CHAPTER 11

METAL ROOFING

Section I. DESCRIPTION AND GENERAL DISCUSSION

11.1.1 General

Metal roofing and flashing materials include: copper, terne (steel coated with lead-tin alloy), zinc-coated (galvanized) steel, aluminum, stainless steel, lead, aluminum or steel (plain or stainless) with factory-applied coatings or claddings, and certain alloys. Some of the commonly used types will be discussed separately, but certain factors which apply to all kinds are discussed jointly. Considerable reference material on the design and installation of architectural sheet metal may be found in the publication "Architectural Sheet Metal Manual" published by and available from the Sheet Metal and Air Conditioning Contractors National Association, Incorporated, 1611 North Kent Street, Suite 200, Arlington, Virginia 22209. Additional information may be found in various industry publications. Tables 4 and 5 giving the properties of sheet metals and the recommended thicknesses for various uses are included at the end of this chapter.

11.1.2 Expansion and Contraction

All metals used in roofing expand and contract with changes in temperature. This must be taken into account in designing metal roofs. Actually, most metal roof forms owe their design in large part to the necessity for providing for expansion and contraction. Buckling of sheets, tearing at seams, loosening or pulling through of fasteners are common failures caused by inadequate provisions for expansion and contraction. The rate of expansion and contraction differs with each metal. Some idea of the magnitude of the change for which provision must be made is given in table 2 below. Note the distance that an 8-foot sheet will expand or contract with a 150°variation in temperature. Changes in dimensions with changes in temperature result equally in all planes of the metal and are the same regardless of the thickness of the metal. Thus, a 1-foot square piece of thin copper or aluminum foil will change as much in length and width as a thicker piece of the same size under similar temperature differences. Because of changes in dimensions with changes in temperature, metal roofs laid in summer require adequate provision for contraction, but little provision for expansion. Conversely, metal roofs laid in cold weather require adequate provision for expansion, but little provision for contraction. The expansion joint shown in figure 39 was installed midway of its expected temperature range and illustrates the position at minimum and maximum temperatures. The movement of the metal can be calculated using table 2. Metal that is exposed to the direct rays of the sun should have an additional 50° F added to its temperature to compensate for its absorption of radiant heat.

Table 2. Expansion and contraction

Metal	Coefficient of thermal expansion (inches per) inch per degree F°	Linear movement per 150° F, change per 8 feet	
		Decimal (in.)	Fraction (in— approx)
Steel Med	0.0000067	0.0965	6/64
Iron-wrt	0.0000067	0.0965	6/64
Nickel Copper Alloy (Monel)	0.0000077	0.1109	7/64
Stainless Steel (300-series)	0.0000098	0.1411	9/64
Copper	0.0000098	0.1411	9/64
Aluminum	0.0000128	0.1843	12/64
Lead	0.0000162	0.2338	15/64
Zinc	0.0000173	0.2491	16/64

11.1.3 Galvanic Action

In metal roof construction it is frequently impossible to prevent the contact of dissimilar metals, which may result in corrosion of one of the metals and the protection from corrosion of the metal in contact with it. This is the so-called galvanic action or electrolysis which occurs when metals of different position in the electromotive series are in

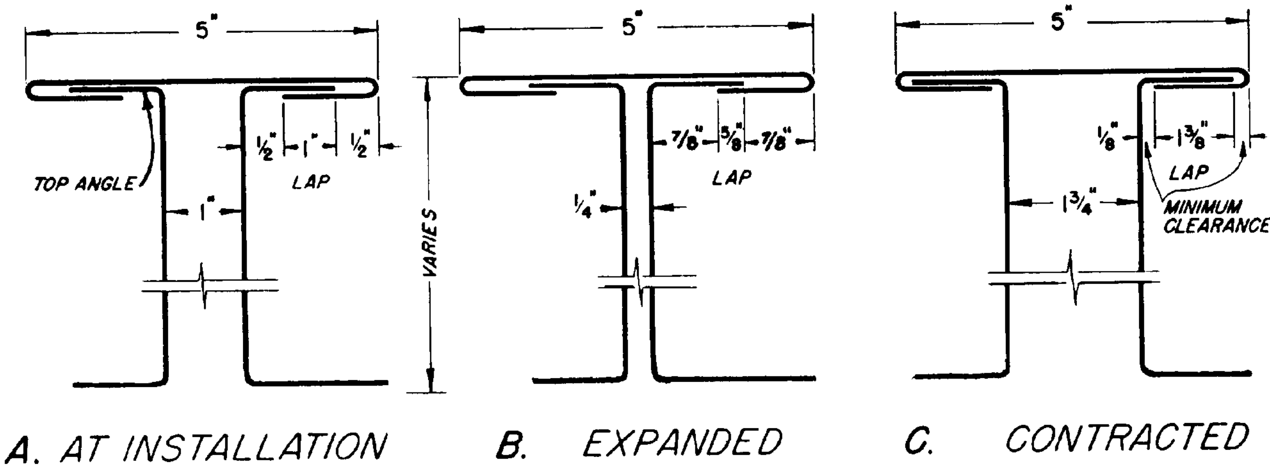


Figure 39. Movement of expansion joints.

intimate contact in the presence of an electrolyte. The metals commonly used for roofing are listed in the electromotive series in the following order:

1. Aluminum
2. Zinc
3. Iron
4. Nickel
5. Tin
6. Lead
7. Copper

When any two metals in this list are in contact in the presence of an electrolyte, the one with the lower number is corroded. Also, the farther apart the metals are, the greater will be the corrosion. Thus, with iron and copper in contact in the presence of water, the iron would be corroded more than lead in contact with copper under similar conditions. Any means that separates dissimilar metals will protect against this action. Frequently used are layers of waterproof building paper or asphalt-coated felt, or a coating of asphalt paint. To the maximum extent feasible, metal roofing, siding, flashing, gutter, downspouts, and fasteners, should be of the same material.

11.1.4 Workability

Workability of metals generally depends upon their hardness and ductility. The hardness regulates the equipment needed to work the metal, and the ductility governs whether the metal can withstand bending without fatigue or fracture.

11.1.5 Types of Metal Roofings

Metal roofings are classified into three general types: flat sheets assembled by means of various seams, corrugated or performed sheets, and unit roofings made in the form of shingles or tiles.

11.1.5.1 Flat Sheets. Flat metal sheets are assembled for roofing purposes by means of various seams, commonly designated as batten seams, standing seams and flat seams.

11.1.5.1.1 Batten-Seam Roofing. In batten-seam roofing (fig. 40 and fig. 41), metal sheets are formed over ribs or battens, of wood or metal, which divide the roof into small areas and provide adequately for expansion and contraction in the direction perpendicular to the battens. Expansion and contraction in the direction parallel to the battens is provided best by unsoldered flat-lock cross seams. Soldered cross seams are sometimes used with the expectation that allowance for expansion and contraction is made at the eaves and ridge or that the soldered seams so stiffen the sheets that slight buckling within each sheet will occur at elevated temperatures. To the extent feasible, seams should be shop fabricated rather than formed in the field to insure accurately formed straight seams which will permit the sliding action to take place as intended. The battens must have edges beveled to permit lateral movement of the roofing. The battens must be smooth, have all nails set, and be treated to resist rot and insects.

11.1.5.1.2 Standing-Seam Roofing. Standing-seam roofing is similar to batten-seam roofing in that it divides the roof into relatively small areas and provides for expansion and contraction in the direction perpendicular to the seams. The roofing sheets are fastened to the roof deck by means of cleats spaced not more than 12 inches apart, nailed to the roof sheathing at one end and folded into the seam at the other. Since standing seams are unsoldered, they are used on roofs with slopes of 3 inches per foot or greater. Standing-seam roofing is illustrated in figure 40 and figure 42.

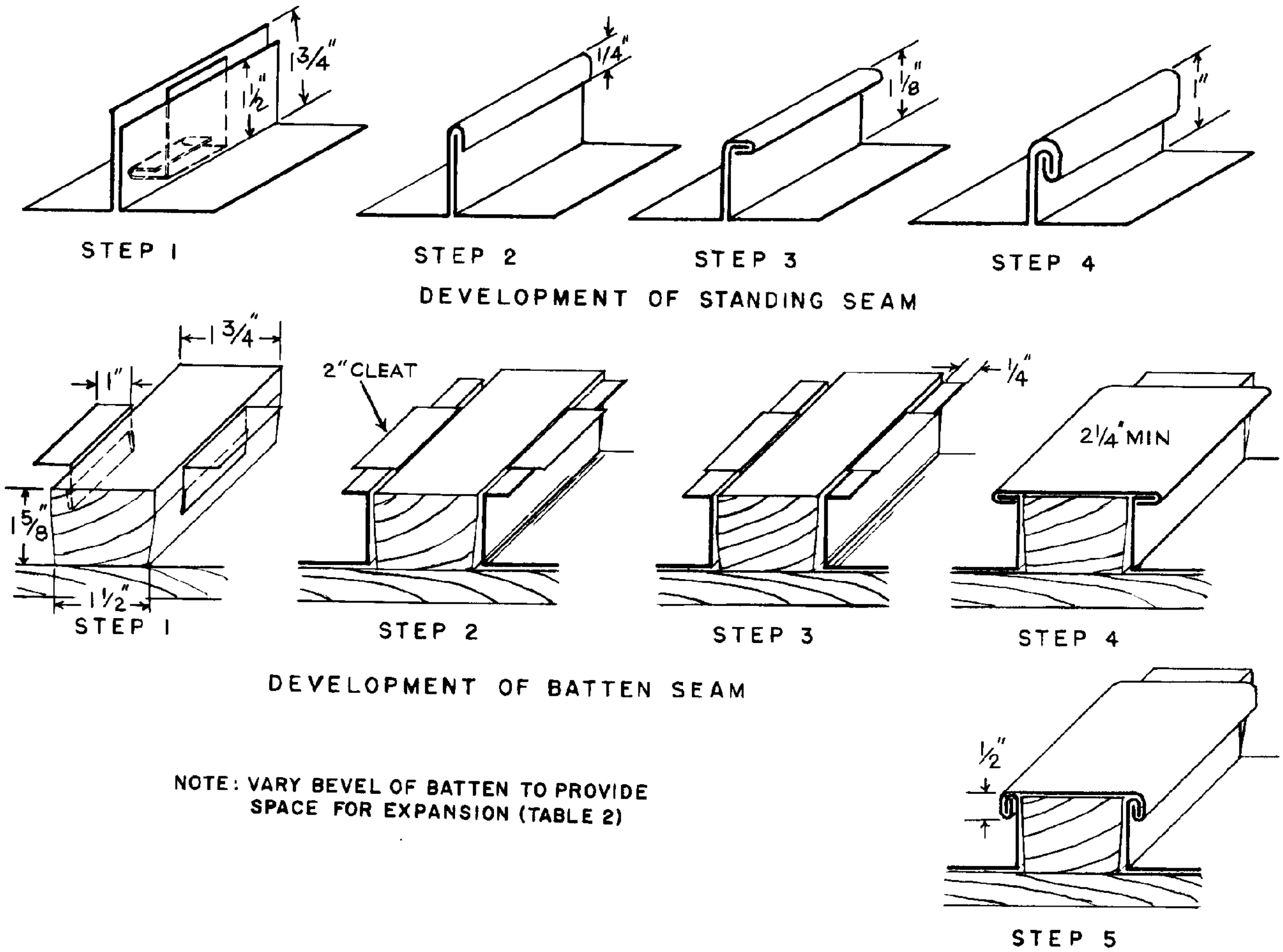


Figure 40. Development of standing and batten seams.

11.1.5.1.3 Flat-Seam Roofing. Flat-seam roofing, forming a continuous sheet, is adaptable to low-pitched roofs, preferably not less than ½ inch per foot, to insure proper drainage. Small sheets, usually 14 by 20 inches, are fastened to the roof deck by means of cleats, one end of which is locked-in to the sheet and the other nailed to the roof deck. A flat-lock seam (fig. 43 and fig. 44) is then formed at the juncture of the sheets and the seams sealed with solder. While the sheets are held in place firmly by the cleat and sufficient elasticity is provided to take care of expansion and contraction, large roof areas covered by this method should have the extremities of the roof covering free or expansion joints should be provided at intervals of 30 to 48 feet. An expansion batten section is recommended because of its watertight construction (fig. 45). Flange type expansion joints are not watertight and will leak if a drain becomes clogged and the water backs up to the top of the joint. Occasionally, long sheets of roofing are applied by the flat-seam method.

11.1.5.2 Preformed (Corrugated) Roofing. In the corrugated or other preformed types of roofing, series of parallel alternate ridges and grooves or crests and vales (hill and valleys) are formed in flat metal sheets. Most commonly used forms are the conventional sinewave corrugation and the V-beam design. Fasteners should be of the same material as the sheets or of a type material which will not result in galvanic action. Fasteners are usually installed exposed and should be used with washers capable of sealing the penetrations. Fasteners should be of a design and so spaced as to be capable of resisting blow-off of the roofing sheets. Both end and side laps should be sealed between sheets with mastic sealing compound, a bead for gun application or a ribbon for tape application. In localities subject to driving rains or severe ice or snow conditions and where the slope is less than 4 inches to the foot, and side laps should be increased in accordance with guide specifications for new construction. Roofing sheets should be laid with crowns or ridges in the direction of the roof slope, starting at the end of the building that is opposite the prevailing wind

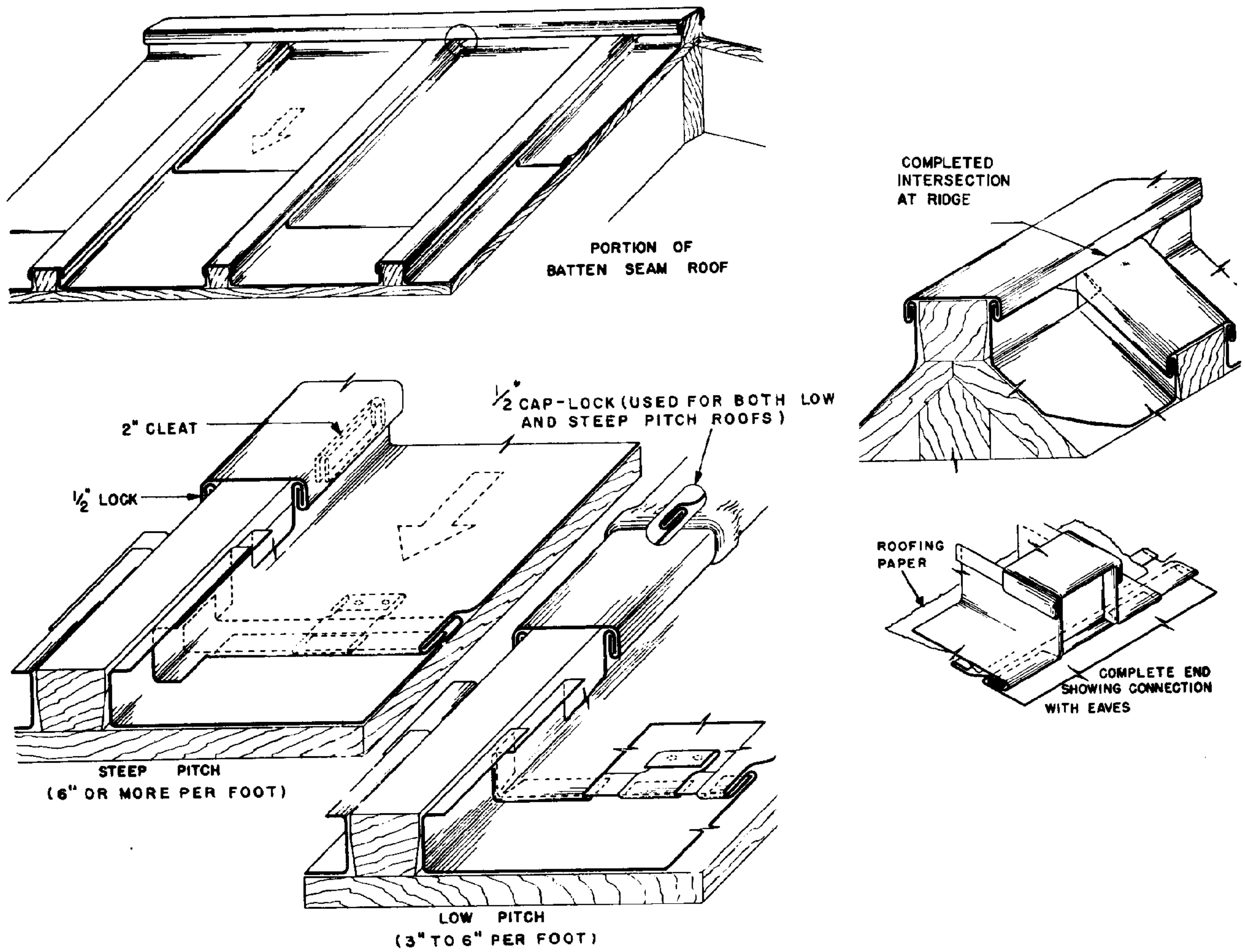


Figure 41. Batten seam roofing.

direction (fig. 46). Rubber end seals are utilized to provide water tight joints at eaves, ridges, and flashings as required.

11.1.5.3 Unit Roofings. So-called metal shingles made to simulate the appearance of slate and forms made to simulate the various kinds of tiles comprise most metal unit roofings. Because of the small size of unit roofings, no provision for expansion and contraction is necessary.

11.1.6 Fire Protection

Metal roofs, generally, are not classified as regards resistance to fire hazards. However, structures with metal roofs usually are eligible for the lowest insurance rates because of the protection afforded from falling sparks and embers.

11.1.7 Soldering

Soldering (Military Specification MIL-S-6872) is a process of joining two metals together by melting a third metal (at temperatures below 1,000° F) and allowing it to flow between the metals being joined. The bond formed is mechanical and relatively weak; therefore, it is primarily used as a sealer or for joining where strength is not required. In sheet metal work, solder is generally used in conjunction with seams to provide a watertight seal and to strengthen the seam. The process of soldering consists of cleaning the two metals, applying flux, heating the two metals to the melting temperature of solder, applying the solder, and allowing the metals to cool slowly and undisturbed.

Caution: **Fumes generated by the heating of flux are usually acid or toxic. Soldering operations should only be accomplished in well-ventilated areas. Personnel must take every precaution to avoid breathing these fumes.**

11.1.7.1 Types of Solder.

(1) Half and half tinners solder consists of ½ tin and ½ lead. This alloy has a melting temperature of 415° F and a shear strength of 5,240 psi (pounds

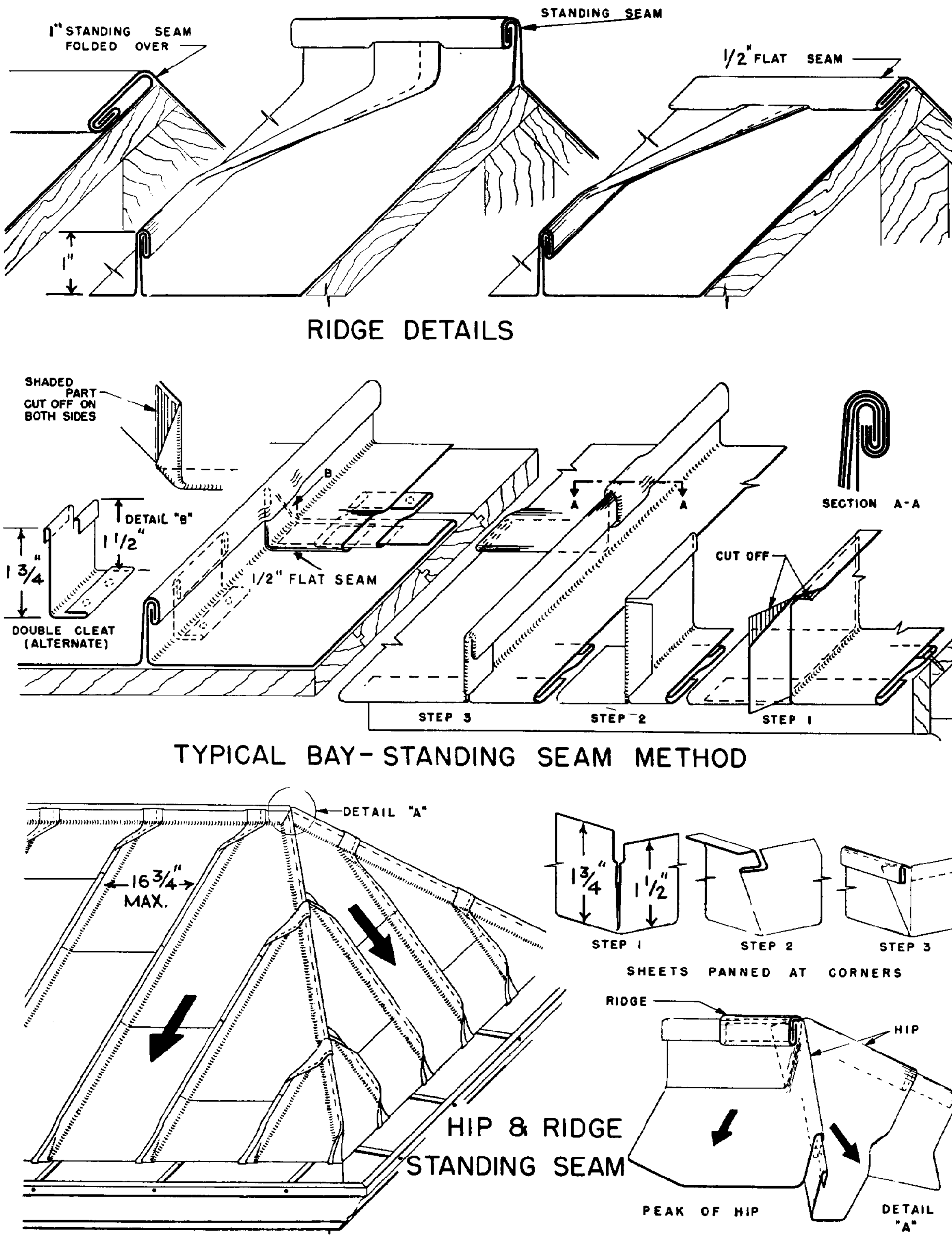


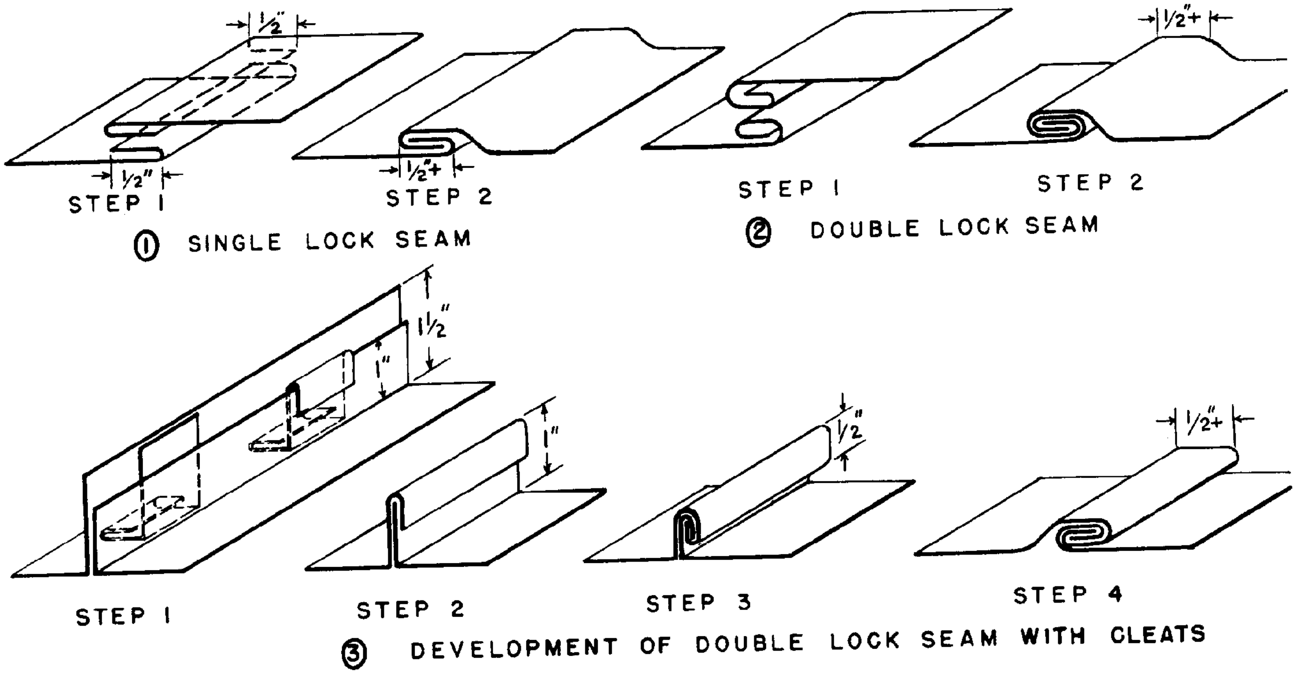
Figure 42. Standing seam roofing.

per square inch) and is the most frequently used solder.

(2) Two-thirds tin and ⅓ lead is used where increased strength is required. This alloy melts at 360° F and has a shear strength of 6,230 psi and is used for joining stainless steels.

(3) Soft solder contains 95 percent tin and 5 percent antimony and is used for soldering brass and copper and places where a low melting temperature is required.

(4) Silver solder is used where more than ordinary strength is required. Silver can be added



(1) Single lock seam.
(2) Double lock seam.
(3) Development of double lock seam with cleats.

Figure 43. Development of lock seams.

to copper-zinc brazing alloy or alloyed with copper in varying compositions to obtain a desired melting temperature. Besides being strong, these alloys are malleable, ductile, corrosion resistant, and nontoxic.

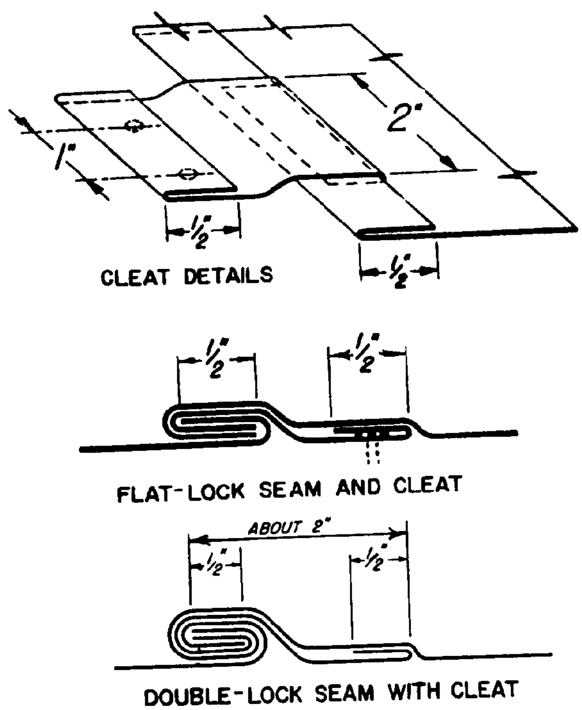


Figure 44. Typical details of cleats.

(5) Aluminum solders are alloys of tin, zinc, and small quantities of aluminum. Small quantities of copper and lead are sometimes added. The solders are strong and ductile and are classed as hard solders requiring a blow torch for application.

11.1.7.2 Types of Flux. Flux (Fed Spec 0-F-506) is used to remove the existing oxide film on metals and to prevent further oxidation during the soldering process. The use of flux is necessary to insure a good bond between metal and solder.

(1) Raw muriatic acid is frequently used on galvanized surfaces and zinc as a flux and on other surfaces as a cleaner before applying flux. This acid destroys zinc and zinc-coated surfaces rapidly and must be washed off immediately after soldering is completed.

(2) Cut muriatic acid, also known as zinc chloride, is made by adding small pieces of zinc to raw muriatic acid until the solution is saturated and the reaction ceases. Cut muriatic acid is used as a flux for terne plate, copper, brass, black iron, monel, copper-nickel alloy, bronze, and nickel. It is also used on stainless steel following an application of raw muriatic acid and on aluminum after the surface has been tinned.

(3) Block or powdered rosin is less corrosive than acids and is preferred for tin or lead coated (pretinned) surface. The block and powdered forms are applied after the metal has been heated.

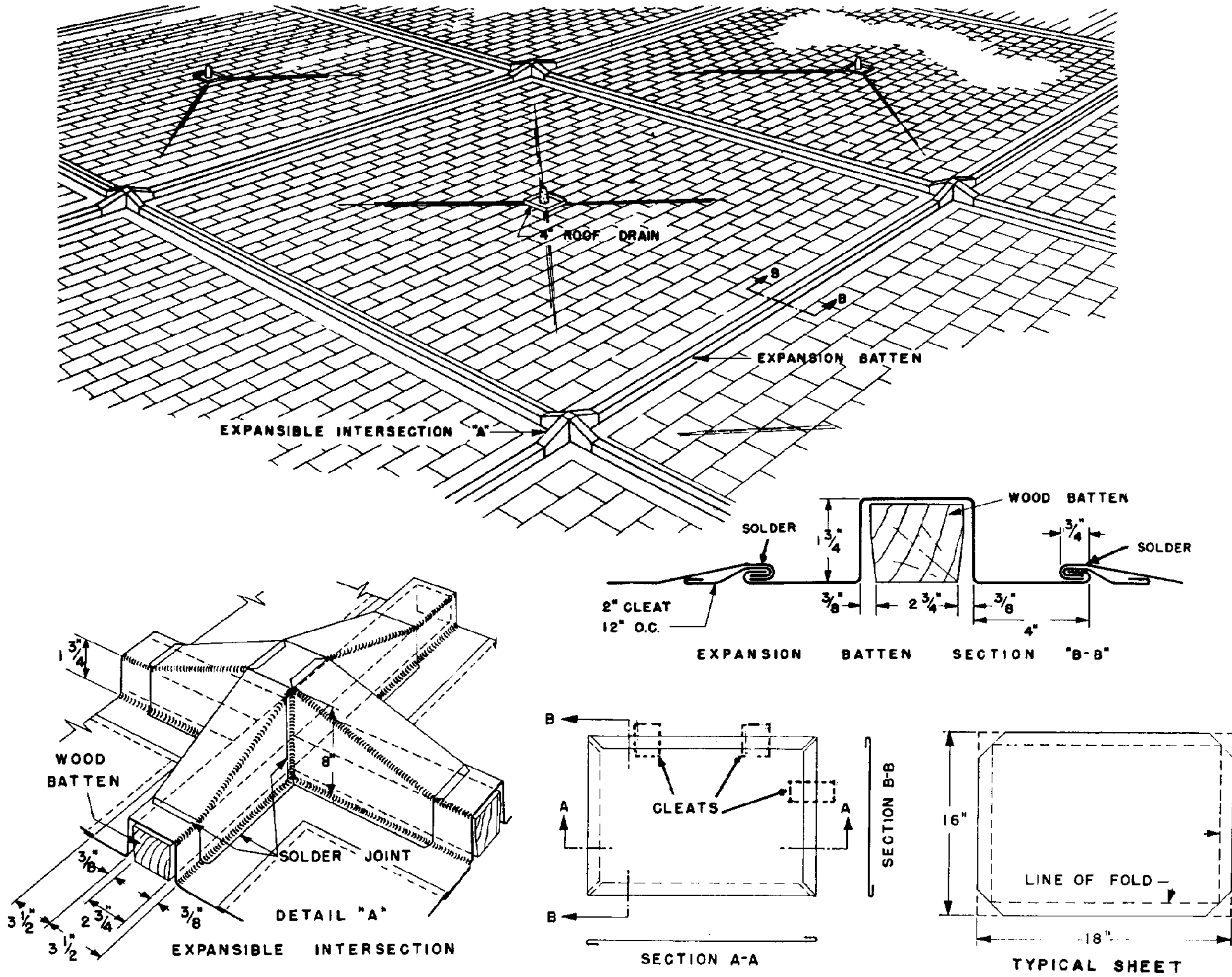


Figure 45. Flat seam roofing.

(4) Tallow is used for soldering and burning lead and in some cases, soldering aluminum.

(5) Soldering paste is a commercial product used primarily for copper wires and zinc.

(6) Sal ammoniac is generally used with a cut acid for tinning operations on large surfaces and as a flux for black iron.

(7) Phosphoric acid is an effective flux for stainless steel and usually produces better results than raw and cut muriatic acid.

11.1.7.3 Soldering Equipment. Equipment necessary for soldering includes solder, flux, source of heat, soldering coppers, and cleaning equipment.

(1) *Soldering Coppers.* Soldering coppers, commonly called soldering irons, are made of copper attached to an iron shank with an insulated wood handle. The weights and shapes of these coppers vary to suit the different soldering operations. Small, light work would require a small iron with a sharp point. Heavy work such as roof seams would require a large iron with a blunt point. The coppers should be cleaned and dressed with a file if necessary, heated dipped in flux, and pretinned before soldering. Untinned and undressed soldering coppers have poor heat transfer and usually result in an unsatisfactory soldering job.

(2) *Source of Heat.* Sources of heat vary from electric heating elements built into the soldering copper to blow torches. For shop work, the coppers are usually heated in bench mounted gas or electric furnaces. For on-the-job work, they are usually heated in gasoline-fired furnaces, stands adapted to blow torches, or charcoal pots.

(3) *Cleaning Equipment.* Cleanliness is essential both before and after soldering. Before soldering, the work must be free of all paint, grease, dirt, and corrosion to insure a good bond and prevent voids in the solder. After soldering, the

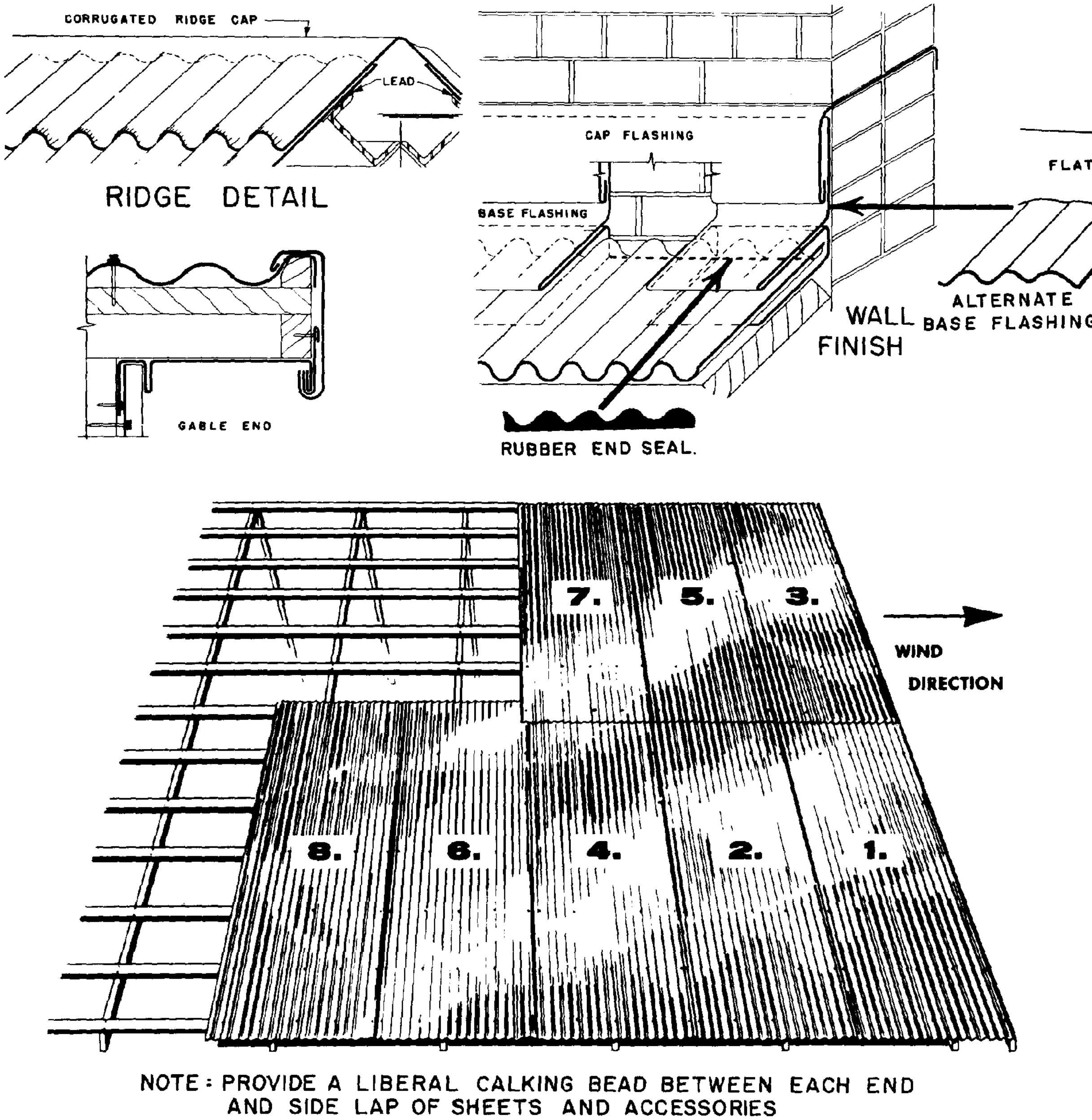


Figure 46. Corrugated roofing.

work must be cleaned to prevent corrosion and staining by the flux. Corrosion can be removed with wire brushes, sandpaper, or emery cloth. Paint and heavy deposits of grease can be removed with solvents (MIL Spec MIL-C-11090). Dirt and light grease should be removed with water and detergents (MIL Spec MIL-D-16791). After soldering, all traces of flux should be removed with solvents followed by a thorough washing with detergent and water, and drying with clean, dry cloths.

Note. Naptha (MIL~N-15178), kerosene (Fed Spec VV-K-211), diesel oil (Fed Spec VV-F-800), and turpentine (Fed Spec TT-T-801), may be used as solvents. However, these solvents are flammable and should not be used if nonflammable, low-toxicity, solvents will serve the purpose equally as well.

11.1.7.4 Soldering Practices. Good soldering practices include -- keeping the work clean; pre-tinning metals that are not coated with lead or zinc; using the proper solder and flux; keeping the equipment in serviceable condition; drawing the copper along the work slowly to allow full penetration of the heat; not disturbing the work until the solder has hardened; removing all traces of flux after soldering. Insufficient heat or moving the joint before the solder is completely solid will result in a cold joint. Good soldering joints are smooth and uniform. Cold joints have high uneven spots and appear to have a crystallized structure.

11.1.8 Thickness of Sheet Metals

The thickness of metal sheets is determined by gage, decimal fractions of an inch, weight per square foot, or a combination of two methods. Two scales of gage thickness are commonly used; the Brown and Sharpe or American Standard for nonferrous wire and sheet metal; and the United States Standard for iron and steel plate. Table 3 lists the common gages of sheet metal with the decimal equivalent for each standard. The weight per square foot system is commonly used for nonferrous metals. A combination of two systems is used for clad metals where the base sheet is measured by gage number and the protective coating is measured in weight per square foot. An example of this would be galvanized iron where the black iron sheet is generally 26 gage coated with 1.25 ounces of zinc per square foot. The thickness of sheet metal is measured with either a slotted metal gage or a micrometer. The number of the slot into which the metal fits snugly without forcing indicates the gage of the metal. Micrometer readings should be taken at intervals to determine the average thickness of the sheet. Micrometer readings are in decimal fractions of an inch and can be converted to the nearest gage number by using table 3.

*Table 3. Sheet Metal Gages**

Gage No.	Brown & Sharpe or American Standard for nonferrous wire and sheet metal	United States Standard Galvanized and Black Iron	United States Standard Stainless Steel
8	0.1285	0.1644	0.1719
9	0.1144	0.1494	0.1562
10	0.1019	0.1345	0.1406
11	0.0907	0.1196	0.1250
12	0.0808	0.1046	0.1094
13	0.0720	0.0897	0.0938
14	0.0641	0.0747	0.0781
15	0.0571	0.0673	0.0703
16	0.0508	0.0598	0.0625
17	0.0453	0.0538	0.0562
18	0.0403	0.0478	0.0500
19	0.0359	0.0418	0.0438
20	0.0320	0.0359	0.0375
21	0.0285	0.0329	0.0344
22	0.0253	0.0299	0.0312
23	0.0226	0.0269	0.0281
24	0.0201	0.0239	0.0250
25	0.0179	0.0209	0.0219
26	0.0159	0.0179	0.0188
27	0.0142	0.0164	0.0172
28	0.0126	0.0149	0.0156
29	0.0113	0.0135	0.0141
30	0.0100	0.0120	0.0125

*__Dimensions in decimal parts of an inch.__

Section II. ROOF DECKS FOR METAL ROOFINGS

Metal roofings are applied on solid or open-slat wood decks, or on wood or metal framing (purlins). Solid wood decks may be of well-seasoned, tongued-and-grooved, square edged or ship-lap sheathing laid to produce a smooth, uniform surface. Solid decks may also be of plywood with exterior glue. Before applying the metal, the deck must be dry, and care should be taken to insure that the surface is clean and smooth, with no rough spots or projections such as nail heads, wood chips, stones, or other debris. In open-slat decks, the sheathing boards may be spaced from 6 to 24 inches, depending on the rigidity of the roofing to be applied. Only the more rigid sheet roofings, usually corrugated, are laid on purlins without sheathing. Metal roofing may also be laid over concrete or gypsum roof decks. Some underlay material such as asphalt-saturated felt is usually applied under metal roofing on tight decks. Contact of dissimilar metals should be avoided.

Section III. STORAGE AND HANDLING OF METAL ROOFING

Metal roofings in storage should be protected from the weather. Although some metal roofings are intended for direct exposure to the weather, some, such as copper, may become stained and others, such as galvanized steel, may corrode if stored in a damp place. Bundles of sheeting should be opened and inspected when received. Damp or wet sheeting should be separated and dried. Stained sheeting should be cleaned before use. Metal sheets should be stored on edge, not in contact with the ground. Sheets should be carefully handled at all times to prevent damage to the surfaces, edges, and ends.

Since the different metal roofing materials normally require different treatments, they are considered separately in this section.

11.4.1 Copper Roofing

11.4.1.1 General. Copper is one of the least chemically active metals used for roofing. Consequently, copper roofings of adequate weight, applied properly, render long service. The weight of copper roofing is designated as ounces per square foot. Sixteen-ounce copper is the generally accepted weight for roofing. Sheets of this weight are approximately 0.0216 inches thick and when applied by the standing-seam method, weigh approximately 125 pounds per square. Copper roofs are usually applied by the flat-seam, batten-seam, or standing seam methods.

11.4.1.1.1 Patina. When copper roofing is exposed to the atmosphere, a green coating known as patina forms on the exposed surface. This coating aids in protecting the metal from further corrosion.

11.4.1.1.2 Lead-Coated Copper. Lead-coated copper is occasionally used for roofing. While this is a case of dissimilar metals in contact, lead and copper are adjacent in the electromotive series so that little action would be expected in any case. Since lead has the lower number, it protects the copper electrolytically as well as physically. Lead-coated copper is used advantageously to prevent copper staining on the surrounding materials.

11.4.1.2 Temper. Copper sheet metal is produced in varying degrees of hardness, but is generally divided into two groups that are best suited for general purpose work in structures. "Soft" is the term given to soft rolled, hot rolled, or roofing temper and is used for standing and batten seam roofing, caps, and through-wall flashings. "Cold" rolled is the term given to hard, hard rolled, or cornice temper and is recommended for most general purpose construction work, especially base and counter flashings, gutters, downspouts, and other places where stiffness is required to support or maintain the shape of an item.

11.4.1.3 Workability. Copper is soft and ductile permitting the use of all types of seams for joining and folds for forming operations. Cold working hardens copper. Repeated folding, bending, or hammering should be avoided or the copper must be annealed to restore its ductility.

11.4.1.4 Galvanic Action. Because of its position in the electrochemical series, copper is seldom damaged by galvanic action. However, the presence of copper can electrically corrode other metals if precautions are not used.

11.4.1.5 Fasteners, Seams, and Joints. All mechanical fasteners should be made of copper. Cleats are generally used to secure sheets of copper. Copper is ductile which permits easy forming for various types of seams for joining. For water tight joints, copper is readily soldered. For water tight joints as in roofing where freedom of movement is desired, paste sealers or expansion joints are recommended. Two types of sealers are commonly used; a paste containing 92 percent lead carbonate and 8 percent linseed oil or a mixture of asphalt and asbestos fiber (Fed Spec SS-C-153). The lead paste is usually specified.

11.4.1.6 Reuse of Copper. The reuse of copper is recommended because of its high cost and ductility which permits reworking. However, care must be exercised to prevent metal fatigue where the metal was previously creased or stressed.

11.4.1.7 Maintenance. Copper roofs do not normally require maintenance as defined for this manual. Any treatment necessary would be classed as a repair, following failure (leak).

11.4.1.8 Repairing to Provide Adequate Expansion and Construction. The most common cause of failure in copper roofs is the failure to provide adequately for expansion and contraction, particularly in flat-seam roofing. Broken soldered seams and breaks in the metal at points other than seams indicate inadequate provision for expansion and contraction.

11.4.1.8.1 Flat-Seam Roofs. When broken soldered seams indicate inadequate provision for expansion and contraction, new expansion joints sufficient to provide a joint at intervals of not more than 10 feet in each direction should be installed.

11.4.1.8.2 Batten and Standing-Seam Roofs. If soldered horizontal seams on batten- and standing-seam roofs are broken, loose lock seams that permit movement of the sheet should be installed at those points.

11.4.1.9 Repair Breaks in Copper Roofing.

11.4.1.9.1 Small Breaks. Small holes in copper roofing can be repaired with a drop of solder. In soldering copper, scrape with a sharp instrument or emery cloth until bright metal shows on any surface that is to contact the solder. Then apply zinc chloride or rosin as a flux and tin the surface with a thin coating of solder.

11.4.1.9.2 Larger Breaks. Larger breaks, not caused by inadequate provision for expansion and contraction, may be repaired by soldering a piece of copper over the hole; the new metal should be mechanically locked to the existing sheet.

11.4.1.10 Reroofing with Copper Roofing.

11.4.1.10.1 Preparing Deck Jo r Reroofing with Copper Roofing.

Restore the deck to as nearly "new" condition as possible as follows:

(1) Remove all protruding nails and renail sound sheathing where necessary.

(2) Remove rotted or warped sheathing boards and install new decking.

(3) Cover all large cracks, knot holes and resinous areas with compatible sheet metal.

(4) Repair or replace copper flashings.

11.4.1.10.2 Applying Copper Roof. Apply copper roof in accordance with current specifications for new construction.

11.4.2 Terne Roofing

11.4.2.1 General. Terne (tin) roofing is composed of a steel sheet coated on both sides with a lead-tin alloy.

11.4.2.1.1 Grades. Terne sheets are usually furnished in grades 1C (approximately No.30 US Gage) and 1X (approximately No. 28 US Gage). Grade 2X (approximately No. 26 US Gage) is also available. The 1C grade, weighing approximately 65 pounds per square, is generally used for flat-seam, batten-seam and standing-seam roofing. The 1X grade, weighing about 25 percent more than the 1C grade, is normally used for flashings, valleys and box gutters. Sheets are commonly available in two sizes, 14 by 20 inches and 20 by 28 inches. Rolls 14, 20, 24, and 28 inches wide by 50 feet long are also available.

11.4.2.1.2 Weight of Lead-Tin Coating. The weight of lead-tin coating for terne sheets is designed as "pounds per double base box," a double base box consisting of 112 sheets, 20 by 28 inches (62,720 square inches). Coating weights of 40 pounds per double base box and 20 pounds per double base box are generally used. For maximum longevity, 40-pound coating should be used.

11.4.2.1.3 Painting. It is necessary to keep terne roofing well painted for long service. The reason is that the lead-tin alloy, while furnishing good physical protection to the iron or steel base, is so placed in the electromotive series that the coating will be preserved at the expense of the ferrous base in cases where pinholes or scratches in the coating expose the base. The underside of terne roofing should be painted with a mill applied shopcoat or a coat of red iron oxide-linseed oil paint.

11.4.2.2 Coefficient of Expansion. The coefficient of expansion of terne sheets is only about ⅔ that of copper, therefore, expansion and contraction with changes in temperature is less of a problem. In addition, the lighter weights of terne sheets that are used permit slight buckling.

11.4.2.3 Temper. The temper of terne plate is dependent upon the mild steel sheet under the coating and is copper bearing steel of low carbon content similar to galvanized iron.

11.4.2.4 Fasteners, Seams, and Joints. Lead coated fasteners should be used with terne plate. The lead-tin coating will withstand severe folding and bending before breaking down and can be utilized in all forming and bending operations. Soldering is recommended for all seaming and joining operations. The lead-tin coating eliminates the necessity of pre-tinning. Brazing and welding destroy the coating in the area of the weld and are not recommended.

11.4.2.5 Maintaining Terne Roofs. Terne roofs must be maintained by periodical painting. The frequency of painting will vary with different conditions of exposure, but painting should never be put off until rust appears no'. should thick coatings of paint be built up by too frequent painting. Instructions for painting terne roofs are given in manufacturer's literature. A linseed oil and iron oxide (FS-TT-P-31) primer is recommended followed by oil exterior paint.

11.4.2.6 Repairing Terne Roofs. Many leaks in terne roofings are caused by faulty seams.

11.4.2.6.1 Broken Soldered Seams. Broken seams are generally due to improper soldering. Seams should be opened up and cleaned before resoldering. The presence of moisture in seams will not permit proper penetration of solder. Half and half solder is used for terne. Rosin is used as a flux. Remove excess rosin before painting.

11.4.2.6.2 Leaky Formed Seams. Repair leaky formed seams by reforming or by calking with a plastic calking material.

11.4.2.6.3 Small Breaks. Repair small holes in terne roofings with a drop of solder.

11.4.2.6.4 Larger Breaks. Larger breaks in terne roofings may be repaired by mechanically locking and soldering a piece of terne roofing over the break.

11.4.2.7 Reroofing with Terne Rooting.

11.4.2.7.1 Preparing Deck for Reroofing. See paragraph 11.4.1.10.1, "Preparing Deck for Reroofing with Copper Roofing."

11.4.2.7.2 Applying Terne Roof. Apply terne roof in accordance with specifications for new construction.

11.4.3 Galvanized Steel Roofing

11.4.3.1 General. Galvanized sheets are available in various sizes and in thickness ranging from No.12 to 30 gage (US Standard for Iron and Steel Plate) and in various weights of zinc coating, the weight of coating being expressed as the total weight of zinc per square foot on both sides of the sheet. The resistance to corrosion of galvanized sheets increases with increased weights of zinc coating. However, since the sheets are formed after the zinc coating is applied, there are practical limits to the thickness of the coating on formed sheets. The heavier coating, up to 2.74 pounds, are normally applied to the heavier gage sheets. For severe bending or forming, only thin, tightly adherent coatings are used. Zinc is an ideal coating material for iron or steel. From its position in the electromotive series, it is obvious that the base metal will be protected electrochemically by the zinc in cases where pin holes or scratches expose it, and it is only when relatively large areas of the base metal are exposed that rusting takes place. Consequently, unlike terne coated sheets, galvanized sheets may be exposed without painting. The length of such exposure depends on the weight of the zinc coating and the conditions of exposure, but painting may be postponed safely until the first sign of base metal corrosion appears. This will be in the form of a rather bright yellow product resulting from the corrosion of the zinc-iron alloy formed on the surface of the base metal.

11.4.3.2 Forms. The common types of galvanized roofing are V-crimp, corrugated, pressed standing seam, rolled roofing, and shingles. All but the roll roofing are preformed, ready to apply. Other special shapes of preformed sheets are also available. Corrugated galvanized roofing is taken as representative of the galvanized metal roofings, since it is the type of galvanized roofing used most frequently on warehouses, sheds, and other industrial type facilities. It is the lowest in cost of all types of metal roofing and, when properly applied and maintained, it renders very satisfactory service. Corrugated galvanized roofing may be applied over tight wood decks, with or without underlay, on open-slat decks or on wood or steel purlins. It is available in sheets of different lengths and depths of corrugations. Full length sheets should be used when possible to eliminate end laps between the eaves and the roof ridge.

11.4.3.3 Temper. The steel sheets are a low carbon steel and provide the maximum strength without sacrificing ductility. Any attempt to increase the temper by heating and quenching will destroy the zinc coating. Excessive cold working will crack the zinc surface.

11.4.3.4 Fasteners. All fasteners must be galvanized (lead or zinc coated), stainless steel or other type which will not result in galvanic attack on the sheet.

11.4.3.5 Maintaining Galvanized Steel Roofing. The most frequent causes of failure in galvanized roofings are improper application and lack of regular maintenance painting. Leaks at seams and fasteners are evidence of improper application. Galvanized steel roofs need not be painted immediately upon exposure. In fact, without special treatment or the use of special paints, it is better to postpone painting of galvanized steel for several months, at least, to insure adhesion of the paint. Painting may be postponed until the appearance of bright yellow corrosion product indicating that the zinc coating is no longer protecting the zinc-iron alloy formed on the surface of the base metal. However, it is much safer to paint prior to the appearance of this product and subsequent regular maintenance painting will prolong the service of the roofing indefinitely. Instructions for painting galvanized steel roofs are given in the tn-services paint manual. New galvanized surfaces should receive an application of wash primer (MIL-C-14504) to provide proper adhesion of paint followed by a coat of zinc dust-zinc oxide paint (F.S. TT-P-641) and an appropriate finish coat.

11.4.3.6 Repairing Galvanized Steel Roofing.

11.4.3.6.1 Leaks at Seams and Fasteners. Inadequate laps in galvanized steel roofings may be repaired by calking the seams or, in severe cases where calking is impracticable, by stripping the laps as described in paragraph 6.6.4.2.1, "Repairing Leaky Seams of Roll Roofings for an Expected Use of More than 1 Year." As stated in this reference, modifications of the method, following the same principle, may be satisfactory. With any method, workmanship is extremely important. It should be realized, also, that repairs of this kind cannot be expected to last as long as the galvanized sheets so that they will require maintenance treatment and probably renewal at intervals. When exposed fasteners are a part of the lapped seam, the membrane treatment should be applied over them.

11.4.3.6.2 Repairing Breaks in Galvanized Steel Roofing. Breaks in galvanized steel roofing are best repaired by replacing the defective sheet of roofing with a new one.

11.4.3.7 Reroofing with Galvanized Steel Roofing.

11.4.3.7.1 Preparing Deck for Reroofing. See paragraph 11.4.1.10.1, "Preparing Deck for Re-roofing with Copper Roofing."

11.4.3.7.2 Applying Galvanized Steel Roof. Apply galvanized steel roof in accordance with current specifications for new construction.

11.4.4 Aluminum Roofing

11.4.4.1 General. Aluminum roofing materials may be homogeneous, with the entire cross section of the same composition, usually not less than *97* percent of aluminum or they may be called clad materials, with a layer of aluminum or aluminum alloy that is anodic to the core material and which will retard corrosion of the core material if it is exposed. The usual core material is an aluminum alloy. Aluminum coated steel sheets are also used. The thickness of aluminum sheets is usually measured in decimal fractions of an inch as opposed to a gage number or weight measure. When gage is referred to it is the Brown and Sharp (American Standard) System. Aluminum roofings are available in essentially the same forms as galvanized steel, namely V-crimp, corrugated, pressed standing seam and shingles. Other special shapes are also available. Sheets are produced in various sizes and thicknesses and in varying degrees of temper. Aluminum roofing when properly applied, renders excellent service. It is similar to copper roofing in that it does not require painting. However, it should be noted that aluminum has a high coefficient of expansion and is subject to galvanic action from other metals.

11*.4.4.2 Coefficient of Expansion.* The coefficient of thermal expansion of aluminum is approximately ⅓ greater than that of copper so that ample provision for expansion and contraction must be supplied when long sheets of aluminum roofing are used.

11.4.4.3 Galvanic Action. Aluminum is the most active of structural metals and decomposes rapidly when in contact with other metals. Therefore, contact of aluminum roofing with dissimilar metals must be avoided, particularly in coastal areas. This precludes the use of bare steel and copper nails, or lead washers, in such areas. Aluminum alloy nails should be used with aluminum alloy roofing to obtain the best results.

11.4.4.4 Temper. For general construction work, aluminum is classified as soft or hard. The letter A (commercially 0) denotes soft and the letter H denotes hard.

11.4.4.5 Workability. Aluminum is ductile and will withstand a 180° bend without fracture. Cold working rapidly hardens aluminum; therefore, straightening, refolding, or reworking will usually fracture the affected area. To trim light gauge soft temper corrugated aluminum perpendicular to corrugations, scribe deeply, and tear by forceful rolling of cut off portion.

11.4.4.6 Contact with Masonry. Direct contact with mortar, lime, cement, and wood should be avoided to prevent corrosive action between the receiving surface and the aluminum. Masonry surfaces (line, mortar, concrete, plaster, etc.) must be coated with alkaline-resistant coatings such as heavy bodied bituminous paint or water-white methacrylate lacquer. Wood can be treated with bituminous paint, or two coats of either aluminum house paint, pentachlorophenal (5 percent minimum concentration), Wolman salts, creosote, or zinc naphthenate. Wood may also be covered with waterproof building paper.

11.4.4.7 Fasteners and Seams. Only aluminum fasteners should be used to secure aluminum sheets because of its high affinity for galvanic action. Soldering of aluminum, although possible, is not recommended. In thickness less than .040 inch, mechanical fastenings should be used, and for greater thickness, aluminum is usually welded using a shield of inert gas.

11.4.4.8 Maintaining Aluminum Roofing. Aluminum roofing, properly applied, does not normally require maintenance. However, if evidence of severe atmospheric corrosion occurs, the roofing may be preserved by regular maintenance painting. Instructions for painting aluminum are given in the tn-service paint manual.

11.4.4.9 RepairingAluminum Roofing. Failures in aluminum roofing that are due to improper application are essentially the same as those encountered with galvanized steel roofing and are repaired similarly. See paragraph 11.4.3.5, "Repairing Galvanized Steel Roofs."

11.4.4.10 Reroofing with Aluminum Roofing.

11.4.4.10.1 Preparing Deck for Reroofing. See paragraph 11.4.1.10.1, "Preparing Deck for Re-roofing with Copper Roofing."

11.4.4.10.2 Applying Aluminum Roofing. Apply aluminum roofing in accordance with current specifications for new construction.

11.4.5 Corrosion-Resisting (Stainless) Steel

11.4.5.1 General. Corrosion-resisting steels (ASTM Standard A167) are alloys of steels with varying compositions of chromium, nickel, and copper. Most of the structural stainless steels are of a chrome-nickel-steel alloy and are austenitic in nature which means they cannot be heat treated but must be cold worked to alter their physical characteristics. Chromium stainless steels contain no nickel and are martensitic (less than 18 percent chrome) or ferritic (18 to 30 percent chrome) in nature. Their physical characteristics can be changed with heat treatment. AISI (American Iron and Steel Institute) numbers are generally used to differentiate between the stainless steels. Composition ratios are also used. The first and the second number indicates the percentage of nickel alloyed with steel. The thickness of stainless steel sheet is usually determined by gage number (US Standard for Iron and Steel Plate). On military facilities, the use of stainless steel for roofing is generally limited to drainage and flashing applications because of the high initial cost.

11.4.5.2 Types. Types of stainless steel commonly used for roofing are AISI 301 ($^{16}/_{18}$—$^{6}/_{8}$ composition), AISI 302 ($^{17}/_{19}$—$^{8}/_{10}$ composition.) AISI 304 ($^{18}/_{20}$—$^{8}/_{12}$ composition), and AISI 316 ($^{16}/_{18}$—$^{10}/_{14}$ composition). Type 316 has 2 to 3 percent molybdenum added which increases corrosion resistance.

11.4.5.3 Finish. Stainless steel sheets are available with several surface finishes. Finish No. 2D is usually preferred for roofing and flashing applications.

11.4.5.4 Coefficient of Expansion. Stainless steel (300 series) has a coefficient of expansion of 0.0000096 which is about 50 percent greater than the coefficient of expansion for carbon steels.

11.4.5.5 Workability. Stainless steel sheet and strip material is readily formed by sheet metal shop tools. For roofing and flashing work, the stainless steel should be furnished in the annealed condition. Stainless steel is ductile enough to permit all of the seams applicable to sheet metal work.

11.4.5.6 Soldering. Stainless steel can be soft-soldered, using the same equipment and procedures as used with other roofing metals. A strong acid flux is required. After soldering, flux residue should be rinsed off. Ordinary "half-and-half" tin-and-lead solder is suitable. However, a 60-40 tin-and-lead solder should be used where appearance is a consideration. Solder should be used only to fill or seal the joint; it should not be relied upon to provide joint strength. Mechanical fastening or welding should be used if strength is an important factor.

11.4.5.7 Fasteners. Fasteners must be of stainless steel. Ordinary iron or steel fasteners corrode and leave rust deposits on the surface of stainless steels.

11.4.5.8 Maintaining Stainless Steel Roofing. Other than routine maintenance inspections, the only periodic maintenance required with stainless steel is cleaning. Normal cleaning is accomplished with mild detergent and water. Heavy accumulations of dirt containing oil or grease will require solvents. Organic solvents are usually satisfactory and will not harm the finish. Other deposits or stains require the use of stainless steel wool or abrasives. Use only stainless steel wool and scraper. Ordinary steel wool and scrapers will contaminate the surface and eventually leave rust stains. Recommended abrasives include fine grade whiting or pumice, stainless steel cleaners, fine grade commercial scouring powders, and abrasive metal cleaners. Abrasives must be applied with a soft, damp cloth, and rubbed lightly to prevent scratching of highly polished surfaces or bright spots in a dull surface.

11.4.5.9 Repairing Stainless Steel Roofing. Repair methods are similar to those for copper roofing. See paragraphs 11.4.1.8 and 11.4.1.9.

11.4.5.10 Reroofing with Stainless Steel.

11.4.5.10.1 Preparing Deck for Reroofing. See paragraph 11.4.1.10.1, "Preparing Deck for Re-roofing with Copper Roofing."

11.4.5.10.2 Applying Stainless Steel Roofing. Apply stainless steel roofing in accordance with current specifications for new construction.

11.4.6 Protected Metal Roofing

This type roofing consists of a steel or aluminum base sheet that is protected from the weather by a factory-applied covering. Coverings are applied to flat sheets, before forming, and include liquid coatings, liquid plus film coverings, and film coverings. Protected metal roofing is available in various colors and in the same configurations as galvanized steel and unit weights depending on the gage of the metal core, the type of metal, and the type of covering. Protected metal roofings are proprietary materials. Consequently, with these materials, the recommendations of the manufacturer should be followed as regards storage and handling, application, maintenance and repair. With materials of this kind, it is practically impossible to avoid breaks in the protective covering during construction. To cover such breaks and to renew the protective covering when exposure makes a renewal necessary, only materials furnished by the manufacturer should be used in order to insure that the new material is compatible with the old.

Table 4. Properties of Sheet Metal

Material	Characteristics	Principal uses	Melting point	Coefficient of expansion (per degree F.)	Method of joining	Precautions
Copper	High corrosion resistance. Excellent workability. Tarnishes easily but eventually forms decorative coating called patina. Toxic.	Roofing, gutters, downspouts, flashing, louvers, scuttles, drains, shower pans.	1980° F	0.0000098	Use caution when welding. Excellent for all other methods.	Water which has been in contact with copper will stain masonry and painted surfaces, and corrode most other metals.
Aluminum	Good corrosion resistance. Light weight. Nontoxic. Good workability. Easily cleaned.	Roofing, siding, trim, flashing, canopies.	1218° F	0.0000128	Welding requires shield of inert gas. Soldering not recommended. Brazing mechanical fasteners and seams recommended.	Not recommended for extensive seaming. Highly subject to electrolytic corrosion.
Galvanized Iron	Fair corrosion resistance. Good workability. Nontoxic. Good fire resistance.	Roofing, siding, gutters, downspouts, canopies, ventilators.	Coating 786° F Base sheet 2700° F	0.0000065	Excellent for soldering, seaming and mechanical fasteners. Welding and brazing destroy galvanized surface.	Protective coating (zinc) highly subject to electrolytic corrosion. High temperatures destroy surface.
Black Iron	Poor corrosion resistance. Good workability. Excellent resistance to abrasion. High strength.	Floor plates, stair treads, roof decking.	2700° F	0.0000065	Excellent for all methods of joining and seaming.	Easily damaged by all corrosive elements.
Stainless Steel	High corrosion resistance. Good workability. Nontoxic. Easily cleaned. Work hardens rapidly.	Flashing, decorative trim, roofing, gutters, downspouts.	2560° F	0.0000058 to 0.0000096	Requires additional power for seaming. Inert gas shield not required for welding but recommended to prevent surface damage.	Extra power required for cutting and forming operations. Surface can be contaminated by iron particles, causing rust.
Nickel Copper Alloy (Monel)	Excellent corrosion resistance. Good workability. Nontoxic. Easily stained. Difficult to clean.	Roofing and drainage components (in highly corrosive atmosphere and salt water areas).	2370° F	0.0000077	Excellent for all methods. Solder offers no strength.	Surface tarnishes easily and is difficult to clean.
Terne	High durability if kept painted. Good workability (same as steel core). Receptive to paint. Lead-tin coating is toxic.	Roofing, flashing, and drainage components.	Base sheet 2700° F	0.0000065	Excellent for soldering, seaming, and mechanical fasteners. Pretinning not required for soldering. Brazing and welding destroy lead-tin coating so not recommended. Use lead coated fasteners.	Painting is required.

Table 5. Use and Recommended Thickness of Sheet Metals

	Copper (wt. per sq. ft.)	Galvanized steel [2] (US Std.)	Aluminum (inches)	Corrosion-resisting steel (US Std.)	Terne (US Std.) 40 pound coating weight	Monel (inches)
Cornices and belt courses	20 oz	24 gage	0.032	26 gage (.018)	24 gage	0.021
Coping	20 oz	24 gage	0.032	26 gage	24 gage	0.021
Corrugated siding	---	26 gage	0.032	26 gage	26 gage	---
Drip strip	20 oz	---	0.032	24 gage (.025)	---	0.021
Edge strip	24 oz	---	0.050	24 gage	---	---
Flashing:						
General	16 oz	24 gage	0.032	26 gage	26 gage	0.021
Closed valley	16 oz	26 gage	0.032	26 gage	26 gage	0.025
Spandrel beam	6 oz[1]	---	---	32 gage (.010)	---	---
Smoke pipes and vents	---	24 gage	---	---	---	---
Through-wall	16 oz	---	---	26 gage	---	0.018
Gravel stops	16 oz	24 gage	0.032	26 gage	26 gage	0.018
Gutter linings	20 oz	24 gage	---	26 gage	24 gage	0.021
Gutters (attached)	20 oz	26 gage	0.032	26 gage	26 gage	0.021
Gutters (hanging)	16 oz	26 gage	0.032	26 gage	26 gage	0.018
Hoods and canopies	20 oz	26 gage	0.032	26 gage	26 gage	0.021
Leaders (downspouts)	16 oz	26 gage	0.024	28 gage (.015)	26 gage	0.018
Roof ventilators	24 oz	24 gage	0.040	26 gage	24 gage	0.025
Roofing:						
Corrugated	---	22 gage	0.032	24 gage	22 gage	---
Batten seam	16 oz	---	0.032	26 gage	26 gage	0.018
Flat seam	20 oz	---	---	24 gage	24 gage	0.021
Standing seam	16 oz	---	0.032	26 gage	26 gage	0.018
Scuttles	16 oz	---	0.032	26 gage	---	0.018
Splash pans	16 oz	---	0.040	24 gage	---	0.021

Note. The above thicknesses are the minimum to be used with the work indicated. Heavier gages should be used when called for by the work or when conditions indicate that the minimum thickness will be unsatisfactory.

[1] Requires coating of plastic bituminous compounds.

[2] Galvanized steel and iron—for use principally on temporary and semipermanent work.