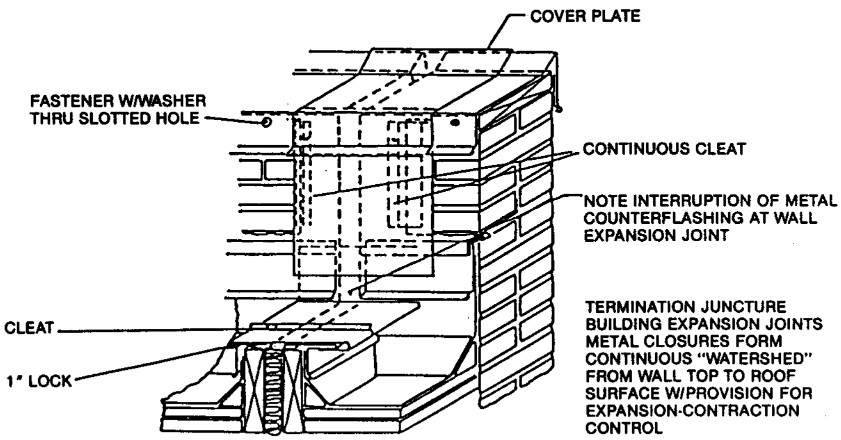

Figure H

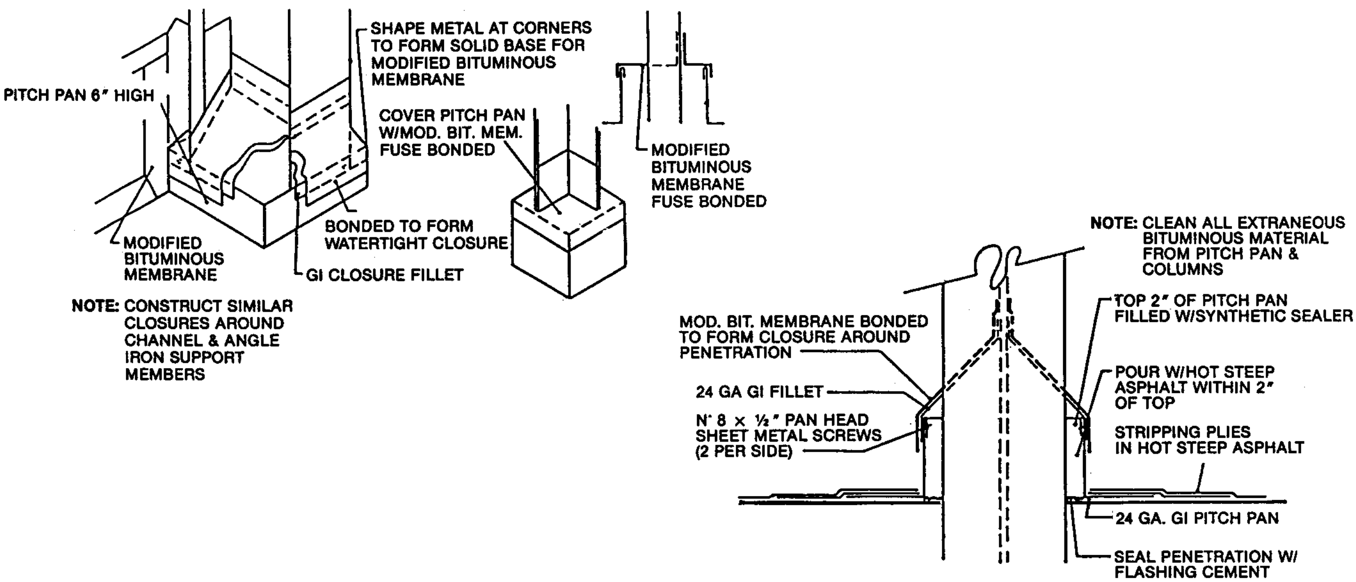

Figure I

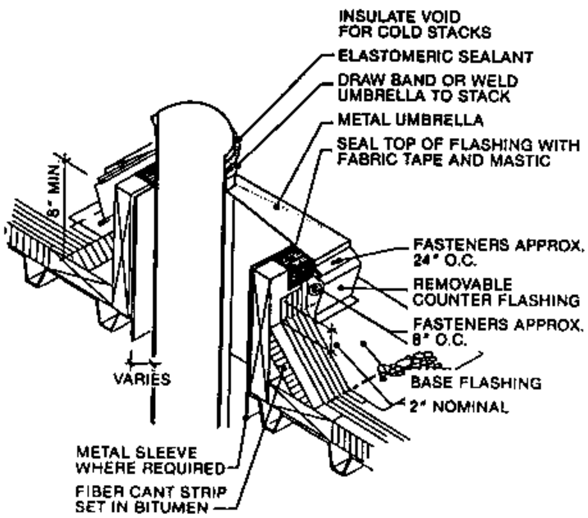

Figure J

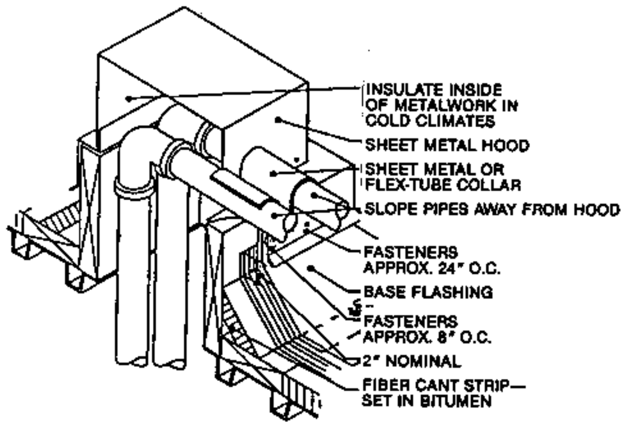

Figure K