called the *patina*. This greenish film of carbonate of copper acts as a protecting coat to the metal below its surface. Copper has a relatively small coefficient of linear expansion, being 0·0000168 per ° C., compared with 0·0000292 per ° C. of lead. As a roofing material copper is superior, but more costly than lead. Unlike lead it does not creep when laid on steeply pitched or vertical surfaces.

Hot-rolled sheets for general roofing are usually specified of " dead soft temper " (condition and degree of hardness) to allow for the hardening (called " work hardening ") which occurs when the sheets are being laid and worked into position.

SIZES.—Sheets are obtainable in any length up to 12-ft., and 6-in. up to 4-ft. in width. When less than 15-in. wide the pieces are known as *strips*, and are usually cold-rolled ; such are used for valley, etc., gutters. The thickness of copper sheets is specified either of Standard Wire Gauge (S.W.G.) or the weight in ounces per square foot. For most roofs 24 S.W.G.[1] (16-oz. per sq. ft.) is used. This gauge is increased to 23 S.W.G. (19-oz. per sq. ft.) for superior work.

Sheets of copper are purchased by the lb. weight, and the so-called *basis price* is that per lb. for sheets not exceeding 14-sq. ft. in area and not less than 24 S.W.G. The dimensions of sheets of basis price area vary, thus : 7-ft. by 2-ft., 6-ft. by 2-ft. 4-in., 5-ft. 3-in. by 2-ft. 8-in., etc. This cost per lb. is increased if the sheets are over 14-sq. ft. in area or are thinner than 24 S.W.G.

GROUNDWORK.—Copper sheets are laid upon t. and g. or butt-jointed boarding [2] of $\frac{3}{4}$ to 1-in. in thickness. Because of its light weight the size of the timber bearers or spars may be less than those required for lead covering, or, alternatively, the spacing of these timbers may be increased. If used on flat roofs the minimum fall is 1 in 80 ($1\frac{1}{2}$-in. in 10-ft.) and the boarding is preferably laid in the direction of the fall, or diagonally, in order that any warping will not obstruct the flow of water. As already mentioned, copper does not creep, and it is therefore especially suited for steeply pitched roofs, domes, etc. The heads of the nails securing the boarding should be punched below the surface and the boarding planed to a smooth finish. The boarding is then covered with felt (preferably) or one or two layers of building paper (see p. 56, Vol. II) to serve as a cushion and an insulating layer to deaden the sound of falling rain. Copper nails should be used for fixing the felt, as iron nails may set up electrolytic action, resulting in the decomposition of the sheeting.

JOINTS.—Although the expansion and contraction of copper, due to changes of temperature, is relatively small, such must not be entirely ignored. Provision must therefore be made for this movement, especially at the side joints. Drips (see p. 144, Vol. I) are not necessary, except in parapet gutters (see p. 132), and instead the *transverse, end to end* or *cross joints* consist of (*a*) welts. The *side* or *vertical joints* are in the form of (*b*) wood rolls or (*c*) standing seams.

(a) *Welts.*—That most favoured for jointing sheets *end to end* is known as the *double lock cross welt*. Four stages in the development of this joint are shown at A, Fig. 50. In the first stage the edge is turned up about 1-in. as shown. In the second operation a portion of this edge is turned down. An edge of the adjacent sheet is turned up and engaged in the fold of the first sheet (see third stage). In the final stage these edges are folded down to form the welt, which is about $\frac{1}{2}$-in. wide. The sheets are welted together in this manner until the required total length is obtained. Such a linked up sheet is called a *string*. The welting operation is generally completed in the shop. The strings are then in turn placed in position on the roof. It is usual for the welts to be staggered. This avoids awkward thicknesses appearing at the vertical (side) joints. *Single lock cross welts* (similar to that shown at E) are sometimes used for stringing sheets required for steep pitches or vertical surfaces.

(b) *Wood Rolls.*—These are employed at *side joints* on flat roofs, or those slightly pitched, which may be subjected to traffic. Five examples are illustrated in Fig. 50, all of them providing efficient watertight side joints and permitting lateral movement of the sheets.

The *conical roll* shown at B is much favoured. Copper *clips* or *straps* (similar to the lead tacks described on p. 144, Vol. I), $1\frac{1}{2}$ to 2-in. wide, are placed under the rolls at about 3-ft. centres. The rolls, secured by copper or brass screws, are spaced at a distance apart equal to 3-in. less than the width of the copper sheets, *i.e.*, 2-ft. 5-in. for 2-ft. 8-in. wide sheets—the latter being a common width ; this permits of an approximate allowance of 3-in. for each overcloak and 2-in. for every undercloak. The three stages of development are shown at B, a welt being formed on one side, as shown, in the final stage. Alternatively, the clips may be as shown at D, each secured at the undercloak side by two $1\frac{1}{4}$-in. copper flat-headed nails.[1]

The four rolls at C differ from the above in so far as each is covered with a strip of copper called a *capping*. In each case the upturned edges of the sheets are welted to the capping. Copper clips (not shown) are provided at 3-ft. intervals, as described above. The *undercut roll* is a good expansion joint. The *square roll* is commonly applied in Scotland. The *round top roll* and the *ornamental roll* are suited, because of their appearance, for pitched roofs ; the shape of the latter roll is only one of several mouldings.

(c) *Standing Seams or Stand-up Welts.*—These are suitable for *side joints* on steeply pitched roofs or flats which are not likely to be subjected to traffic. It is a good expansion and watertight joint. The sheets are first welted end to end, as described above, the strings are then placed in turn on the roof, and the standing seams formed by means of wide lipped pliers (called *seamers*) or dressers (similar to that shown at A, Fig. 76, Vol. I). The stages of development of this joint are shown at D. Copper clips, $1\frac{1}{2}$ to 2-in. wide, are shaped as indicated in the first stage and fixed in alignment at 1-ft. centres, each clip being secured with two $1\frac{1}{4}$-in. copper flat-headed nails. The edge of the first sheet is turned up $1\frac{1}{2}$-in., that of the second strip is turned up $1\frac{1}{4}$-in., all of the clips and first

[1] The thickness of 24 S.W.G. is 0·022-in. and that of 23 S.W.G. is 0·025-in.
[2] Concrete roofs are also sometimes covered with copper.

[1] These nails should be without shoulders (enlarged connections between the head and stems), which latter tear the copper when the nails are driven home.