Hip and Valley Framing

Most timber framers learned their roof framing using the steel square. This is adequate for stick-built hips and valleys with their thin butted members set plumb and level, but timber-framed roofs use thick stock, often cut into non-rectangular shapes and set in a variety of orientations to the roof plane. To make things worse, timber framers don't simply butt pieces together, but connect them with mortise and tenon joints. These multiple compound intersections result in angles which cannot be obtained with the steel square in any straightforward way.

Help does sometimes arrive from an unexpected quarter. In the decades near the turn of this century, fashions in architecture ran to styles often requiring elaborate hip and valley roofs, and often enough these were framed in steel. Builders had to find ways to lay out and cut compound intersections of I-beams, channels, angles and tees. Roof framers' handbooks appeared, some produced in-house for a limited audience. Most of these are gone now except for a few copies kept by steel detailers, the specialists who design the connections for steel-framed buildings. One of these handbooks, known familiarly as *Martindale's*, has come to light and proved most helpful to timber framers.

Martindale's presents us with two powerful tools as alternatives to the square for deriving lengths and angles in hip and valley roofs: geometry and math. Nowadays most framers take a mathematical approach—tabulated trigonometric formulas are worked out with the aid of electronic calculator or personal computer. In the most highly evolved applications, entire joint layouts are produced parametrically by special-purpose software. But all this high-tech wizardry is based on ancient techniques of geometry. The formulas for angles are derived from drawings which can be produced with simple draftsmen's tools (dividers, straightedge, square). With its complementary presentation of both geometric drawing and derived trigonometry, *Martindale's* serves as a convenient point of departure for the development of both systems.

Speaking of development, the essence of the geometric method is a technique called developed drawing. In this technical sense, a development is the unfolding of a three-dimensional object so that all of its surfaces lie in a single plane. In other words, developed drawing is a way of reproducing the parts of a complex shape on a piece of paper. This is useful when searching for angles in hip and valley roofs since the same three points which determine an angle also define a plane, and, typically, once you have developed the surface on which an angle falls, finding the angle itself is a simple matter.

This article is the first of a series covering applications of geometric and mathematical methods to the design, layout and cutting of hip and valley roofs. Our introduction to the subject is a geometric one, drawing on the presentation made at the 1990 conference by Frederic Brillant of Celtic Construction, Vashon Island, Washington. Frederic received his carpentry training in southern France as apprentice and journeyman in the unbroken tradition of the Compagnons du Devoir, the French trade guild. As he points out, the system presented here was "developed and refined by skilled journeymen at a time of general illiteracy. The approach does not use numbers or mathematics and the amount of abstraction is minimal."

The core of Frederic's workshop was a simple geometric construction which generates the data needed to frame a hip. This roof layout can be lofted full-size on the shop floor in order to obtain stock lengths and joint locations as well as angles, or it can be drawn to scale at the drawing board, yielding angles only.

To perform the latter exercise, all you need to start is the ground line and the lattice. Some definitions: the tops of the rafters and fascia meet at the eaves to form a level line called the *gutter track* (Fig. 1). The extension of this plane throughout the building is the *ground line*. The roof surface as defined by the tops of the rafters and purlins is called the *lattice*. Once you have laid out ground line and lattice, you can create a developed drawing that will generate all the framing angles.

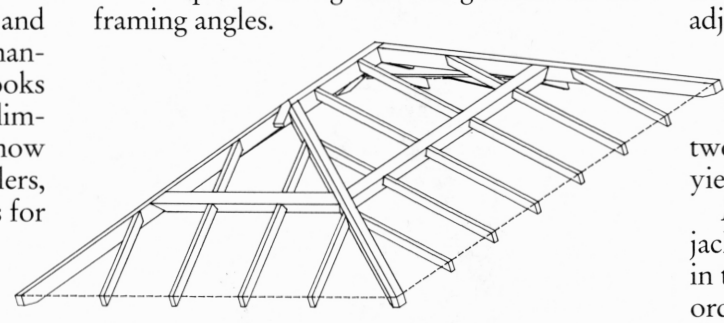

Fig. 1. The Gutter Track.

Our model is a hip roof with both purlins and jack rafters. You can tell from the roof plan (Fig. 2) that this is an irregular pitch roof in which the adjacent pitch on the ends is steeper than the main pitch on the sides of the building. One advantage of geometric methods is that supposedly complicated roofs (irregular pitch, irregular plan) are no more challenging to deal with than simple ones. Eaves and ridges which don't meet at 90 degrees, or hips or valleys that don't join them at 45 in plan are no more difficult to draw than ones that do. In addition, all drawing procedures are identical for main and adjacent pitches. One problem that is worth mentioning: in order to maintain a level gutter line all around, builders of irregular pitch hips must vary either plate heights or overhang widths on main and adjacent eaves.

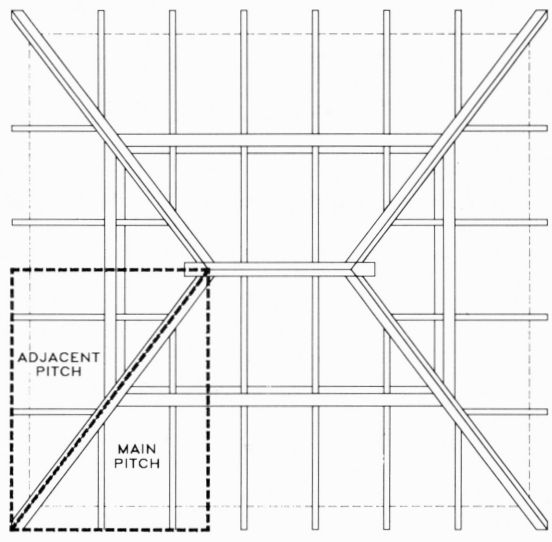

Fig. 2. The Roof Kernel.

All the information needed for framing is contained in the roof *kernel* delineated by the heavy dashed rectangle in the roof plan. This is the starting point for the drawing. The long sides of the rectangle represent the run of the main roof slope, the short sides the adjacent run, and the diagonal the run of the hip. The drawings which follow (Figs. 3-7) are Frederic's, recast and translated for a North American audience.

Pitches, Plumb Cuts and Backing (Fig. 3). For the sake of simplicity and clarity, the layout is broken up into several drawings. Begin the first by reproducing the plan of the kernel. While the various runs differ in length, the rise, a given, is common to all three, so you can add elevations to the drawing by erecting the rise perpendicular to each of the three runs, and connecting foot to peak. You now have three triangles whose sides are the run, rise and length of the main common, adjacent common and hip rafters, and whose interior angles are the level and plumb cuts of these three slopes.

To obtain the main backing angle for the hip rafter, draw a line from the foot of the main common perpendicular to the run of the hip. Continue on from there with a perpendicular to the hip itself. With the center at the beginning of this second line, swing an arc from its end back to the hip run and draw a third line from this last point back to the original starting point. The angle between the first and third lines is the main backing angle. Repeat the operation starting with the adjacent common for the adjacent backing.

Top Cuts (Fig. 4). With the center at the foot MF of the main common, swing an arc down from the peak P to meet the rise of the adjacent pitch and draw a line connecting this point with the foot HF of the hip rafter. Repeat, beginning at AF, for the adjacent pitch. The triangles formed by these two lines and the sides of the kernel rectangle yield the top cuts for jacks and purlins.

Purlin Track (Fig. 5). Unlike the commons, jacks and hip, the sides of the purlins do not lie in the vertical plane, as is plain from Fig. 1. In order to determine the purlin side angles, you must first draw the plane in which they fall. This is done by locating where the face of the purlin intersects the lattice and ground. A word about the notion of the *purlin track*: assume for the purposes of the model that the purlin is laid out from the corner where its front face (the long or downslope side) and top edge (roof surface) meet. The face of the purlin defines a plane—the purlin track—at right angles to the roof surface that cuts all the rafters at the same height. To fully develop this surface, the purlin track must be found both in plan and elevation. Remember that the major rectangle in Fig. 5 is a plan view of the kernel, while the three large triangles represent the vertical sections taken at the main, adjacent and hip rafters.

Start with the elevations. The single circles show where the upper (lattice) end of the purlin track hits the rafters. To locate these points in plan, drop plumb (dotted) lines down to the runs and continue straight on in plan until the three lines intersect the hip run. As you would expect, they all converge on the same point (double circle). The plan of the lower (ground) end of the purlin track is found by dropping perpendiculars (dashed) from the same starting points on the commons down to the common runs. From there extend the lines at right angles from the common runs until they strike the run of the hip (triangles).

Purlin on Hip (Fig. 6). To find the projection of the faces of the purlins on the sides of the hip, connect the hip-purlin intersection (single circle) with the hip run-purlin ground intersections (triangles). The angles between these two lines and the hip mark the downslope ends of the mortises for the main and adjacent purlins in the side of the hip.

Purlin Side Cuts and Lip Cuts (Fig. 7). To find the side cuts, you'll need some additional construction lines. Extend the purlin lattice (dotted) lines from Fig. 5 beyond their intersection with the hip run (double circle). Arc the common-purlin intersection points (single circles) down to the common runs and drop perpendiculars from there to meet the dotted lines. Connect these two points (pentagons) with the hip run-purlin ground intersections (triangles). The angle between the two (solid) lines is the purlin side cut.

The lip cut is needed only in those instances where the purlin is deep enough that part of it passes under the hip. The lip cut is the angle on the side of the purlin between the bottom of the purlin and the bottom of the hip. Raise a perpendicular from the lower end of the hip run. Extend it and the purlin ground tracks until they meet and connect these intersections (diamonds) with the pentagon points (see above). The lip cuts are the angles between the ground tracks and these last two lines.

—Ed Levin

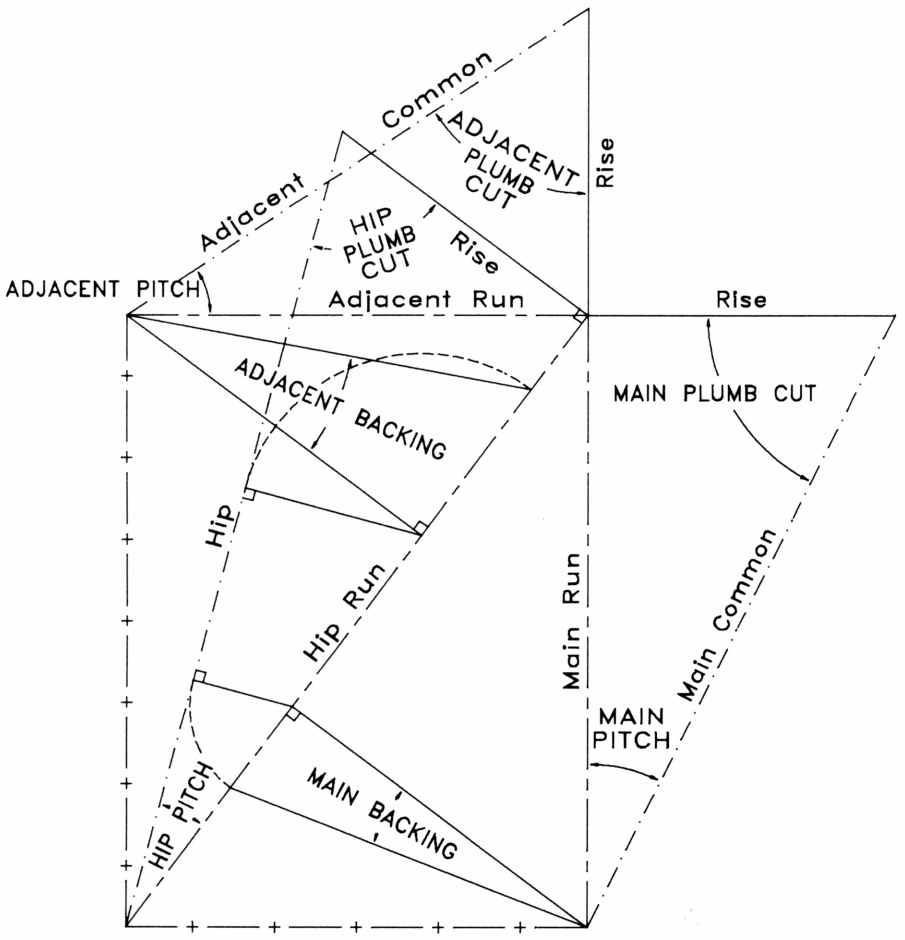

FIG. 3. PITCHES, PLUMB CUTS, BACKING.

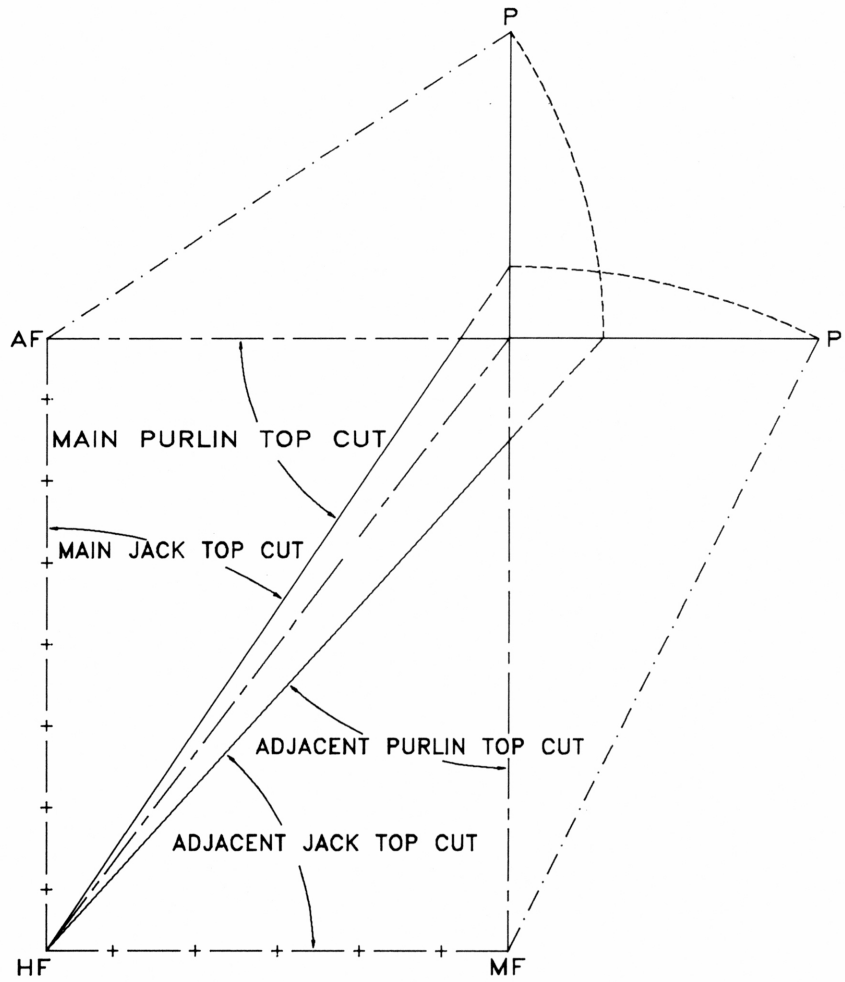

FIG. 4. TOP CUTS.

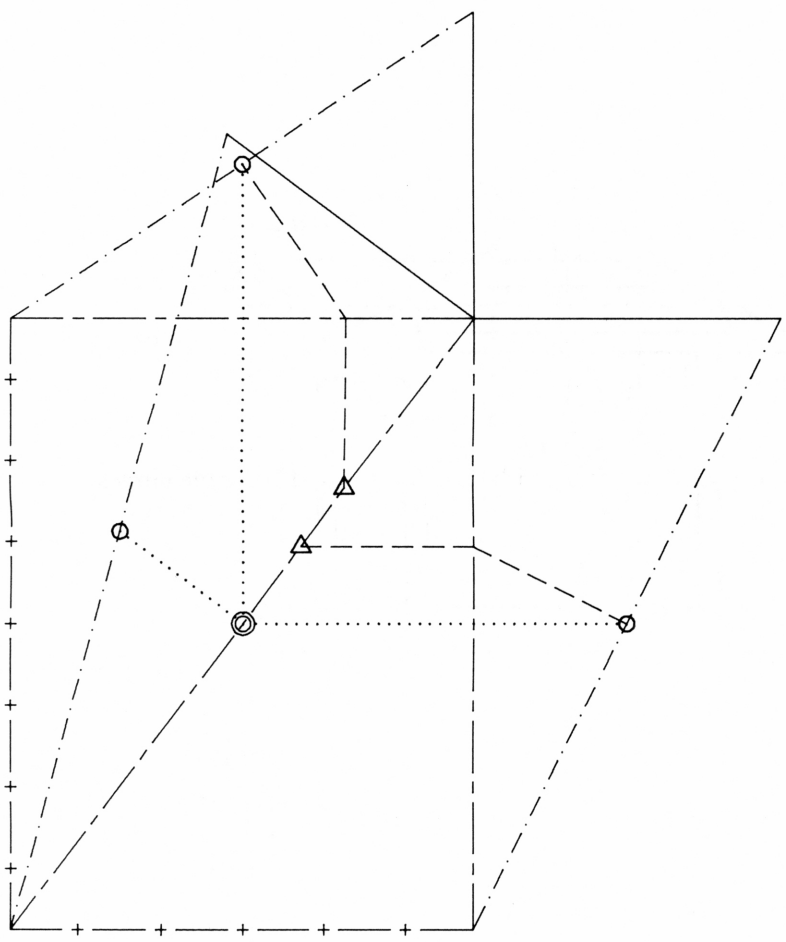

FIG. 5. THE PURLIN TRACK.

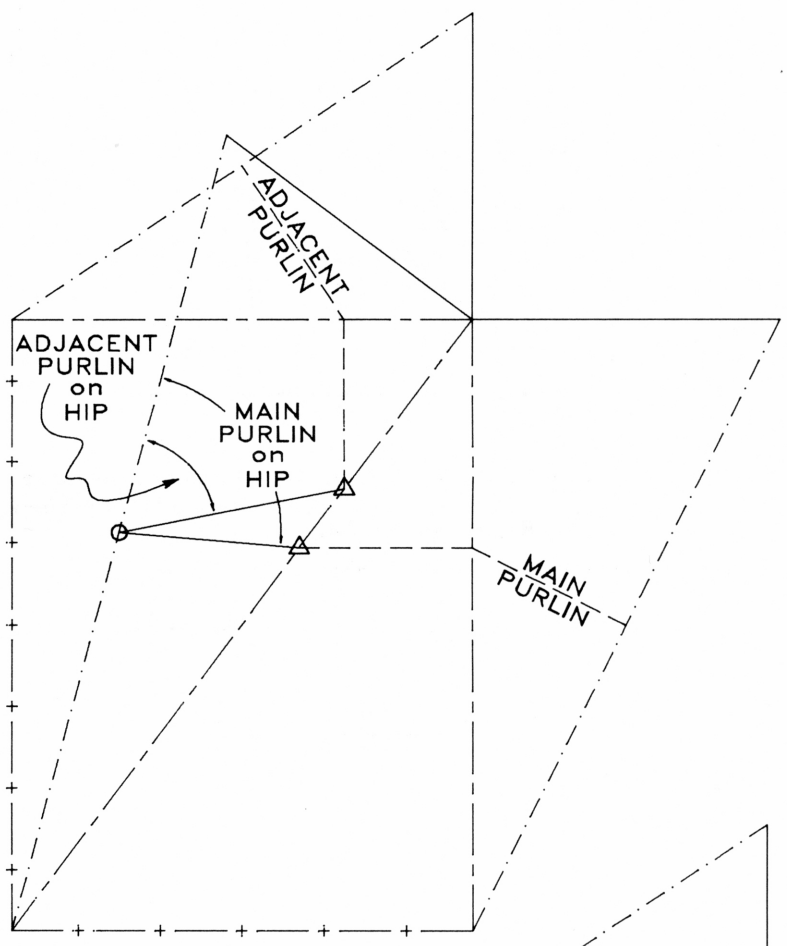

FIG. 6. PURLIN FACE ON HIP.

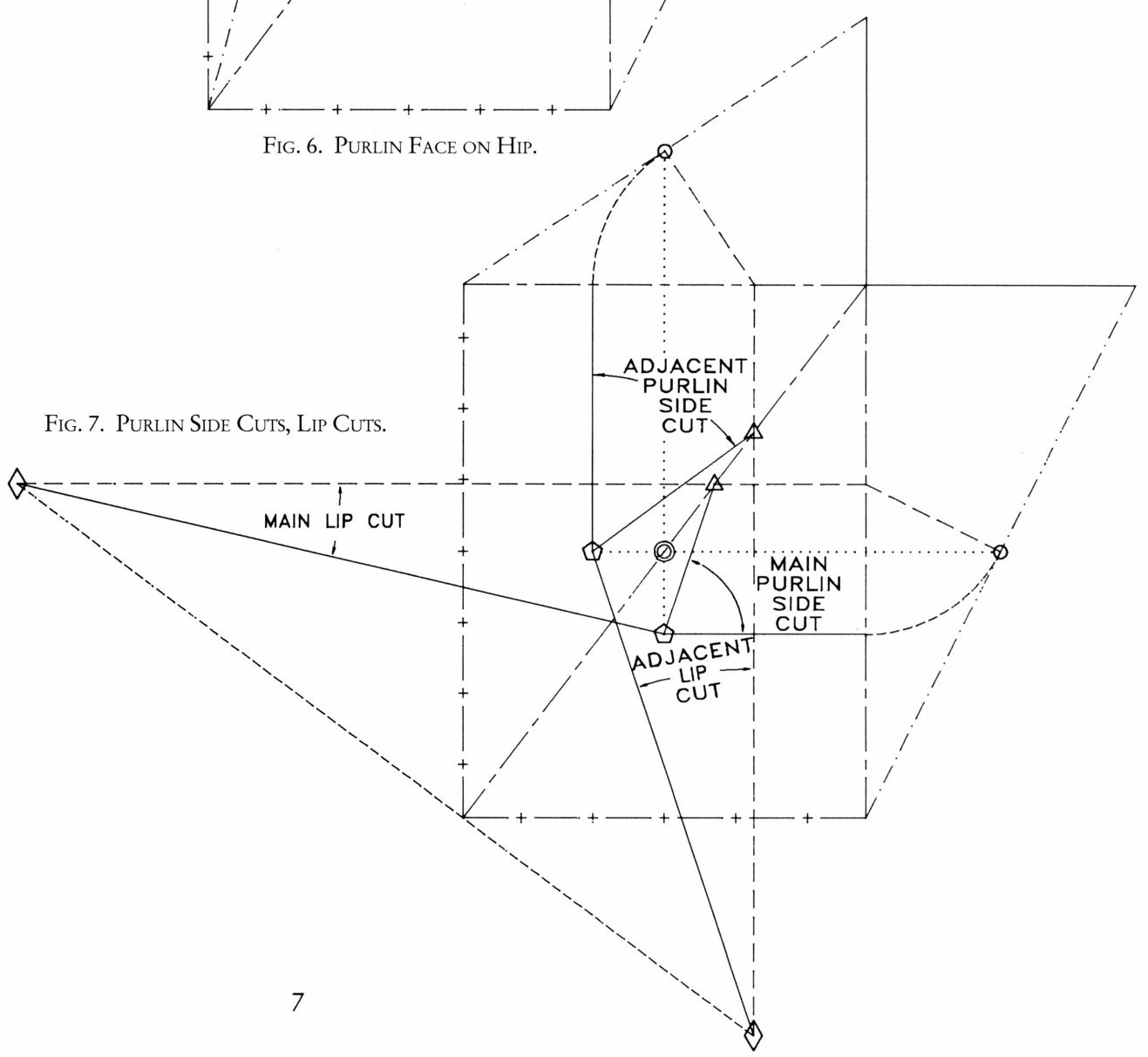

FIG. 7. PURLIN SIDE CUTS, LIP CUTS.

KEY

GUTTER TRACK — + — + —

GROUND LINE — - — - —

LATTICE — · — · — · —

PURLIN TRACKS

AT LATTICE .....

AT GROUND - - - - - -