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BUILDING MATERIALS AND STRUCTURES

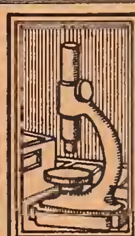
REPORT BMS49

Metallic Roofing for Low-Cost House Construction

by

LEO J. WALDRON

NATIONAL
BUREAU OF STANDARDS



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BUILDING MATERIALS *and* STRUCTURES

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ISSUED MAY 7, 1940

The National Bureau of Standards is a fact-finding organization; it does not "approve" any particular material or method of construction. The technical findings in this series of reports are to be construed accordingly.

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Foreword

This report was written in response to a widespread demand for descriptive information on the properties, application, and uses of various metallic roofing materials suitable for low-cost house construction, and is based upon results obtained by the National Bureau of Standards and its work on the weathering qualities of roofing materials, data furnished by manufacturers of metal roofing, and information found in various publications.

A similar report on asphalt roofing materials is in preparation.

Lyman J. Briggs, *Director.*

Metallic Roofing For Low-Cost House Construction

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CONTENTS

ABSTRACT

The general aspects and status of metals utilized for roofing purposes are discussed. Consideration which apply in general to all roofing materials and to metals in particular are given. Basic principles of metal-roof construction are listed, together with descriptions of the type of seams, decks, nails, and coverings used.

Galvanized sheet steel, terne, and copper roofings are discussed in detail because they constitute the bulk of present-day roofs. The durability of galvanized sheet-steel roofings is shown by the data obtained from outdoor-exposure tests conducted by the American Society for Testing Materials.

Information on the maintenance of terne and galvanized roofs is given.

I. INTRODUCTION

This publication describes the various types of conventional and commercially available metallic roofing materials suitable for use in low-cost house construction. Such materials need not necessarily be low cost in themselves to meet this classification. The proportionate cost of the roof covering to the total cost of a house is relatively small; therefore, most roofing materials can be used on houses costing $5,000 or less, provided that the initial cost of the covering is not excessive and that its use does not involve too great an expenditure for decking, roof structure, etc. Furthermore, a material may be suitable for low-cost housing in one location but not in another because of either the variation in cost according to geographic location or the unsuitability of some materials to withstand certain climatic or local atmospheric conditions.

Surveys of the weathering qualities and the extent of use of roofing materials in two large eastern sections of the United States, representing different climatic conditions, have been made and are described in Building Materials and Structures Report BMS6, Survey of Roofing Materials in the Southeastern States[1], and BMS29, Survey of Roofing Materials in the Northeastern States.[2]

Sheet-metal roofing has become fairly well standardized, so that full constructional details of installation need not be given here. This information may be found in standard handbooks and in various manuals issued by the manufacturers of metallic roofing [1].[3]

II. GENERAL ASPECTS OF METAL ROOFING

Metal roof coverings formerly had a much wider use than at present and were equally popular in cities, villages, and rural districts. The use of suitable materials and their skillful application and proper maintenance were responbible for their long life. Many of these metal roofs, with years of service behind them, can be found in various sections of the country at the present time.

The roofing situation has changed considerably within recent years, however. Apparently social influences and general appearance have been important factors in restricting the use of ferrous metal roofing. The wide use of this class of material on lower-cost dwellings in cities and rural sections has unfortunately classified it as a "cheap" material. Improper methods of application and inadequate maintenance rendered the sheet roofings unsightly and the conventional patterns of stamped shingles had little appeal. Within recent years, on the other hand, manufacturers of nonmetallic roofing have been emphasizing the pleasing color effects that can be obtained with their materials, and architects are striving for roofs that are individualistic and that do not repeat the same pattern over the entire surface of the roof. Recently manufacturers of metal roofings have been giving more consideration to the appearance of their products, resulting in the increased application of sheet-metal roofs of low cost.

Galvanized ferrous metals, copper, and roofing ternes are the principal metals now being used in roof construction. Separate sections in this report are devoted to discussions of the utilization of these three roofing materials.

The use of zinc, lead, aluminum, Monel metal, porcelain-enameled steel, lead-coated steel, painted black steel, and bituminous-coated steel for roofing purposes has been actively promoted. However, their use in low-cost house construction has been limited. This does not mean, necessarily, that they are excluded from this field, because future developments and trends may change their present classification entirely. Various metals are widely used for accessories, such as flashings, valleys, gutters, and downspouts, with metallic or nonmetallic roofs. These items are of major importance and will be discussed in a separate publication.

III. CONSIDERATION OF METALS FOR ROOFINGS

1. General

The fundamental requirements of any roofing material are

To form a satisfactory cover to keep out water and protect the property and its occupants from the weather.

To have long durability under service conditions.

To be capable of being easily applied to form a roof.

To have a pleasing appearance.

Numerous other factors may be worthy of consideration. They need not necessarily be fundamental in nature, although they are of importance in the selection of any specific material. These are effects of temperature, relative weights of the material when laid as

[1] Price 15 cents. See cover page III.
[2] Price 10 cents.
[3] Figures in brackets indicate the literature references at the end of this report.

a roof and the ability of a roof structure to support a given material, fire and lightning protection, and mechanical strength and rigidity.

2. Effects of Temperature

The fact that all metals used for roof construction expand and contract with changes in temperature accounts largely for the prevailing design of metal roofings. The particular design to be employed will be that one of the basic types best adapted to the structure and, generally, the one that will fulfill the fundamental requirements previously mentioned.

The movement of metal sheets resulting from temperature changes is much greater than for other types of roofing materials.

The rate of expansion and contraction differs with each metal. The approximate changes (expansion or contraction) in an 8-foot sheet of the principal roofing metals used resulting from a 150° F variation in temperature are as follows:

Iron	6/64 in.
Monel metal	7/64 in.
Copper	9/64 in.
Aluminum	12/64 in.
Lead	15/64 in.
Zinc	16/64 in.

The change in dimensions resulting from temperature differences for any metal roofing sheet can be calculated from the linear coefficient of expansion of that metal, which may be defined as "the rate at which the unit of length changes, under constant pressure, with a change of unit temperature." It should be remembered that these changes of dimension result equally in all planes of the metal, and are the same regardless of the thickness of the metal. Thus a 1-ft square piece of thin copper, a few thousandths of an inch in thickness, will change in length and width the same amount as a heavier piece (say, 16-oz sheet, 0.021 in. thick) of the same size, under similar temperature differences. An important constructional item frequently neglected is, that provisions for expansion and contraction of a metal roof must cover both longitudinal and transverse movement.

Failure to provide adequately for these changes in dimensions of the roofing sheets manifests itself in the setting up of stresses in the metal, the magnitude of which will deform and may ultimately crack the metal sheet.

When installing a metal roof consideration should be given to the season in which the metals are assembled. If laid during the summer, when the temperature is close to maximum, the metal will require little provision for expansion but ample means for contraction. The reverse is true if the work is carried out in cold weather, when subsequent expansion must be provided for.

Installation of metal roofs in this country requires either the fastening of the metal sheets to the roof deck with metal cleats, together with suitable joints and seams to compensate the temperature movements, or small-sized sheets to be nailed to the deck as individual units; all these units being made continuous by means of laps or loose-fitting seams. In the latter case, movement resulting from temperature changes is so slight for the area involved as to be practically negligible. One possible exception is the flat-seam roof, in which small sheets are all locked and soldered together. Expansion and contraction for these areas result in only a slight buckling at the center of each sheet.

Exceedingly high or low temperatures may greatly affect the durability of some roofing materials. Extreme heat decreases their relative life over that observed at normal temperatures, while low temperatures may cause some materials to become brittle and to be easily broken by strong winds. The life of metal roofing is just as long in a hot climate as in an extremely cold one.

3. Relative Weights of Roofing Materials

The weight of any roofing material, when laid, must be taken into consideration in designing the roof structure. These weights vary widely, as is indicated in table 1.

A roof structure must have sufficient strength to support the covering materials, as well as snow loads, and to resist the force of high winds. This may definitely limit the type of roofing that can safely be used. Heavy roofing materials require stronger deck construction than lighter materials, which increases the total cost of the roof.

Table 1.—*Weights of roofing materials when laid*

Material	Approximate weight
Terne Plate:	*lb/square* [1]
IC grade	60.
IX grade	75.
Corrugated galvanized sheet:	
20 gage	215.
22 gage	180.
26 gage	120.
V-Crimp galvanized sheet:	
20 gage	215.
22 gage	175.
26 gage	120.
Zinc sheet, 20 gage	125.
Copper sheet:	
16 oz/ft²	130.
10 oz/ft²	80.
3 oz/ft²	60.
Lead sheet, ⅛ in. thick	750.
Wood shingles	250.
Cement asbestos shingles	275 to 600
Slate	500 to 1,000
Tiles:	
Plain	1, 800.
Spanish	850.
Asphalt shingles	130 to 325
Asphalt roll roofing	35 to 80
"Built-up roofing" (saturated felt, bitumen, and slag or gravel)	400 to 675

[1] A roofing square is a 100 ft² area of a roof. These weights may vary considerably, depending upon design of the material, allowance for lapping, etc.

As a class, metal sheets are the lightest of all roofing materials. Prefabricated sheets of iron and steel roofing have great strength and rigidity without adding undue weight to the roof.

4. Fire and Lightning Protection

A metal roof offers protection to the building against fire resulting from sparks or falling embers. Buildings covered with metal roofing generally receive the benefit of the lowest insurance rates.

Metal roofs that are grounded properly are reasonably safe from damage by lightning. Directions covering the grounding of metal roofs are given in Farmers' Bulletin 1512 [2] and in National Bureau of Standards Handbook H21 [3].

5. Mechanical Strength and Rigidity

Many types of metal roofing add strength and rigidity to the supporting structure. Some of them, particularly corrugated galvanized sheets, do not require closely laid sheathing and represent a saving in construction costs to the owner. These roofs are as strong and rigid as those which require solid sheathing.

IV. BASIC PRINCIPLES OF METAL-ROOF CONSTRUCTION

1. General

Sheet-metal roofs are normally installed by assembling individual sheets of limited size, using the joints, or seams, described in the following sections. The provision for adequate expansion and contraction under changes in temperature by the use of small sheets and joints or seams, constitutes the principal factor in the satisfactory installation of metal roofings. For this reason, and in contrast with other types of roofings, the individual sheets usually are not nailed to the deck but are held by cleats (of the same metal), nailed to the roof deck, and then incorporated in the seam or joint. If the roof is flat (pitch of 3 in. to the foot or less), soldering of the assembled sheets is necessary to produce a waterproof surface. There is less soldering on roofs of greater pitch than on flat ones, and the soldering is largely confined to ridges and hips where fitting of members cannot be done with standard seams.

2. Seams

A vital point in all metal-roofing construction is the method employed in fastening together the individual sheets, or units, into the continuous roof. The following conditions govern the selection of the method:

Durability of the roof—its freedom from leaking and ability to resist weathering, high winds, etc.

Expansion and contraction of the metal.

Slope of the roof.

Appearance of the finished roof.

Installation costs.

Various types of seams and joints are employed by sheet-metal workers in meeting these requirements.

(a) *Lap Seam*

The lap seam is the simplest of all roofing seams (fig. 1), and is widely used on preformed sheets such as V-crimp and corrugated roofings and on shingles. It is also used in flashing, gutter, downspout, cornice, and valley construction. Free movement of the two sheets at the lap is unhampered if the joint is unsoldered. In mechanical strength, the lap seam is one of the weakest soldered joints used in roofing. This type of seam may also be riveted. The unsoldered lap seam is subject to penetration of water by capillary action.

FIGURE 1.—*Lap seam.*

Unsoldered seam is illustrated by A and soldered seam by B.

(b) *Flat-lock Seams*

The flat-lock seam widely used for soldered flat-seam roofing is made by bending a strip, approximately ½ in. wide, along the butting

FIGURE 2.—*Flat-lock seam.*

Common-lock seam is illustrated by A and groove-lock seam by B.

edges of two adjacent sheets through 180° in opposite directions, hooking the two bent portions together, and flattening, with a mallet, the seam thus formed. Cleats are installed wherever necessary during the latter operation. Figure 2 (A) illustrates the common lock or hook seam. If the metal on the high side of the hook seam is pounded with a grooving tool so that it is flush with the roof deck, the resulting seam is known as a groove-lock, or flat-lock, seam (fig. 2 (B)). This seam may also be developed between two adjacent sheets after the sheets have been placed on the roof deck (fig. 3). The seam is then dressed with a mallet and soldered. It should be well sweated with solder so as to fill the lock completely.

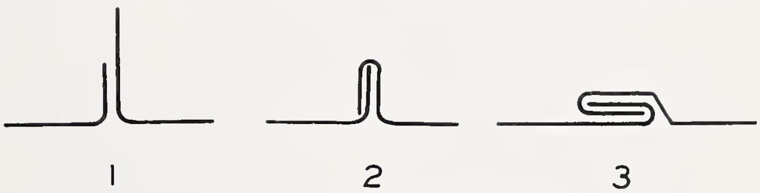

FIGURE 3.—*Development of a flat seam.*

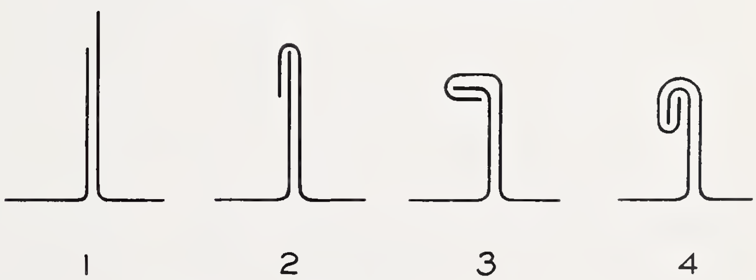

FIGURE 4.—*Development of a standing seam.*

(c) *Single-lock Seam*

The single-lock seam is of very simple construction but is relatively weak and has insufficient rigidity. It is little used, except possibly where sheets pass over sharp angles, as at corners. It may be considered the second step in the development of a standing seam (see fig. 4.)

(d) *Standing Seam*

The standing seam is employed to fasten sheets together, ample provision being made for their expansion and contraction. Figure 4 illustrates the essential steps in forming the double-lock standing seam, which is generally unsoldered. The transverse movement of the sheet resulting from temperature changes is absorbed by movement of the metal at the base of the joint. Thus, it is important to consider the temperature at the time of installation in order to allow for subsequent movement. Provision for expansion is made by leaving a space at the bottom of the seam.

The 1-in. finished standing seam commonly used is made by turning the edges of adjacent sheets 1¼ and 1½ in., respectively, while a ¾-in. finished seam is made by turning the edges 1 and 1¼ in., respectively.

In addition to its general use in roof construction, the standing seam is sometimes inserted at the high point of a flat roof or in a gutter to provide for expansion and contraction.

(e) *Double-lock Seam*

The double-lock seam is frequently used in roofing work, particularly with some of the newer, lightweight copper roofs. Essentially, it is a standing seam bent flat, as shown in figure 5. Cleats are usually made a part of the seam. On the heavier grades of roofing sheets, these seams can be made by bending the edges to form half of the seam, interlocking

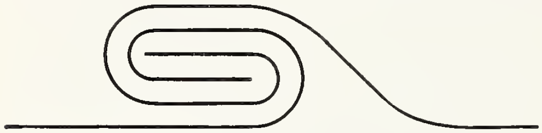

FIGURE 5.—*Double-lock seam.*

the two edges by slipping adjacent sheets together, and then flattening the seam with a mallet. If the sheets cannot be slid together, the seam is developed in the same manner as a standing seam and then flattened out.

These seams are unsoldered and are used on pitched roofs; they are folded over in the direction of the slope to prevent water from entering under the edge of the seam.

(*f*) *Loose-lock Seams*

Provisions for expansion and contraction of roofing sections sometimes necessitates some kind of sliding joint at the intersection of various roof surfaces, at the high point of built-in gutters, and on long lengths of standing-seam

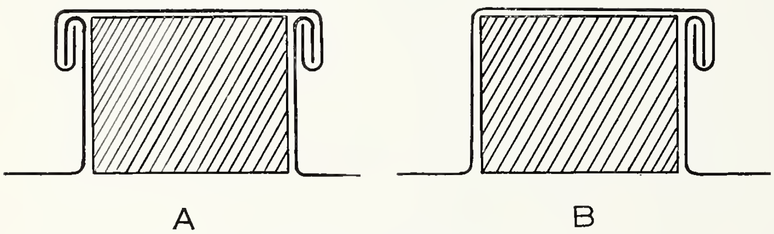

FIGURE 6.—*Batten seam.*

Batten cover is illustrated by A and without batten cover by B.

and batten-seam constructions. For this purpose either a hook lock or a loose double lock, both unsoldered, with or without cleats, can be used. Care must be taken to place the loose lock, which is not watertight, in a position where it will not let water through.

(*g*) *Batten Seams*

In making batten seams the edges of adjacent metal sheets are turned up so as to leave a small space between them. Ribs, or battens, usually of wood, are then inserted in this space and covered with a strip of the same metal, which is formed into a flat lock with the turned-up edges of the sheet, as shown in figure 6 (A). In another method, not so commonly used, the special metal strip for the batten cover is eliminated, as one of the roofing sheets covers the batten strip and is joined to the adjacent sheet by a flat-lock seam (fig. 6, B). In either case, ample provision for expansion and contraction of the sheets across the batten is afforded by the clearance at the base of the batten.

3. ROOF DECKS

An important part of any roof is the deck, or structure, upon which the roofing material rests and to which it is fastened. An uneven deck of rough, unsound lumber gives an insecure base for the applied metal roof and may be responsible for premature failure of the roofing material. Improperly secured metal-roofing sheets may be torn loose and blown off the building by winds; whereas, if nailed tightly, they would be expected to withstand winds of normal velocities for many years.

Three general types of wooden roof decks are used in connection with metal roofing: close deck, open-slat deck, and purlins. For the first of these, square-edge, tongue-and groove, or shiplap sheathing is used, the sheating being so nailed as to produce a smooth and continuous deck. In an open-slat deck the sheathing boards are laid with intervening open spaces, which may range from 6 to 24 in., this being governed largely by the rigidity of the metal roofing sheet. Purlins are wooden lengths, generally heavier than ordinary rafters, laid parallel to the eaves several feet apart. Generally no sheathing boards are needed and the roofing sheet is fastened directly to the purlins. A heavy rigid roofing sheet, such as corrugated material, is employed. This type of construction is widely used on farm and industrial buildings but seldom on residences.

Metal roofing is also laid over concrete and precast gypsum decks, particularly on industrial, office, and monumental buildings.

Most metal roofs for residential construction are applied over a close wooden deck. The deck should be of sound lumber, securely fastened to the roof rafters, and the surface free from all projections (nails, heads, etc.) that could puncture the metal sheet.

A good grade of asbestos felt, weighing 14 to 16 lb per square, is recommended by many manufacturers for use between a metal roof and the deck. This felt acts as a fire retardant and adds thermal insulation to the roof. Waterproof building paper or asphalt-roofing felt is also widely used. No tar papers or papers containing any trace of acid should be used, since they may have a deleterious effect upon the under side of the metal. This is particularly true with terne roofing, with which most specifications require the use of rosin-sized building paper wherever an intermediate layer is specified.

4. Nails for Metal Roofs

Metal nails are widely used for securing roofing material to the underlying roof deck. Most metal roofing is in the form of thin sheets and consequently must be securely fastened to withstand the action of wind and weather over a period of years. If the roof is to render satisfactory service, the nails must be as durable as the roofing material.

To avoid any "galvanic" corrosive effect, the nails should be of the same material as the roofing sheet. Copper nails should be used with all types of copper roofing; galvanized nails with galvanized and zinc roofs; tinned nails with terne roofs. It is better to pay a few additional cents per pound for a more protective nail than to have a cheaper nail rust away in a few years and allow the roofing sheets to become loose. For this reason bright or blued steel-wire nails should not be used where exposed. Galvanized nails [4] should be coated, after fabrication, with as heavy a zinc coating as possible. With corrugated and V-crimp galvanized sheet roofing, either lead washers or nails with lead-covered heads should be used if the heads are exposed to the weather. The soft lead will fill the hole around the nail and prevent leakage and rusting of the sheet at that point. The shank of the nail should be roughened to give it a good grip on the wood deck. For this reason, barbed nails are frequently used with galvanized roofing. The nails commonly used in applying roofing to clean roof decks are 1¾ in. or 2 in. in length. When galvanized roofing covers an old roof, the nails must penetrate not only the old roof but the wooden deck beneath. Various types of lead-headed nails are also used. Being in one piece they are much easier to work with than is an assembly of nail and lead washer. The available types have either a compressed lead head or a mushroom head. Lead washers are procurable for use with galvanized nails and are cut to the right size, with the center slightly raised and with a central hole for insertion of the shank of the nail. When driven, the head of the nail forces the washer tightly against the sheet and seals the hole against penetration of water and also prevents the head from cutting the sheet and damaging the zinc coating.

5. Galvanic Action

In roofing construction the contact of dissimilar metals is sometimes practically unavoidable, and the question may be raised as to the ultimate effect of such contact upon the general serviceability of the roof.

"Galvanic action", or electrolysis, is defined as the deterioration by corrosion of one metal while protecting a dissimilar metal in metallic contact with it. This action will occur only when metals occupying different positions in the electropotential series [4] are in intimate metallic contact in the presence of a suitable electrolyte, such as moisture.

In general, it is believed that galvanic action between the several metals used in roof construction will be negligible, since any accumulation of moisture usually drains off readily and thereby eliminates one of the prime causes of such action. However, adequate precautions should be taken when the conditions previously

[4] The commonly used metals may be arranged in the following order: zinc, iron and steel, tin, lead, and copper. If any two metals in this list are in metallic contact with each other and a suitable electrolyte is present permitting passage of an electric current between the two, the metal first on the list (anodic) will be corroded, whereas the succeeding one (cathodic) will be protected. Thus iron or steel, bare or galvanized, in contact with copper and in the presence of moisture will be corroded. Lead and copper are quite close together and while theoretically the tendency is for the lead to corrode, its effect would hardly be noticeable. However, complications often result so that prediction of galvanic corrosion on the basis of the relative position of metals in the electropotential series is by no means reliable.

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mentioned occur simultaneously and cannot be avoided.

Consideration of galvanic action is important in the selection of metallic coatings for iron or steel sheets used in roofing. These coatings may be grouped as follows: (1) those in which the coating is anodic to the ferrous base, as represented by galvanized material; and (2) those in which the coating is cathodic to the base, as represented by terne or lead-coated iron or steel sheets. The zinc coating on galvanized iron or steel will corrode in preference to the ferrous base and thereby protect it, as zinc is above iron or steel in the electropotential series. If the base metal is exposed at occasional thin spots, holes, or scratches, corrosion of the steel base will not occur until the area of the exposed spot is of considerable size. On the other hand, at discontinuities in the coating of lead, tin, or lead-tin alloys (roofing tin or terne) on iron or steel, the ferrous base will corrode in preference to the coating, because iron is above both lead and tin in the electropotential series. Long-continued corrosion of the base metal will eventually result in perforation of the sheet.

Roofing sheets of the first type (zinc-coated) will give relatively long service without additional protection (painting), provided they carry mediumweight coatings and are exposed under conditions in which corrosion is not unduly severe. However, painting adds greatly to the life of the material. Sheets of the second type should be painted immediately after installation and this paint coating maintained in good condition to assure maximum life of the roof. One of the principal advantages of these coatings is the excellent bond which they give to applied paint coatings.

6. Types of Metal Roof Coverings

Metal roof coverings may be classified into the following basic types: flat sheets assembled by means of various seams, corrugated sheets, and roofing units made of sheet metal in the form of tile, shingles, and cluster shingles. A description of each type follows

(a) *Flat Sheets with Various Types of Seams*

(1) *Batten-seam roofing.*—In batten-seam roof construction, metal sheets are formed over ribs, or battens, extending down the roof slope. This divides the roof into numerous small areas, thus eliminating the monotony of flat-seam construction, and this also restricts movement of the metal resulting from temperature changes to small sections. Different types of battens are used. Generally they are of wood, but may be of metal, preferably of the same kind as the roof covering.

Expansion and contraction transversely across the sheet is taken care of by the space at the base of the batten (see fig. 6, A). Expansion and contraction in the direction parallel to the battens is taken care of by:

Unsoldered flat-lock cross-seams;
Flat-lock, soldered cross-seams with allowance for expansion and contraction at the eaves or ridge;
Soldered cross-seams which stiffen the sheet and allow slight buckling within each sheet.

The sheets are attached to the battens by means of metal cleats which are fastened to the battens and hook over the upturned edge of the metal sheet. The cleats are nailed either to the top or side of the batten. Inasmuch as these cleats are the only means of holding the sheets to the deck, they should be spaced not greater than 12 in. apart along the batten.

Figure 26 shows the appearance of a batten-seam roof.

(2) *Standing-seam roofing.*—The standing-seam roof is similar to the batten-seam roof in that it breaks the roof area into small sections by longitudinal seams and either loose-locked or soldered cross seams. The longitudinal standing seam, which extends in the direction of the slope of the roof, provides for expansion and contraction across the sheet, and cross seams take care of any longitudinal movement. The seams are secured to the deck by cleats 8 to 12 in. apart along the seam. These cleats are nailed to the roof sheathing at one end and folded over within the seam at the other. This type of roofing is adapted to roofs with a pitch not less than 2 in. per foot, preferably 4 to 6 in./ft. Since the standing seam is an unsoldered joint, an accumulation of snow or ice, or the damming of water may result in leaking if the roof has insufficient pitch. Most of the dissatisfaction expressed concerning this type of

roof arises from such causes. Too much emphasis cannot be placed on sufficient pitch for roofs on which standing-seam construction is used. A well-constructed metal roof with standing seams presents an attractive appearance (fig. 16).

(3) *Flat-seam roofing.*—Flat-seam roofing is applied to decks of very low pitch (½ to 2 in./ft). A slight pitch is necessary to insure satisfactory drainage.

Small metal sheets with flat-locked and soldered seams are utilized in constructing this

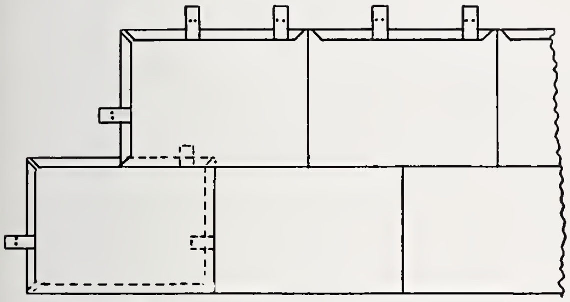


FIGURE 7.—*Method of laying flat-seam roofing with cleats.*

type of roof (fig. 7). The practice of using 14- by 20-in. sheets has become almost universal in the United States. Larger sheets can be employed, but the greater number of seams necessitated by sheets of smaller size tends to stiffen the surface and helps to prevent buckling. Where steeply pitched areas are covered, as on domes, spires, etc., unsoldered seams may be used, but roofs of this kind are seldom found in residential construction. The sheets are held firmly in place by the cleats, and enough elasticity is thus provided to take care of the contraction and expansion. Since no allowance for free movement is provided for in large areas, the flat seam should not be permitted unless the extremities are free or some sort of expansion joint is inserted.

After the sheets have been cleated together, the seams are formed and then soldered. Care must be taken to see that all seams are folded in the direction in which water will drain from the roof and that they are well sweated with solder. Figure 27 shows the appearance of a small section of this type of roof.

Roofs of this type are made either by applying individual sheets, as previously described, or by applying rolls of sheets. For the latter method the individual sheets are assembled in long lengths in the shop by locking the short dimensions together and thoroughly soldering the cross seams thus formed. Lengths from the rolls are laid parallel with the gutter or eaves. The edges of the unrolled length are locked, cleated, and soldered in the manner described previously.

(*b*) *Corrugated Roofing*

Corrugated metal roofing is used principally for industrial buildings, sheds, warehouses, and farm buildings and only occasionally for residences. A series of parallel alternate ridges and grooves, or hills and valleys, are formed in flat metal sheets. This feature adds stiffness to, increases the load-carrying ability of the sheets, and aids in discharging rain water.

The heavier grades of corrugated roofing are laid on purlins or open-slat decks, which permit the omission of sheathing, thereby lowering the cost. The lighter weights of corrugated metal are used on sheathed decks.

Corrugated sheet metal is designated in terms of the distance from the top (or ridge) of one corrugation to the top of the next. Sheets 26 in. wide and in lengths of 5 to 12 ft with 1¼- and 2½-in. corrugations are in common use. A sheet of this width will cover a strip 2 ft wide.

Corrugated roofing sheets are easily assembled over roof decking of the lowest cost with a minimum of skill. They are not recommended for roofs with a slope less than 3 in./ft.

Much of the corrugated metal roofing in use at present is zinc-coated iron or steel sheet. Corrugated sheet zinc is employed to some extent for roofing and siding on industrial buildings, and corrugated sheet copper on monumental and other buildings in higher price ranges than residential construction.

(*c*) *Roofing Units*

Metal shingles, which practically fill this basic classification, are made to simulate in general appearance slate, Spanish tile, and interlocking tile. They are applied as individual units and generally are fastened to each other by sundry interlocking devices and methods. The individual units are secured to the deck by nailing. Because of their small size, it is unnecessary to make provision for expansion and contraction.

Most types of metal shingles have side locks and are lapped slightly at the top. Patented features, such as ridges or corrugations at the top of the shingle, tend to stop the passage of water. This reduces to a minimum the amount of metal necessary for the lapped joint.

Metal shingles are available in galvanized iron or steel, copper, terneplate, and zinc. The galvanized variety is applied either plain or painted.

Plain shingles applied in conventional shingle fashion without locking devices have been used to some extent. They come in square, rectangular, and hexagonal patterns. Since relatively large areas of the metal must be used in lapping, their cost is relatively high. With normal lapping, these shingles are limited to roofs of steep pitch. On roofs of low pitch, capillary action between the lapped surfaces may result in leakage.

The various types of metal shingles present no difficulty in application. Special attention, however, should be given to nailing with the proper kind of nails selected to hold the shingles securely in place. An unsound wooden roof deck is often responsible for buckling and loosening of the shingles. Careful installation and proper maintenance of metal shingles will result in long service.

The older types of embossed, stamped, or formed shingles (all of one color) gave a somewhat monotonous appearance to the roof (fig. 20). Within recent years, however, manufacturers have sought to vary the appearance of their products so that today a very pleasing appearance is obtainable in metal-shingle roofs either through design of the individual shingles or by proper painting (figs. 19 and 21).

Flashing, valley, ridge, and eaves details have been well standardized and difficulties in application reduced to a minimum largely through the availability of these accessories in prefabricated forms.

7. Units of Roof Measurement

The slope, or pitch, of a roof determines the speed with which water or wet snow drains from its surface and therefore governs the selection of type of metal roofing best adapted to any particular building. There are three methods in general use for expressing the pitch or slope of a roof:

In terms of vertical rise in inches to each foot of horizontal run.

Ratio of total rise of the roof to its total span. (This is obtained by dividing the rise of a rafter to twice its horizontal run and is generally expressed as a fraction.)

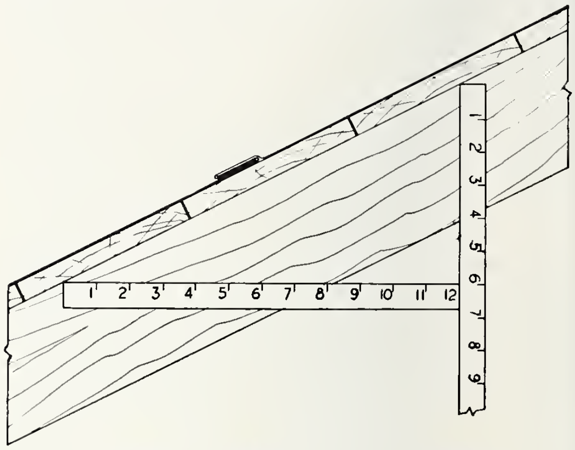


Figure 8.—*Measurement of roof pitch.*

The angle, in degrees, between the roof surface and the horizontal.

The first method, inches of rise per foot of horizontal run, is probably used more than the other two. All expressions of pitch in this publication are based on this method. Table 2 gives a comparison of values obtained by these three methods.

Table 2.—*Comparative measurements of roof slope*

Pitch		Angle with horizontal	
Method 1	Method 2[a]		
in./ft		*Degrees*	*Minutes*
½	1/48	2	23
1	1/24	4	46
2	1/12	9	28
4	1/6	18	26
6	¼	26	34
8	⅓	33	42
12	½	45	------
18	¾	56	19

[a] Fraction denotes ratio of total rise of the roof to its total span.

The pitch of a roof can readily be obtained by placing one end of a 1-ft rule on the roof and, while holding it level, measuring the vertical distance in inches at the other end, figure 8. This will designate the slope; for example, 1 in./ft will indicate a very slight slope, 6 in./ft a medium slope, 18 in./ft a steep slope.

The unit of measurement of roof area is the "square," or 100 ft^2. Estimation of quantities required and their price are generally based on this unit. Because of the lapping of metal-roofing sheets at joints, and the use of extra material at gables, ridges, and for the construction of various types of seams, the area of metal necessary for a square of roofing is actually greater than 100 ft^2.

V. GALVANIZED SHEET STEEL

1. General

Galvanized sheets are made by passing clean steel sheets through a bath of molten zinc. By this treatment the sheet is covered on each side with an adherent layer of zinc, the thickness of which may be varied to meet different service requirements. The desirable properties of a zinc coating for protecting iron or steel roofing sheets against atmospheric corrosion have been amply demonstrated in the past. For a high degree of protection or long life of the material, a relatively thick coating (2 oz of zinc per square foot of sheet, i. e., 1 oz/ft^2 on each side of the sheet) is desirable, but if very severe bending or forming operations are carried out in fabrication, a thinner zinc coating is preferable.

Both the American Society for Testing Materials in its specification for Zinc-Coated (Galvanized) Iron or Steel Sheets (designated as A 93–27) and Federal Specification QQ–I–696 covering the same subject classify galvanized sheets as follows:

Class *A*.—Extra heavily coated. Intended only for corrugating.

Class *B*.—Heavily coated. Intended for corrugating and curving to large radii.

Class *C*.—Moderately heavily coated. Intended for moderate bending.

Class *D*.—Ordinary coating, for general utility. These coatings approximate those of Class *C*, except in medium gages in which coatings of class *D* are appreciably lighter. Class *D* represents material generally available in warehouse stocks, not intended for use where relatively long life is required, as represented by classes *A*, *B*, and *C*, or where severe forming is encountered, as represented by class *E*.

Class *E*.—Lightly coated with tightly adherent coatings to reduce liability of flaking of the coating during severe forming.

Some variation in the thickness of coating on different parts of a galvanized sheet is unavoidable. Galvanized sheets, however, should be free from such defects as laminations, blisters, slivers, open seams, pits from heavy rolled-in scale, ragged edges, holes, turned-down corners, etc. They should also be free from bare or imperfectly coated spots, serious abrasions, drops of zinc except on ends, sal ammoniac (flux) spots, or similar defects affecting their general appearance or serviceability. The gages of this type of material, weights per square foot, and nominal weights of zinc coating are shown in table 3.

Table 3.—*Weight of galvanized sheets*

Galvanized sheet gage [1]	Approximate weight per square foot	Desired or ordered weight of zinc coating [2] (oz/ft^2 of sheet)		
		Class *A*	Class *B*	Class *C*
No.	*Oz.*			
16	42.5	2.75	2.50	2.00
18	34.5	2.75	2.50	1.75
20	26.5	2.75	2.50	1.75
22	22.5	2.75	2.50	1.75
24	18.5	----	2.50	1.50
26	14.5	----	2.25	1.25
28	12.5	----	1.75	1.25
29	11.5	----	1.50	1.25
30	10.5	----	1.25	1.25

[1] The galvanized sheet gage is based upon the United States Standard Gage for sheet and plate iron and steel; 2.5 oz/ft^2 being added to the weight per square foot corresponding to a given gage number of the U. S. Standard Gage to determine the weight per square foot of the corresponding gage number of the galvanized sheet gage. This is a weight gage for finished sheet regardless of the weight of coating and has been established by custom in the United States.

[2] No coatings are specified for class *D* and *E* sheets.

There is often marked variation in the "spangle," or crystal, structure of the zinc coatings on sheets produced by different manufacturers. This variation, however, has little effect on corrosion resistance. Occasionally, galvanized sheets take on a white film ("white rust") as a result of either being stored in piles in a damp place or in locations where condensation may occur. This often merely affects the surface appearance, but in serious cases has a detrimental effect on the corrosion resistance of the sheets, so that care should be exercised in the storage of sheets to avoid this condition.

Further details regarding galvanized sheets are given in Federal Specification QQ–I–696 [5].

2. Types of Galvanized Steel Roofing

The types of galvanized steel roofing in general use are V-crimp, corrugated, pressed standing-seam, roll roofing, and shingles.

(a) V-Crimp Roofing

V-crimp roofing consists of a flat sheet with formed ridges parallel with the longitudinal dimension of the sheet. In cross section, these ridges, or crimps, appear like the letter V inverted (fig. 9). Sheets having one crimp at each side edge are known as 2 V-crimp. If,

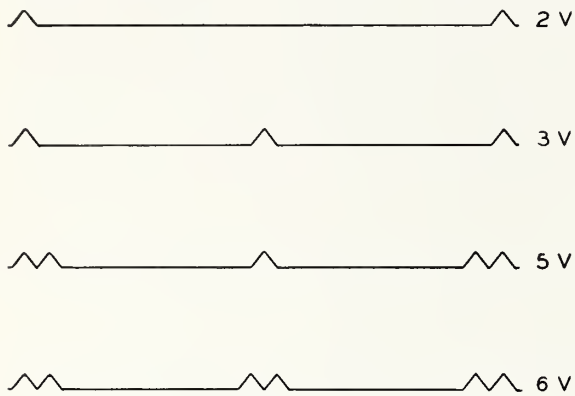


Figure 9.—*Four types of V-crimp roofing.*

in addition, the sheet has another longitudinal crimp in the center to provide greater stiffness, it is called 3 V-crimp. A common type of sheet, 5 V-crimp, has two ridges, or crimps, at each side edge and one in the center. These additional crimps provide still greater stiffness and offer further protection against seepage and blowing of rain and snow through the joint. Six V-crimp sheets, which are similar to the 5 V-crimp sheets, except that each sheet has a double center crimp for additional support, are also available.

V-crimp sheet roofing should not be used on roofs with a pitch less than 2½ in./ft, and preferably only on roofs having a slope greater than that.

Most V-crimp roofings are so made that a width of 24 in. is exposed to the weather. They are stocked in a variety of lengths, those commonly used being 5, 6, 7, 8, 9, 10, and 12 ft. Wood strips of triangular cross section under the side crimps are necessary to provide a solid joint for nailing. These strips, usually furnished by the manufacturer, also serve to stiffen and brace the sheet.

The heads of the nails that secure the ordinary forms of V-crimp roofing are exposed to the weather and should therefore be selected with care as previously explained, inasmuch as the life of a metallic roof is no greater than that of the fasteners.

Figure 23 shows the appearance of a finished roof of V-crimp materials.

(b) Corrugated Sheets

Corrugated galvanized roofing is widely used on farm and industrial buildings, but its use on residences is limited.

It is the lowest in cost of all types of metal roofing, is easily and quickly laid with a minimum of skill, and, when properly applied and maintained, will give long service.

The sheets are applied in various ways. They are laid over close decks with or without sheathing paper or asbestos paper, on open slat decks, or on purlins (wood or steel). The sheets are lapped about 6 in. at the ends and are of such lengths as to stagger the end laps in adjacent rows. This both improves the appearance of the roof and aids in holding the sheets more securely. In laying, the sheets are always started along the drip eaves at the end of the building opposite the direction of

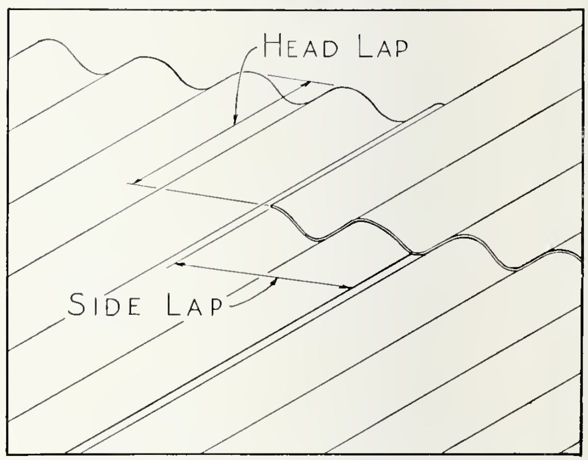


Figure 10.—*Methods of side- and end-lapping.*

prevailing winds, so that the wind and rain will blow over the laps and not under them. Figure 10 shows side and end lapping.

The nails used with corrugated sheets are generally exposed to the weather and, therefore, should be as durable as possible. They should be heavily zinc coated and lead washers should be used with nails not having lead heads.

Galvanized steel sheets, 5 to 12 ft. long, with either 1¼- or 2½-in. corrugations are available for roofing. Standard 2½-in. corrugated sheets come in 27½- and 26-in. widths, covering 24 in. when lapped 1½ and 1 corrugations, respectively. The 26-in. width is used for siding purposes and is not recommended for roofing as the lap is insufficient to prevent leakage. The 1¼-in. corrugated sheets are 26 in. wide and cover 24 in. when lapped 1½ corrugations.

(c) *Pressed Standing-Seam Roofing*

Pressed standing-seam roofing is somewhat similar to the 2 V-crimp type, except that the seam, in section, resembles an inverted U rather

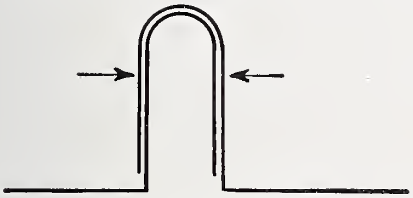


FIGURE 11.—*Joint of pressed standing-seam roofing.* Arrows indicate direction of squeezing with tongs.

than an inverted V. In general, the seam is slightly higher than that of a V-crimp sheet. This renders additional protection against the seepage of water into the joint.

In laying this type of roofing, the sheets are secured to the roof deck and to adjoining sheets by means of side and end cleats. The cleats are strips of galvanized sheet fastened at one end to the deck with 1-in. galvanized barbed nails; the other end is fitted into the seamed joint, as illustrated in figure 11. The end lock, or cross seam, is made by the use of flanging tongs, and the vertical standing seam is made tight against the cleats with squeezing tongs. These special tools are necessary, and careful workmanship is required to insure a satisfactory job. Side cleats are spaced every 12 to 14 in. The only nails that are driven through the sheets are those at the eave and gable drip edges. The horizontal, or cross, joints are also cleated. This method of assembling permits removal of the sheets from the roof and reapplication elsewhere with the loss of only the cleats and drip edges.

(d) *Rolled Roofing*

Rolled roofing consists of several galvanized sheets assembled in a continuous length by having their ends locked together at the factory by double cross-seam locks. The long sheet thus formed is put in rolls, usually 50 ft long and 26½ in. wide, and covers an area of 100 ft^2 (roofing square) when laid.

The rolls, cut to proper length, extend from eaves to ridge. With a flanging tool one edge of the sheet is turned up at right angles to form a flange 1½ in. high. The other edge is given a flange 1 in. high. All sheets are flanged alike and laid on the roof side by side so that the taller flange is next to the shorter one of the adjacent sheet. Galvanized metal cleats are inserted between flanges every 12 to 14 in. and nailed to the deck. The taller flange is then bent through 180° over the shorter one and forms a single-lock standing seam. This type of roofing is known as self-capping roll roofing.

If the seam is again folded over on itself the type is known as double standing-seam roll roofing. In this respect it resembles the standing-seam roofing previously described. This double-seaming operation necessitates the bending of two thicknesses of metal again within the short distance of ½ in. and requires the use of a double-seamer tool. For most satisfactory results skilled workmanship is required.

Metal caps consisting of narrow strips of galvanized-steel sheet, approximately 26 in. in length and U-shape in section, are furnished by various manufacturers. After the vertical flanges of adjacent sheets of the roll roofing are placed in position, and the cleats have been inserted and nailed, the metal caps are placed over the joint and the seam closed with tongs. This type of roofing is known as roll and cap roofing.

(e) *Shingles*

Individual shingles are stamped from galvanized sheet iron or steel and applied to a roof in a manner somewhat similar to that for other types of shingles With the exception of cluster shingles, they are made 8 to 10 in. wide and 12 to 15 in. long. They are fastened to the deck by nailing along one side or side and top. Most types of these shingles have interlocking side locks and are lapped slightly at the top. They should not be used on low-pitched roofs because of the small lap at the top of the shingle which allows water to pass through. The shingles may have various embossed designs on their surface; they may be relatively smooth and painted to simulate wood or slate shingles; or their surface may be curved to resemble Spanish Mission tile (fig. 22).

Cluster shingles are similar to individual ones, excepting that they measure 20 by 28 in. or larger, and that the designs embossed on the surface are made to simulate a number of individual shingle units. These large shingles are applied easily and quickly, but are not widely used at present for roofing of houses.

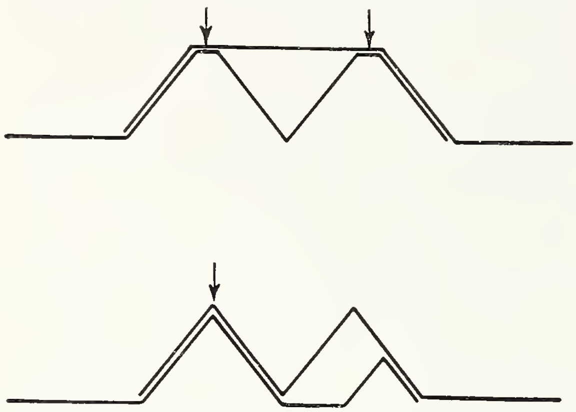


Figure 12.—*Details of two nonsiphoning features on V-crimp roofing.*

Arrows indicate approximate direction of nailing.

Galvanized shingles should be painted periodically to increase their attractiveness and, if so maintained will present a pleasing appearing roof for years.

(*f*) *Patented Features*

Many types of galvanized sheet roofings marketed at the present time have special features of construction and installation which, it is claimed, will greatly increase the durability and efficiency of the finished roof. However, the relative merits of such features and their desirability on galvanized sheet roofings are not discussed here, only a general description being given of the prevailing types without reference to either specific details or to manufacturers.

Rib stiffeners.—Transverse V-crimps on the roofing metal across the bottom of the sheet or shingle are advocated for eliminating leaks in the end laps of sheets. The claim is made that they decrease capillary attraction of water through the joint. Without doubt, they do increase the transverse stiffness of the sheet.

Pressure lip.—A slight depression of the sheet is sometimes used at the lower end, near the cross crimp, to insure good contact between overlapping sheets at end laps.

Nonsiphoning features.—Various types of crimps in the side of the V-crimp joint are used to prevent the passage of water through the joint. They tend to form a break in any siphoning action across the joint. Figure 12 illustrates two common types.

Tension curves.—Sheets are sometimes slightly curved transversely in order to make them cling closely to roof decking when nailed.

Interlocking devices.—Various methods are used for interlocking the adjacent edges of shingles, corrugated sheets, and V-crimp sheets. They tend to reduce leaks caused by siphoning, because air is permitted to circulate in nearly all of these types of joints. Nails and nail holes are covered, thus they are protected against the weather.

Stickless V-crimp roofing.—Instead of the conventional V-shaped crimp, crimps of special shape are formed to increase the rigidity of the sheet at the joint and to eliminate the use of underlying supporting wooden strips. The special form of the crimp tends to prevent flattening when the sheets are being nailed to the roof deck.

Ridge, flashing, gable, and eaves details.—Care with respect to these details is reflected in the durability and appearance of the finished roof. These items can be formed by hand of galvanized sheet and assembled in place, but this requires skillful workmanship and special tools. Manufacturers of galvanized metallic roofing supply these accessories in prefabricated forms ready for installation with the various types of roofing. This greatly simplifies the installation and assures a satisfactory job

3. Durability of Galvanized Ferrous Sheets

In the attempt to evaluate zinc coatings of different commercial thicknesses under various conditions of outdoor exposure, the American Society for Testing Materials started an investigation in 1926 on the outdoor weathering of zinc-coated (hot-dip galvanized) iron and steel sheets. The results have been reported from time to time in the proceedings of that society. A summary of these follows:

(*a*) *Details of American Society for Testing Materials Tests*

The basis metals were 16- and 22-gage sheets made from steels and irons with and without added copper. The sheets, coated by the hot-dip galvanized process, carried coatings of 2.5, 2.0, 1.5, 1.25, and 0.75 oz. of zinc per square foot of sheet. After galvanizing the sheets, they were corrugated and cut into 26- by 30-in. specimens, and these were exposed on racks at the different test sites. These locations were Brunot Island in the Ohio River below Pittsburgh, and Altoona, Pa., both typifying severely corrosive industrial atmospheres; Sandy Hook, N. J. (foggy, seacoast atmosphere, possibly with some industrial contamination); Key West, Fla. (tropical seacoast atmosphere); and State College, Pa. (rural atmosphere). Inspections have been made at least twice a year, and a coating was considered to have failed when the basis metal itself rusted at one or more spots of specified size.

(*b*) *Results of American Society for Testing Materials Tests*

The results that have been published to date are plotted in figures 13 and 14. Inspections of the sheets after the coating has been removed by corrosion are being continued to determine the time of perforation. Hence, any conclusions now as to the complete life of the galvanized sheets at the different locations must be based on the assumption that the total life of a galvanized sheet consists of the life of the coating plus the life of the basis sheet metal. The data that are being obtained would indicate that the life of galvanized sheets is somewhat more than this, although a definite statement on this point based on the results of the test cannot be made at this time.

Table 4 lists the time in years for perforation of 22-gage uncoated black sheets exposed at the various test locations along with the galvanized sheets.

TABLE 4.—*Time, in years, for perforation by rusting of 22-gage black sheets exposed continuously to the weather*

[Average of results obtained on open-hearth iron and steel]

Type of material	Brunot Island, Pittsburgh, Pa.	Altoona, Pa.	Key West, Fla.	Sandy Hook, N. J.	State College, Pa.
Without copper	2.2	3.2	3.1	4.4	(a)
With copper	9.0	8.5	4.4	8.4	(a)

[a] No perforation after 11½ years' exposure.

The curves of figure 15 show the manner in which the rust spreads over the surface of the

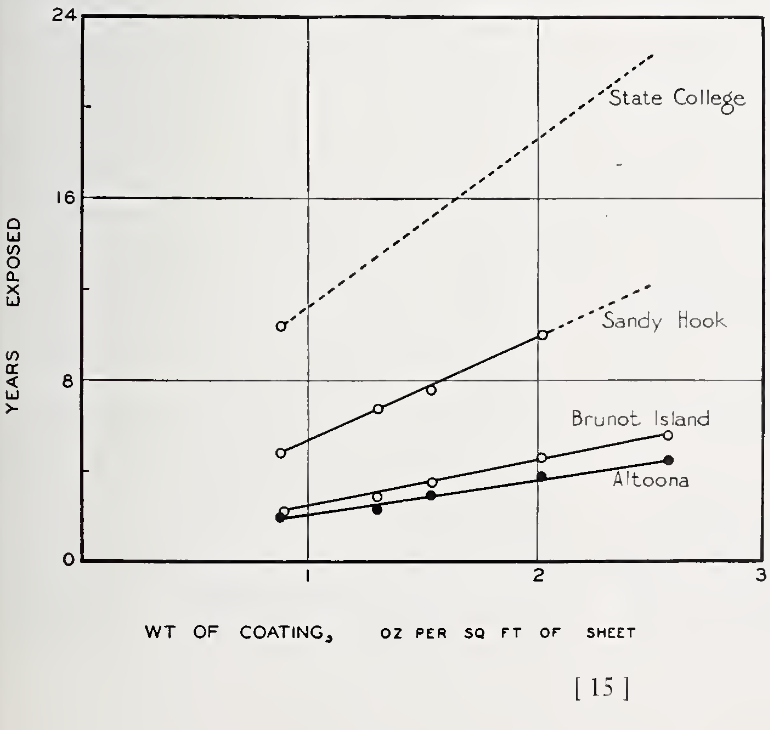
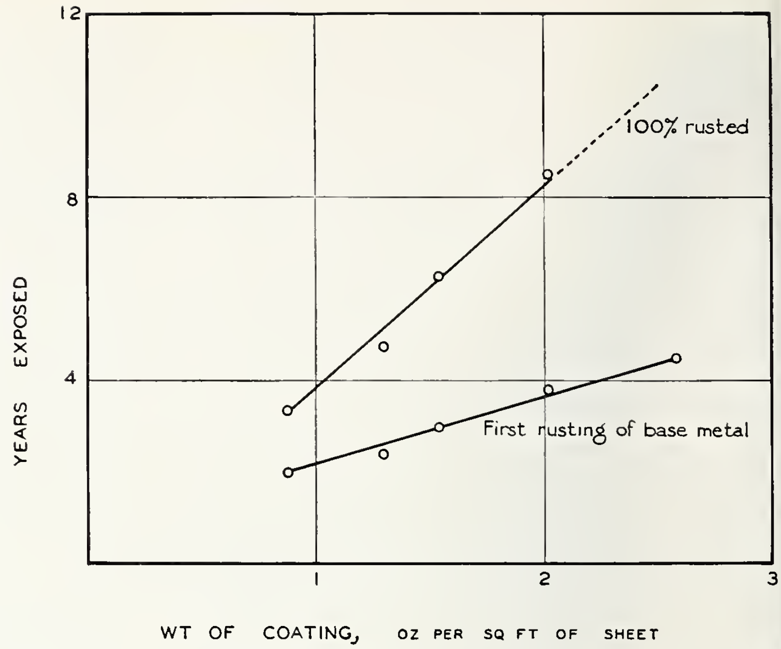


FIGURE 13.—*Relationship between weight of zinc coating and time at which rust first appears on surface of galvanized sheets exposed by the American Society for Testing Materials at four locations.*

Dotted lines indicate probable course of the curves.

FIGURE 14.—*Manner in which rusting proceeds on galvanized sheets exposed by the American Society for Testing Materials at Altoona, Pa. (heavy industrial atmosphere).*



¾-oz sheets at three locations. In general, all curves which show the development of rust over the surface of the galvanized sheets are S-shaped. The rusted area increases relatively

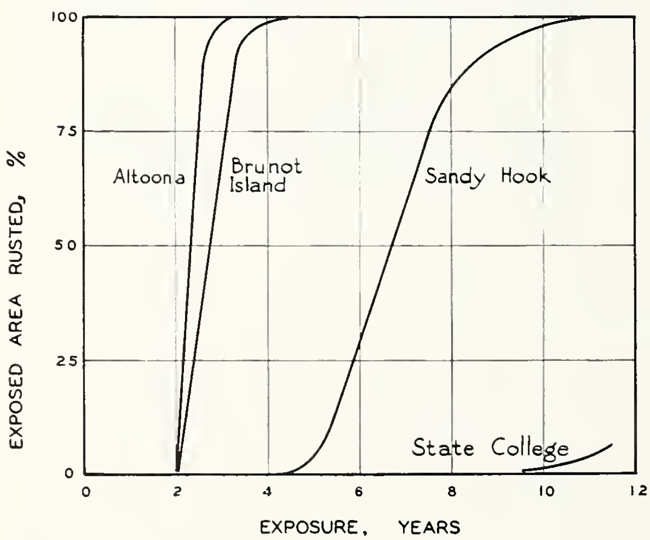


FIGURE 15.—*Development of rust on surface of ¾-oz. galvanized sheets exposed by the American Society for Testing Materials at four locations.*

slow at the start and the last traces of zinc are slow to disappear. The rate at which zinc disappears from the surface of the sheet depends upon the corrosive conditions existing at the particular location where the sheets are exposed. Thus the industrial atmospheres were found to be very destructive to all weights of zinc coatings in comparison to the rural atmospheres, which can be considered very mildly corrosive to galvanized sheets.

The information summarized in the curves of figure 13 is of value in drawing conclusions as to the relative durability of various weights of zinc coatings on galvanized sheets when exposed to different types of atmospheres and emphasizes the importance of relatively thicker zinc coatings. The first appearance of rust or complete coverage of the sheet with rust, is closely proportional to the weight (thickness) of the zinc coating. For roofing sheets, one should endeavor to obtain the heaviest zinc coating that is compatible with manufacturing operations. Consideration should also be given to the use of a heavier gage sheet in preference to a lighter one in that both additional life and greater rigidity of the roof will result.

The life of galvanized material can be lengthened by painting the sheets. Unless they are treated by one of the several pretreatment methods [6] now available commercially, it is considered good practice to allow the material to weather before the first paint coating is applied. This period of natural weathering may vary from 1 or 2 months for lightweight coatings exposed to industrial atmospheres to several years for the heavier coatings in rural atmospheres. In any event, this period should be less than that indicated on the curves of figure 13, when first rusting of the basis metal occurs.

In applying the data assembled here to the durability of galvanized roofing sheets, it should be borne in mind that the American Society for Testing Materials tests cover only isolated corrugated sheets and furnish no data concerning the relative life of the metal at laps, locks, fasteners, and covered places such as occur in all roofs. It is quite possible that the life at these locations may be less than on the central portions of the sheet [7]. Galvanized sheets are also subject to deterioration if condensation occurs in storage, and some cases of premature failure of galvanized roofs may be attributed to the fact that the zinc coating was damaged prior to erection on the roof.

VI. TERNE ROOFING

1. General

The so-called "tin-roofing" is actually terne roofing, and consists of an iron or steel sheet coated on both sides with a layer of a lead-tin alloy (usually 75 percent of lead and 25 percent of tin). Roofing ternes are used for roofing, flashing, valleys, and gutters. Tin plate, or "bright tin", sheets consist of iron or steel sheets coated with tin only. Although sheets of this kind may have been used to a limited extent for roofing in the past, their importance for other uses is more prevalent today. Their cost is greater than terne sheets. Many believe that tin roofing consists of sheets of pure tin. This, of course, is not the case as the employment of sheet tin for roofing would be exceedingly expensive, and such sheets would have insufficient rigidity for that purpose.

Terneplate is made by coating annealed and pickled iron or steel sheets in a bath of molten lead-tin alloy in a manner closely analogous to that used in producing galvanized sheets. A sheet covered on both sides with a reasonably uniform coating of the alloy is thus produced.

Terneplate is usually furnished in grades *IC* (approximately No. 30 U. S. Gage) and *IX* (approximately No. 28 U. S. Gage). The *IC* grade weighs approximately 65 lb/100 ft^2 (roofing square) when laid on a roof. The *IX* grade is approximately 25 percent heavier. The *IC* grade of sheets is used for flat-seam, standing-seam, and batten-seam types of construction, as it is more easily formed than the *IX* sheets. In the lighter sheets, expansion is taken up by buckling instead of by the breaking the seams. The *IX* sheets are used principally for flashings, valleys, and box gutters.

Sheets are generally available [8, 9] in two commercial sizes, 14 by 20 in. and 20 by 28 in. The larger sheets are commonly used in standing-seam construction on roof slopes of more than 3 in./ft, and the smaller ones are used in flat-seam construction on roof slopes of 3 to ½ in./ft. 100-ft^2 rolls are also available, consisting of 28 sheets, 20 by 28 in., in widths of either 20 or 28 in. The sheets in these rolls are cross-locked and all seams soldered. Valley terne is available in rolls of 50 and 100 lineal feet in widths of 10, 14, 20, and 28 in.; all sheets are cross-locked and the seams soldered.

Table 5 gives the weight of the uncoated sheet for the *IC* and *IX* terne in ounces per square foot or pounds per "base box," and the corresponding weights of the coated sheets for coating weights varying from 8 to 40 lb per box. Standard roofing practice calls for the use of terne sheets with a minimum coating of 25 lb. A "base box" of terneplate consists of 112 sheets, 20 by 28 in., which is the equivalent of 435.56 ft^2 of sheet.

Roofing terne sheets should be laid over a well-prepared close-sheathed deck. The sheathing boards should be smooth and free from blemishes or defects. Especially should they be free from sharp projections, such as nails, that might cause perforation of the sheets.

The use of rosin-sized building paper weighing at least 6 lb per square and laid with 2-in. lapped joints is recommended. Asphalt-saturated felt is used also, but tar papers or papers containing traces of acid should not be used. The sheathing paper makes a resilient base for the terne sheets and tends to deaden the noise of rain and wind on the roof.

Roofing ternes are regularly supplied with one surface painted. This is to be used on the under side when installed on a roof. They are supplied frequently with both sides primed with paint, which eliminates the initial paint-

Table 5.—*Data for commercial terneplate*

Trade symbol		Weight of sheets after pickling		Weight of coating, in pounds per box											
				8		15		20		25		30		40	
				Weight of coating,[1] in ounces per square foot of sheet											
				0.2939		0.5510		0.7347		0.9184		1.020		1.4694	
				Weight of finished sheets											
		oz/ft²	lb/box	oz/ft²	lb/box	oz/ft²	lb/box	oz/ft²	lb/box	oz/ft²	lb/box	oz/ft²	lb/box	oz/ft²	lb/box
IC	Minimum	7. 00	191	7. 29	199	7. 55	206	7. 73	211	7. 92	216	8. 10	221	8. 47	231
	Nominal	8. 00	218	8. 29	226	8. 55	233	8. 73	238	8. 92	243	9. 10	248	9. 47	258
	Maximum	9. 00	245	9. 29	253	9. 55	260	9. 73	265	9. 92	270	10. 10	275	10. 47	285
IX	Minimum	9. 00	245	9. 29	253	9. 55	260	9. 73	265	9. 92	270	10. 10	275	10. 47	285
	Nominal	10. 00	272	10. 29	280	10. 55	287	10. 73	292	10. 92	297	11. 10	302	11. 47	312
	Maximum	11. 00	299	11. 29	307	11. 55	314	11. 73	319	11. 92	324	12. 10	329	12. 47	339

[1] Total for both sides.

ing on the exposed surface though one or more coats of good metallic paint should be given the roof immediately after installation.

2. Types of Terne Roofings

Terne roofs are usually of three types, flat-seam, standing-seam, and batten, or combination-rib.

(*a*) *Flat-Seam Roofs*

Roofs of low pitch generally are made with 14- by 20-in. sheets assembled into rolled lengths by means of soldered flat-lock seams. The smaller-sized sheets are used in preference to the larger, because the greater number of seams stiffens the surface and helps to prevent buckling. The sheets are laid and the seams constructed in a manner similar to that described under the general section on flat-seam roofing. The roof is fastened to the deck by cleats, spaced about 6 in. and held down by two 1-in. barbed and tinned roofing nails, as shown in figure 7. Sometimes cleats are dispensed with. In such cases nails are driven through the sheet under the edges of the seam, so as to be entirely covered by the sheet. The roof can be laid by locking individual sheets together, inserting two cleats on the long side and one on the short side, and soldering. Frequently, prior to installation, the sheets are assembled into long lengths by locking and soldering the short edges together. When this is done, cleats are inserted at the long edges only, and the seams of adjacent lengths locked and soldered.

(*b*) *Standing-Seam Roofs*

Terne roofs of standing-seam type are constructed in the manner described in the general section on standing-seam roofing. Standing seams are finished approximately 1 in. high from sheets 20 by 28 in., which generally are assembled into long lengths by cross-locking and soldering prior to installation on the roof. Cleats are inserted in the standing seam and made a part of it at intervals of 8 to 12 in. Figures 24 and 25 illustrate the appearance of a finished roof of this type.

(*c*) *Batten- and Combination-Type Roofs*

The full batten type of terne roofing is constructed in the manner described in the general section on batten-seam roofing. One recommended practice calls for the use of square wooden battens with application of the sheets between them. Cleats, approximately 1 ft apart, are nailed to the top of the batten and engage the two top seams alternately. Combination types of batten and standing-seam or batten- and flat-seam construction are sometimes utilized. In both cases the sheet extends in a continuous width over the battens and adjacent sheets are joined between battens by means of standing or flat seams. These seams are parallel to the battens.

Roofing ternes have been used for roof coverings for a great many years. Well-coated sheets that are given periodical protection by painting should render long service. In the

United States, old roofs of this type may be found that have protected homes for periods up to a hundred years or more and are still in good condition.

VII. MAINTENANCE OF TERNE AND GALVANIZED ROOFS

1. Galvanized Roofs

Galvanized roofs, unless pretreated [10], should not be painted for several months after installation. Weathering by roughening a galvanized surface greatly improves the adherence of paint applied thereon. Even when precautions have been taken to prepare the surface, paint scaling and peeling on galvanized surfaces may occur. National Bureau of Standards Letter Circular LC422 [11] gives directions for painting various metallic surfaces. The need for painting galvanized roofing should be strongly emphasized. Methods for pretreating the surface of galvanized-steel sheets before painting, which greatly improve the paint adherence, have recently been developed and their use is gradually increasing. Pretreated sheets are also available commercially.

2. Terne Roofs

Terne sheets are regularly supplied with one or both sides painted. If only one side is painted, that surface is used for the under side of the roof. The top, or exposed, surface should be painted immediately after the roof is completed. It is a mistake to let the material weather for a few months prior to application of the first coat of paint. All rosin and foreign material should be removed from the sheets, and the oil film removed by wiping with benzene, turpentine, or benzol. It is essential that the surface be free from moisture when applying the paint, particularly the priming coat. The priming coat should be thin enough to wet all parts of the surface and to fill joints or depressions, with no bridging over. It should contain inhibitive pigments and should cover the metal completely. After the first coat has dried, the finishing paint should be applied in one or more coats as desired. Each coat should be allowed to dry thoroughly before the next is applied. It is important to avoid building up paint films to an excessive thickness because of the trouble which may result from scaling.

Periodic inspections should be made at intervals of 10 to 12 months to determine the condition of the paint coating. Breaks or failures should be repainted immediately. The frequency of repainting will depend upon the characteristics of the top coat, characteristics of the roof, and climatic conditions. As stated above, a terne roof properly maintained will give good service.

VIII. COPPER ROOFING

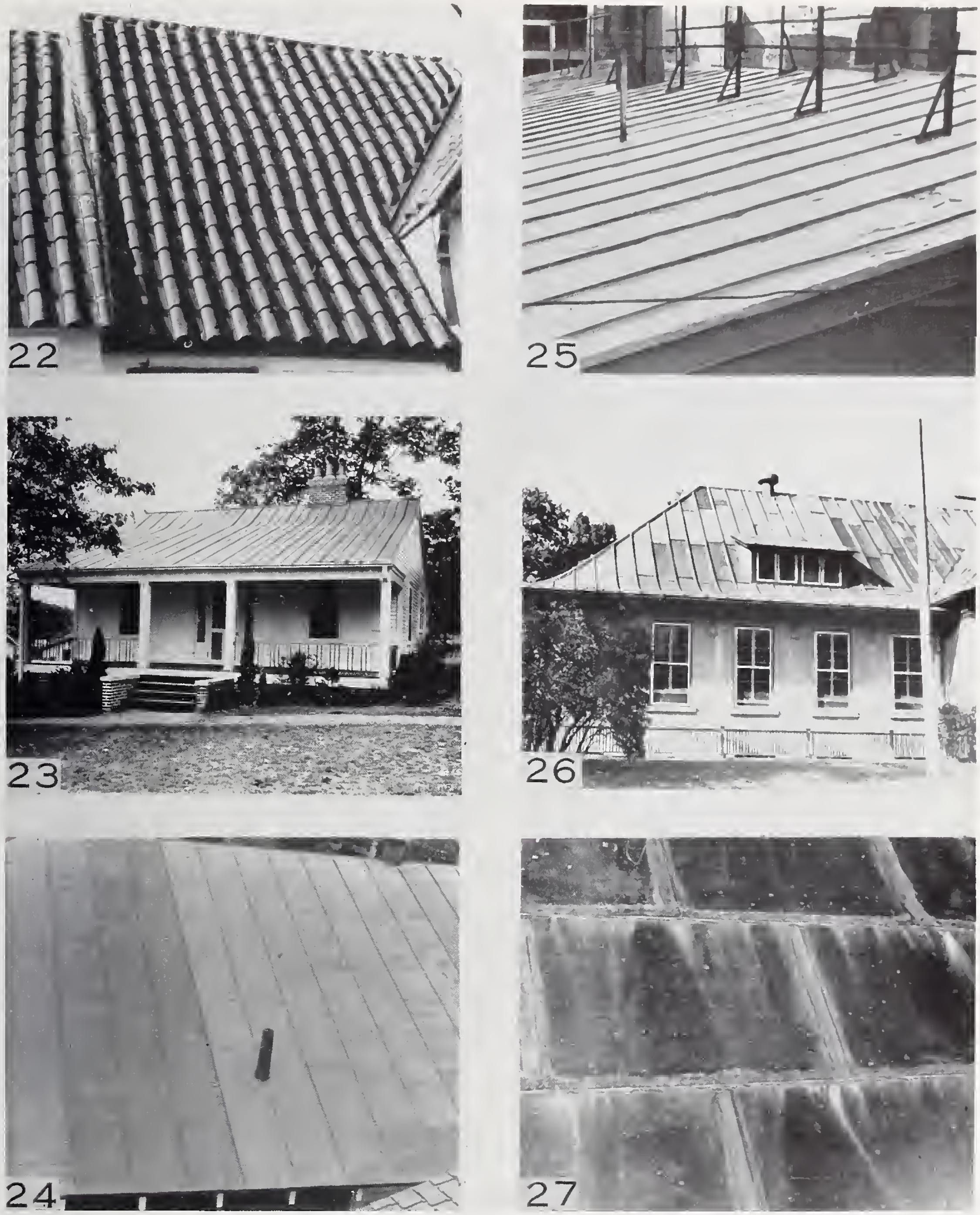
1. General

From the standpoint of service, copper is one of the oldest of the metals used for roofing. In general, it is one of the least chemically active of the ordinary metals commercially used for this purpose. When copper roofing is exposed to the atmosphere, a green coating known as patina develops after a few years, which aids in protecting the metal. Copper is easily worked and soldered; these qualities, combined with its durability, lightness in weight, ease of handling, and beauty, make it an excellent metal for roofing. The cost of material and installation of 16-oz copper, which hitherto has been used generally for roofing, is rather high compared with other materials, and this factor has limited its use. Numerous important buildings and large residences in the United States have copper roofs many years old (fig. 18), and other examples which have lasted for centuries can be found in Europe. Its use on the smaller-type residences in this country, however, has been negligible mainly because of the high initial cost of installation.

Roofing sheet copper is now commercially available in a variety of weights and gages up to a thickness of 0.25 in. [12]. The gage of sheet copper is defined by the weight in ounces per square foot of sheet; 16-oz copper means copper weighing 16 oz/ft^2. Copper of this weight is approximately 0.0216 in. thick. Sheet copper is made in varying degrees of temper, or hardness, with two types used for building construction. These are known as soft and hard, or cold-rolled. Soft copper is also known as roofing temper, inasmuch as it is used for all roofing, flashing, counter-flashing work, and shaped or formed work where it is

FIGURES 16 TO 21.—*Metal roofs.*

Figure 16, standing-seam sheet-copper roof; figure 17, lightweight sheet-copper roof; figure 18, heavyweight sheet-copper roof on Christ Church, Philadelphia, Pa., applied in 1749; figure 19, copper shingles; figure 20, painted galvanized metal shingles (old type); figure 21, painted galvanized metal shingles (new type).



FIGURES 22 TO 27.—*Metal roofs.*

Figure 22, painted galvanized shingle tile laid to resemble old European tile; figure 23, V-crimp roofing; figure 24, standing-seam terne roof; figure 25, old standing-seam terne roof approximately 80 years old; figure 26, zinc batten roofing; figure 27, flat-seam roofing on low-pitched deck (picture taken at an angle).

supported, such as built-in gutter linings. The hard copper is known as cornice temper and is used wherever strength and rigidity are required to support hanging gutters, eaves troughs, downspouts, cornices, etc.

The expansion of copper is considerably greater than that of iron of steel and suitable precautions must be taken in installing a copper roof. Normally, the vertical seams, particularly the standing or batten seams, provide adequately for temperature movement. Loose-lock seams are also utilized in many instances and they permit expansion. On flat decks where small sheets are locked and soldered together and held to the roof by means of cleats, a slight bulging of the sheets will take care of some movement of the sheets. However, large areas should be provided with expansion joints. The fact that contraction and expansion of the sheet occurs in all directions should be borne in mind in installing these joints. Premature failure has resulted on some copper roofs because expansion joints were installed in one direction only on the flat sections. Some roofing contractors break flat-seam sections into areas approximately 10 feet square, with expansion joints at right angles to each other.

2. Types

(a) *With Standard-Weight Sheets*

In the past it has been the usual practice to install copper roofs with a minimum weight of 16 oz and to use heavier sheets for cornices, ventilators, etc. Thus the 16-oz grade had become more or less standard for roofing purposes. It is installed in the following types: batten, or ribbed-seam, standing-seam, flat-seam, corrugated roofing, shingles, and tiles. These are installed in accordance with the general types of roofing already described.

(b) *With Lightweight Sheets*

Several new types of copper roofs weighing less than the conventional 16-oz type have been introduced in this country within the last decade, but service experience with them is limited. They range from 10 oz to the lighter weights. The cost of these new grades is considerably less than the 16-oz type, and they are finding an application for residential roofings.

Ten-ounce roofing copper is applied as the standing-seam type on slopes with a minimum pitch of 3 in./ft in warm climates and 6 in./ft in sections of the country having considerable snow. Soldering is not recommended. Sheets 16 in. wide and 6 ft long are either formed into pans on the roof or locked with cross seams in the shop and assembled into rolls. A length extending from ridge to eaves is then cut from the roll and the sides turned up. A standing-seam joint is formed with either adjacent pans or turned-up edges of adjacent unrolled lengths. In the pan method, successive upper pans are locked to each other by means of loose-locked horizontal cross seams. This provides for longitudinal movement of sheets due to temperature changes, and similar movement across the sheet is permitted by the standing seam, which should have a base spacing of at least $\frac{1}{16}$ in.

A roofing square of this 10-oz type of copper sheet weighs approximately 80 lb. Figure 16 illustrates a finished roof of this type.

Long strips of 3-oz weight (approximately 0.004 in. thick), cold rolled, copper sheet with either asphalt-saturated felt or thick paper cemented to one surface (under side) are first attached to the roof at the edges of, and parallel with, the eaves. Additional strips are then applied until the roof is completely covered; adjacent courses being joined by either double-locking (flat) or single-locking with continuous metal clamps. The insertion of short pieces of wooden lath or crimping of the metal across the width of the sheet is to provide for expansion and contraction and to produce a shingle-like effect on the finished roof.

A square of this type of roofing weighs approximately 60 lb fully installed.

Figure 17 illustrates one of the 3-oz copper roofs installed on a small house.

Copper sheet (3-oz weight), cemented with asphalt-saturated felt on the under side, is also applied in corrugated form as strip shingles somewhat similar to asphalt strip shingles.

IX. SUMMARY

Many metals have satisfactory properties which make them ideal materials for roof coverings. Several metals which are suitable for roofing and whose cost is compatible with other materials used in low-cost housing construction are discussed in detail in this publication.

The following general properties of metals make them easily adaptable and advantageous for roof coverings: long durability; ease of application (of some types); good fire-resistance; good lightning protection when properly grounded; mechanical strength and rigidity; lightness in weight: and minimum effect upon their durability by extremes of temperature.

The disadvantages are the problem of adequate provision for expansion and contraction; monotonous appearance of some types; high heat conductivity; requirements for periodic inspections and maintenance; and noise that may result from rain, hail, and wind.

Galvanized ferrous metal probably is used to a greater extent than any of the other roofing metals. Low initial cost and satisfactory service life in not too corrosive an atmosphere and with an average weight of zinc coating, together with those advantageous properties mentioned previously, combine to account for their widespread use on residential, farm, and industrial buildings. Increased interest, in recent years by manufacturers, in producing a product having a pleasing appearance is tending to extend their field in residential roofing.

Roofing ternes cost slightly more than galvanized roofings and render long and satisfactory service when properly maintained by painting. Careful design, choice of type of roof, and care and skill in application will produce a pleasing and durable cover for low-cost houses.

Sheet copper is in a still higher-price bracket, but when carefully applied by skilled workmen and then allowed to weather for a period of years should present an attractive and enduring roof covering for almost any type of house. Little information is available as to the durability of the lightweight sheets over a long period of years.

Other metals have been used for roof coverings but thus far initial cost, limited availability, or the difficulty of application has restricted their widespread use on dwellings in the low-cost field.

The assistance of H. R. Snoke, of the Chemistry Division, and of roofing manufacturers is acknowledged.

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WASHINGTON, November 29, 1939.

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[5] Where prices are given in the list, the publication may be purchased from the Superintendent of Documents, United States Government Printing Office, Washington, D. C. Postage stamps should not be sent.

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