# Roof Framing Revisited

## A graphic way to lay out rafters without using tables

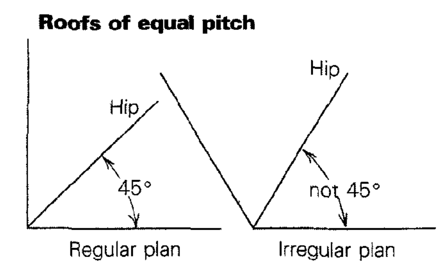
by Scott McBride

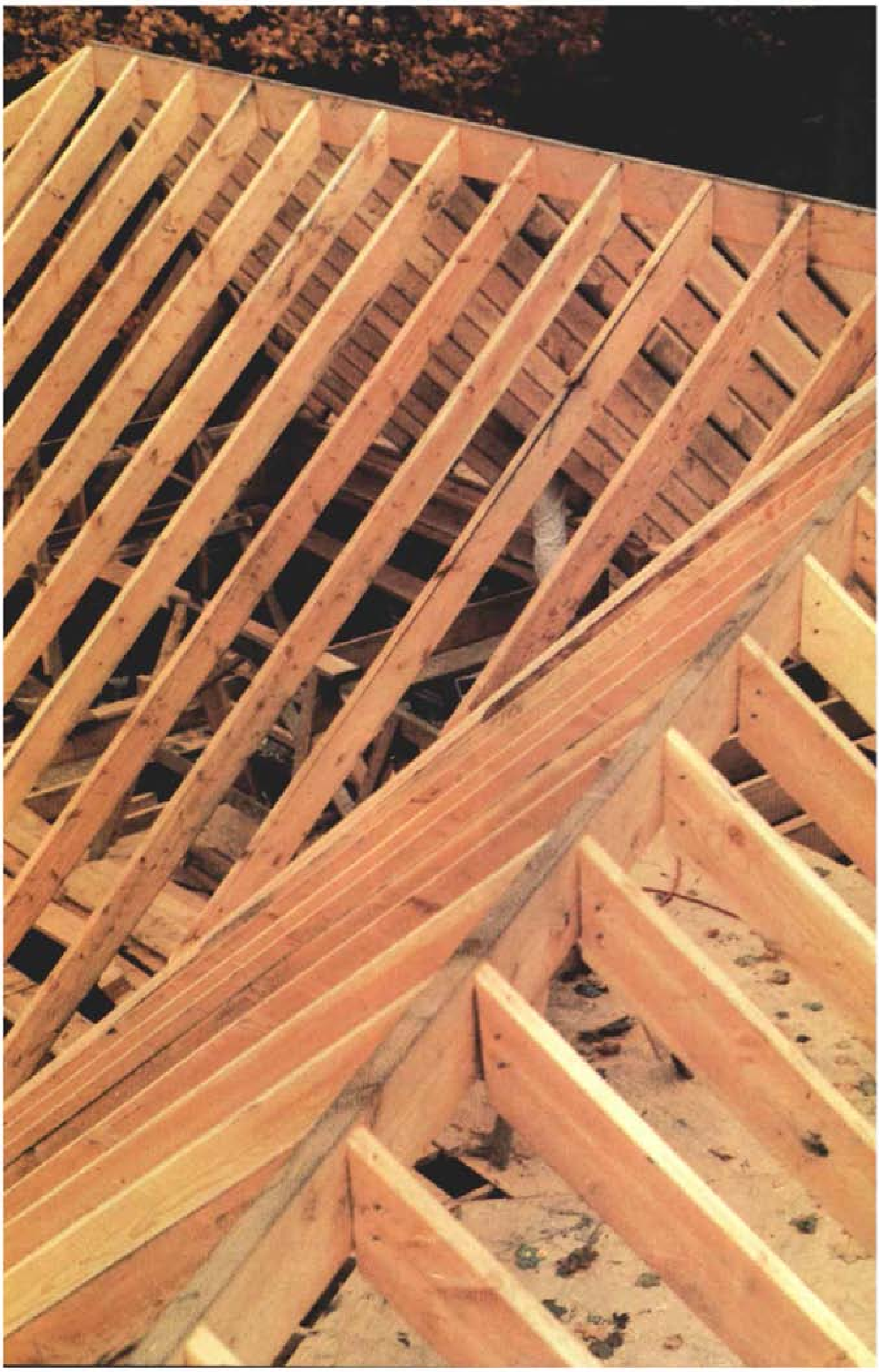
When architect Stephen Tilly presented me with the drawings tor a house he planned to build in Dobbs Ferry, N. Y., I flipped through the pages one at a time. I stopped when I got to the roof-framing plan. In addition to the roof's steep pitch (12-in-12) and substantial height (more than 40 ft. in some places), I would have to deal with a plan that included few corners of 90°, roof intersections of different pitches and a portion of a cone.

**Irregular plan**—When adjoining roof planes rise at the same pitch, their intersection (either a hip or valley) bisects the angle formed by their plates on the plan. For instance, a square outside corner on a plan calls for a hip whose run bisects the plates at 45°, as shown in the drawing below. This is why the skillsaw is set to a 45° bevel in most cases to cut hips. Similarly, square inside corners produce valleys lying at 45° to their adjoining ridges.

When plates join at an angle other than 90°, things get a bit more complicated. The Dobbs Ferry house contains a number of these irregular situations, including a large bay that angles off the master bedroom at 45°, and a wing that joins the main body of the house at 60°.

**Theory**—Conventional methods of roof framing involve the use of rafter squares *(FHB* #10, pp. 56-63), but I took a different approach. My study began by reading *Roof Framing* (Sterling Publishing Co., Two Park Ave., New York, N. Y. 10016) and *The Steel Square* (Drake Publishers, 381 Park. Ave. South, New York, N. Y. 10016), both by H. H. Siegele. These books are a hap-



***An irregular plan.*** **With intersecting roof planes of the same pitch, the hip or valley bisects the angle formed by their plates in plan (drawing, above). On this house, right, the main wings join at 120°. As a result, the valley is an irregular one, since the angle at which it bisects the plates in plan is other than 45°.**

Photos: Stephen Tilly

hazardly arranged series of magazine articles from the 1940s, and the illustrations are poorly reproduced in the current editions. Nevertheless, they contain the necessary applied geometry that is the essence of roof framing.

Understanding Siegele and the subject of irregular framing in general isn't easy. I spent hours rereading a page; in some cases, even a single cryptic paragraph. But when, after following his convoluted instructions, that weird cut I made on an 18-ft. double 2x10 valley rafter fit perfectly, it all seemed worthwhile.

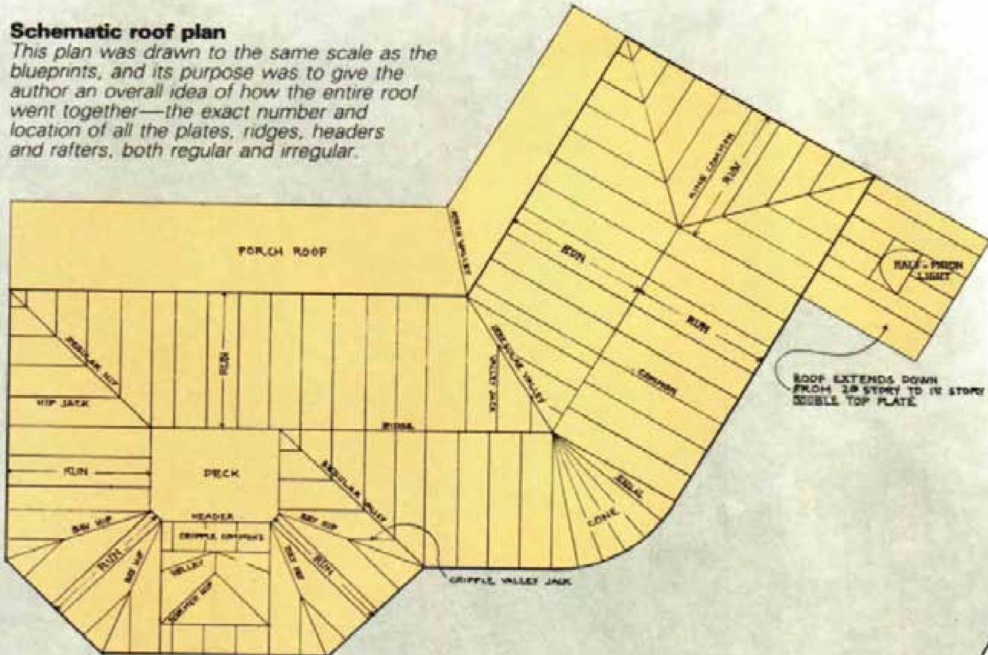
**Preparation**—I began work on the house by making a ½-in. = 1-ft. scale model of the entire house frame (photo right). Lofted directly from photographically enlarged working drawings, it allowed architect Tilly and me to analyze the downward transfer of the roof load, and to visualize the relationship of one rafter to another in three dimensions. Finally, the model proved helpful with the materials takeoff, since determining the rough length of hip, valley and jack rafters from a plan alone is difficult on a complex roof.

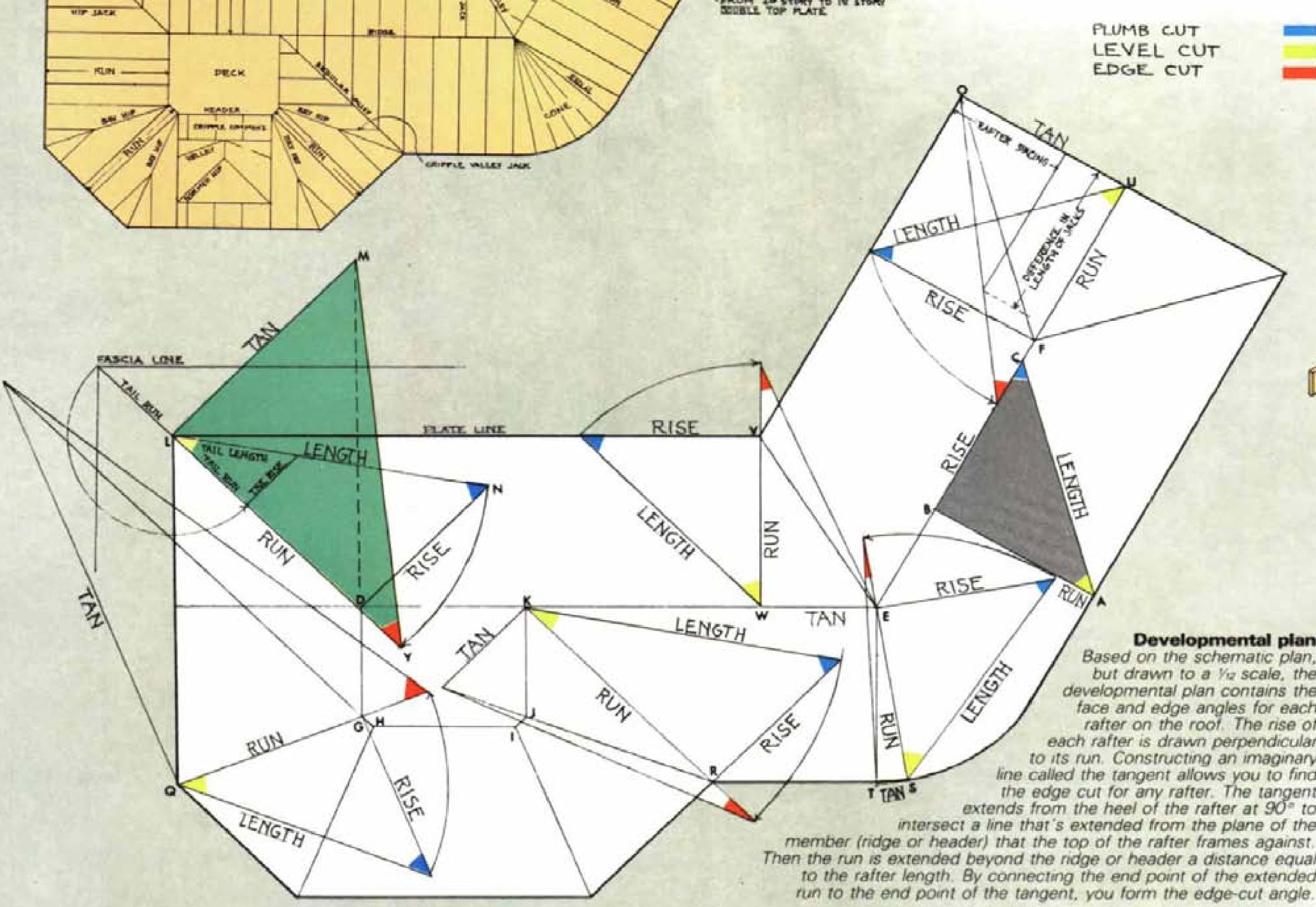
Once the last double top plate on the second story was nailed down, I began to deal with the roof in earnest. I drew two roof plans to use in the actual framing process. The first is a schematic (drawing, below) showing the position of plates, ridges, rafters, etc. This plan, like the model, gave me a general idea of how the roof

The structural model, above, shows just how complicated the roof is. The author had to deal with both an irregular plan and irregular pitches for some hip, valley and jack rafters, as well as a portion of a conical roof and dormers of several shapes. To keep on-site calculations to a minimum, he used a large developmental plan (drawing, below) that allowed angle take-offs using a sliding T-bevel, and unit measurements using a pair of dividers.

**Schematic roof plan**

*This plan was drawn to the same scale as the blueprints, and its purpose was to give the author an overall idea of how the entire roof went together—the exact number and location of all the plates, ridges, headers and rafters, both regular and irregular.*




**Developmental plan**

*Based on the schematic plan, but drawn to a ½ scale, the developmental plan contains the face and edge angles for each rafter on the roof. The rise of each rafter is drawn perpendicular to its run. Constructing an imaginary line called the tangent allows you to find the edge cut for any rafter. The tangent extends from the heel of the rafter at 90° to intersect a line that's extended from the plane of the member (ridge or header) that the top of the rafter frames against. Then the run is extended beyond the ridge or header a distance equal to the rafter length. By connecting the end point of the extended run to the end point of the tangent, you form the edge-cut angle.*



Drawings, except where noted: Scott McBride would work, and I drew it to the same scale as the prints. On this plan, the common rafters are always oriented perpendicular to the plates, and the run, or horizontal distance traveled by the rafters, is the same on both sides of the roof.

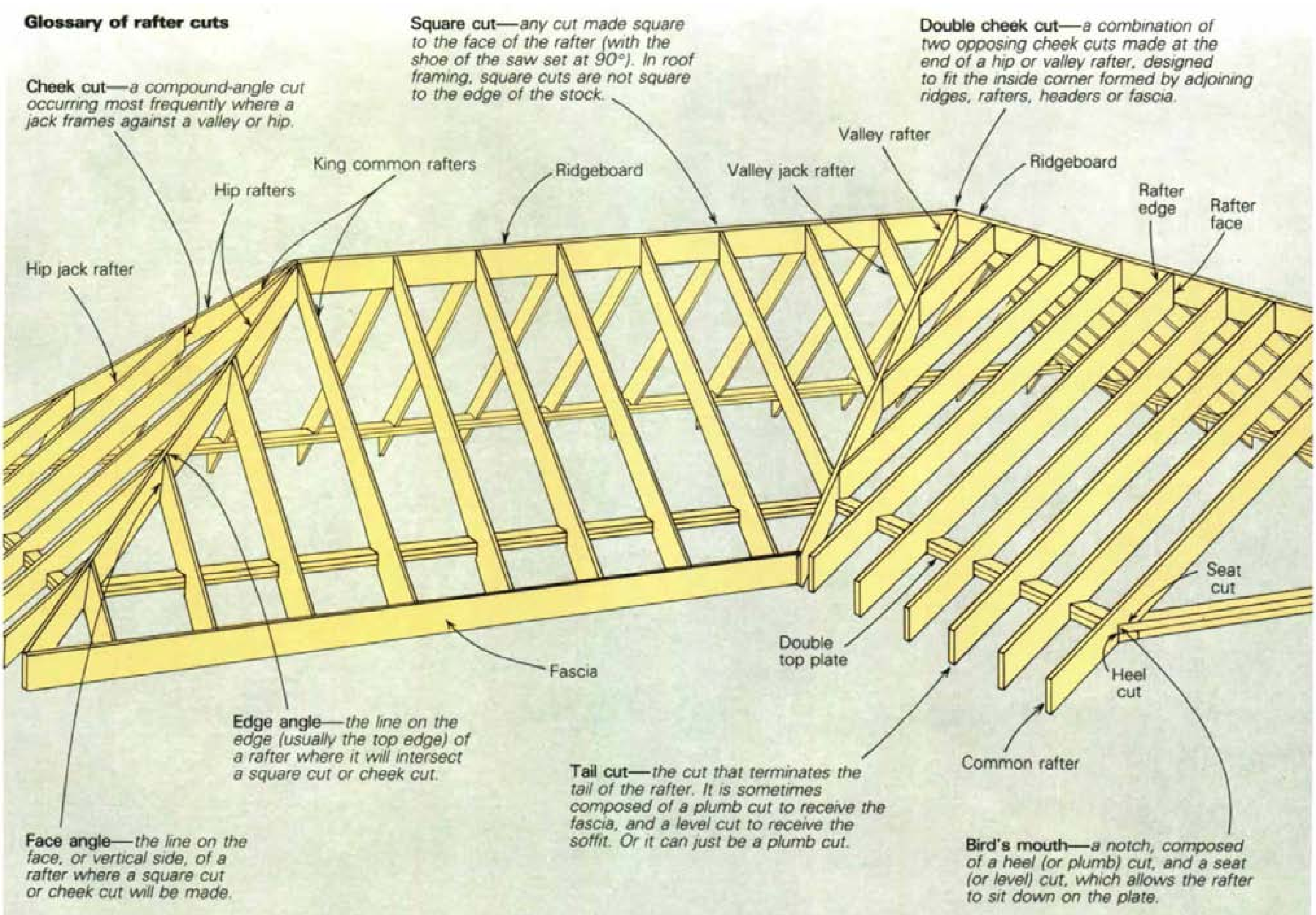
I drew the second plan (drawing, bottom of facing page) at 1 in. = 1 ft.—four times as large as the first plan. This developmental plan contains the face and edge angles of each common, hip, valley and jack on the roof, making it possible for me to transfer them from the paper right onto the rafter stock with a sliding T-bevel. (For definitions of roof members and roofing cuts, see the drawing below.)

Also, the graphic constructions on this plan provide unit rafter lengths equal to 1⁄12 the extended rafter lengths since I used a 1-in. = 1-ft. scale. To get full-scale lengths, I adjust a large pair of dividers to the unit length on the plan and step off this distance twelve times along the measuring line on the rafter stock. This gives me the *extended length* (or unadjusted length) of each rafter. The extended length is the distance from the center of the ridge to the outside edge of the top plate. To find the actual length of a common rafter, you must deduct one-half the thickness of the ridge and add the necessary amount to the tail for overhang at the eaves. I like this graphic system because it avoids math entirely—no rafter tables, no Pythagorean theorem. Also, the dividers are handier and more accurate for stepping off than the steel square.

**Using the plan with commons—**To draw the plan, I began with the development of a common rafter, which is seen in plan as line segment AB in the developmental drawing (facing page, bottom). The distance from A to B is the *run* of the rafter. It represents the distance across the attic floor from the outside edge of the plate to directly below the center of the ridge, and it forms the base of a right triangle. This triangle carries the geometric information you need to know about a rafter to cut it. The other leg of the triangle, line BC, is the *rise*. In actual three-dimensional space the rise goes from point B on the attic floor to point C, directly above B on top of the ridge. The hypotenuse of this triangle, line AC, is the unadjusted length of the rafter. The angle opposite the run is the plumb-cut angle, and the angle opposite the rise is the seat-cut angle.

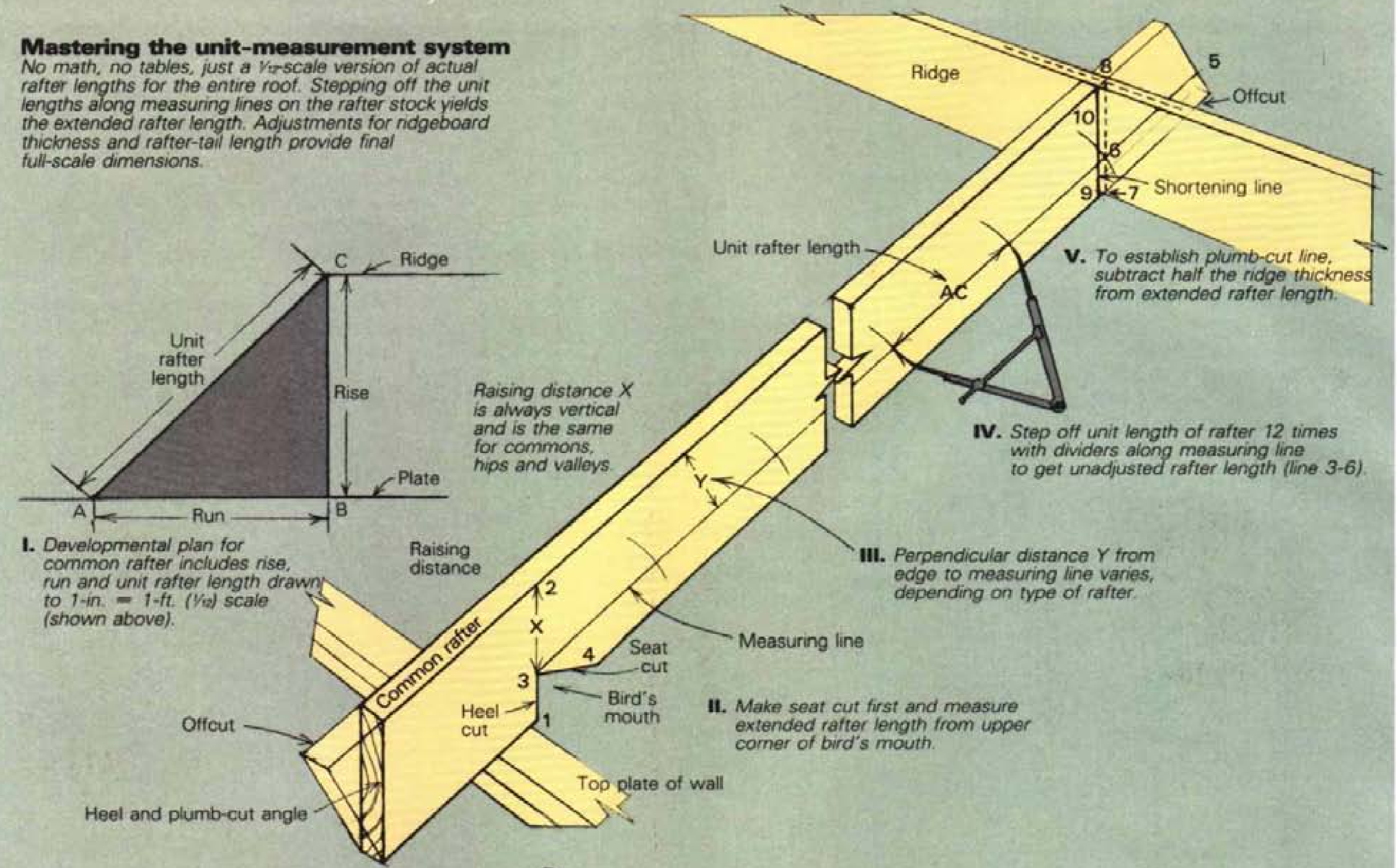
If you are thinking in three dimensions, you're probably confused. You can see that right triangle ABC is lying flat instead of standing in three dimensions as it would on a model. It is literally pushed over on one side, using AB as a kind of hinge. This is the key to understanding the way this developmental drawing expresses spatial relations using a flat piece of paper. The constructions for all of the rafters in the drawing employ the same basic transposition by bringing the rise and the rafter length down onto the paper, along with the run.

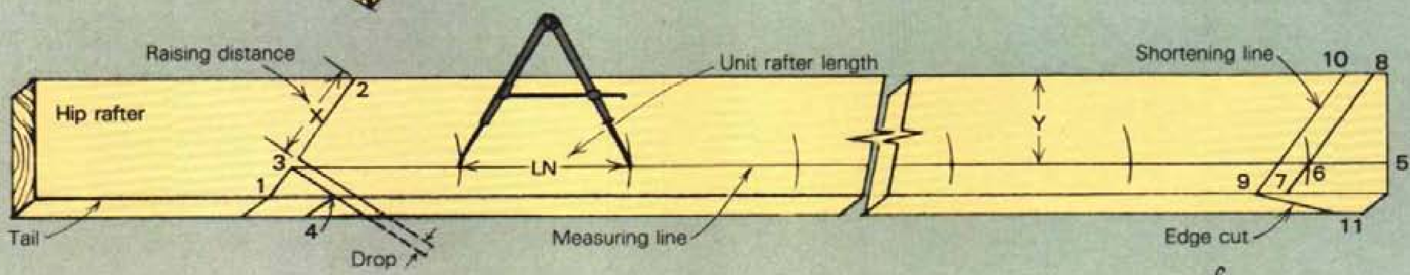
**From paper to rafter stock—**Cutting a common rafter from the developmental drawing requires taking the information graphically represented in the plan and applying it full scale to the rafter stock. For the common rafters represented by line AC, use a sliding T-bevel to transfer angle BCA onto the rafter stock. This will



## Mastering the unit-measurement system

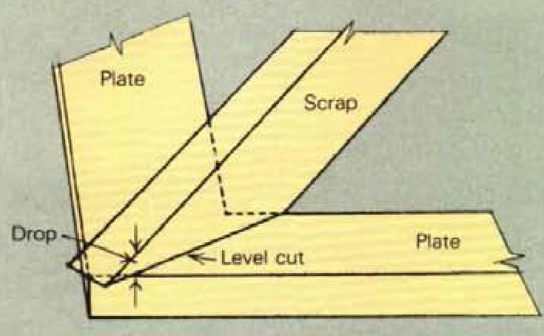
*No math, no tables, just a 1/12-scale version of actual rafter lengths for the entire roof. Stepping off the unit lengths along measuring lines on the rafter stock yields the extended rafter length. Adjustments for ridgeboard thickness and rafter-tail length provide final full-scale dimensions.*



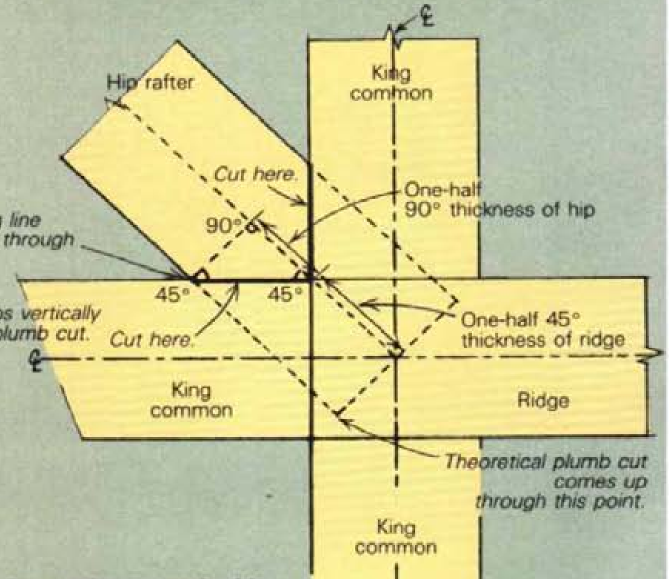

### Hip-rafter layout

*The extended length of the hip rafter is calculated with the same unit-measurement system used for commons. But hip-rafter tails have to be made longer, and the hip's seat cut has to be adjusted slightly to keep the top edges of the hip rafter from extending up above the adjoining roof planes (1). Also, the shortening line is figured differently (2) because a double cheek cut is required.*




### Calculating hip-rafter drop

*Hip rafters must be lowered so they won't extend beyond the sheathing. To find the amount by which to adjust the seat cut, place a sample hip so it bisects the angle formed by the plates, and measure up perpendicularly from where the outside of the plate crosses the scrap to the top edge of the scrap, as shown above.*




### Shortening a regular hip

*Where the hip meets the king common rafters and the ridge, the plumb face cut must be shifted back a distance equal to half the 45° thickness of the ridge plus half the 90° thickness of the hip. Repeat on the other side to form the double cheek.*

give you a plumb line. Use it first to establish the heel cut 1-3 near the bottom of the rafter (drawing; facing page, top), making sure to leave enough stock below this line for the rafter tail.

Now, holding the blade of the T-bevel perpendicular to the heel cut, use angle BAC against the edge of the rafter to scribe the horizontal seat cut 3-4. I make the seat cut 3½ in. to equal the width of the rafter plate. Cutting away triangle 1-3-4 will establish the bird's mouth.

To establish a length on the rafter, you have to scribe a line to measure along. Starting at the inside corner of the bird's mouth (point 3), and proceeding parallel to the edge of the rafter, scribe the *measuring line* 3-5. Going back to the plan, set the dividers to the unit length of the rafter AC. Starting from point 3 again, step off this increment 12 times along the measuring line. This will bring you to point 6. Draw a plumb line 7-8 (it will be parallel to line 1-2) through this point. This represents the imaginary line down through the exact center of the ridge, and the distance from 3 to 6 is the unadjusted length of the rafter.

To make the actual face cut for the rafter where it bears against the ridge, draw line 9-10 (known as the *shortening line)* parallel to line 7-8. The shortening line is offset from the theoretical plumb cut by a horizontal distance equal to one-half the thickness of the ridge—in this case ¾ in.

Note that the top edge of the rafter is offset from the measuring line by the vertical distance 3-2 (equal to 6-8). This is what I call the raising distance (X). It represents the difference between the level at which the roof is calculated and laid out, and the tops of the actual rafters. Measuring lines on all rafters are offset from their respective edges by this same raising distance, as measured vertically along their respective plumb cuts. If all the planes of a roof are to meet smoothly, then this measurement must remain constant from rafter to rafter.

**Raising the roof**—After cutting all the common rafters, I cut temporary posts to support the ridge. I erected these at points D, E, and F (developmental drawing, p. 32) and toenailed ridge boards DE and EF in from above. Headers DG, GH, HI, IJ and JK were propped up at the same elevation as the ridge. There was a reason DG and KJ were not permitted to intersect directly with HI in a square corner: given the dimensions of the floor plan below, to have done so would have made the run of the canted bay roofs less than the run of the adjoining roofs. Since the rise of all roofs here is the same, and pitch is the function of run and rise, giving the deck a square corner would have given the bay roofs a slightly different pitch than their neighbors. This would have combined an irregular pitch condition with the existing irregular plan. Have mercy!

**Regular hips**—After spiking in all the commons, I proceeded to draw the regular hips (DL, OF, and PF) starting with DL on the developmental plan. I first drew the rise DN, perpendicular to the run (DL). Then I connected L to N to produce the unit length of the rafter as seen in profile. Note that the rafter length of the hip is greater than that of the common, because its run is greater, even though the rise is the same.

In much the same way as I did with the common rafters, I used the T-bevel set to angle DNL from the plan to strike the heel cut on the rafter stock, again making sure to leave enough length on the tail for eventual trimming at the fascia (middle drawing, facing page). Hips and valleys require longer tails than commons and jacks, because although the rise of the hip tail is the same as the rise of the common tail, the run of the hip tail is greater. To calculate the length required for the hip tail, I drew in the fascia lines to scale on the plan parallel to the plate lines.

Extending the run of the hip until it intersects the fascia line produces the run of the tail. Set the dividers to this increment and swing them around 180° to a point along the hip run. Squaring up from this mark will establish the rise, and its intersection with the hip length establishes the end point for the tail length. Remember, though, this is a unit length, and will require being stepped off 12 times on the rafter.

The next task is to scribe the rafter stock with a measuring line from the inside corner of the seat cut to the top end of the rafter. It's parallel to the top edge of the rafter and offset from it by the same vertical raising distance established on the common rafters. To complete the bird's mouth on this hip, I drew a line through the intersection of the measuring line and the heel cut, using angle DLN on the T-bevel. This produced the seat cut. Well, almost.

**Dropping the hip**—A hip seat cut has to be *dropped,* which is the procedure of lowering the entire hip slightly in elevation by making a somewhat deeper seat cut. If the hip were not dropped, the corners on its top edge would protrude slightly beyond the adjoining roof planes, interfering with the installation of the sheathing.

To determine the amount of drop necessary, I took a piece of scrap the same thickness as the hip (drawing, facing page, bottom left) and made a level cut through it, using angle DLN. I placed this so that it bisected the 90° angle formed by the intersection of the adjoining plates. I then squared up from the level cut at the point where the outside of the plate crossed the face of the scrap. The distance from this point to the top edge of the scrap was the amount of drop. Accordingly, I moved up the theoretical seat cut a vertical distance equal to the drop, to arrive at the actual seat cut (middle drawing, facing page).

When stepping off a hip for length, you start from point 3 and repeat the unit hip-rafter length LN (obtained from the plan) 12 times. Using angle DNL, I struck a plumb line through the point 6. This is line 7-8, and represents the center of the ridge. Shifting this plumb line back horizontally a distance equal to half the 45° thickness of the ridge (1¹⁄₁₆ in. for a 2x ridge) plus half the 90° thickness of the hip (¾ in. for a 2x hip) established the actual plumb face cut (shortening line), 9-10. The bottom right drawing on the facing page demonstrates why these reductions are necessary by showing hip plumb cuts.

To complete the hip rafter, the shortening line has to be laid out in the same relative position on both sides of stock, and cut with a skillsaw set at a 45° bevel from each side. This produces a *double cheek cut* (see the drawing on p. 33), which nuzzles into the corner formed by the adjoining faces of the king common rafters.

**Irregular hips and valleys**—After completing the regular hips, I was ready for a bigger challenge—the irregular parts of the plan. The easiest of the irregular rafters to cut (for reasons I will explain later) was the group of bay hip rafters typified by QG, so I started with those.

All cheek cuts, regular and irregular, fall into one of two categories: those that can be cut with a skillsaw (with a bevel of 45° or greater) and those that cannot (with a bevel less than 45°). This difference is determined by the angle formed between the run of the given rafter, and the ridge, header or other rafter against which it frames. For instance, the irregular hip rafter QG frames against header GH at a 67½° angle (112½ if measured from the opposite side of the rafter). As a result, it can be easily cut with a skillsaw, and in a sense is no more difficult to cut than a regular hip.

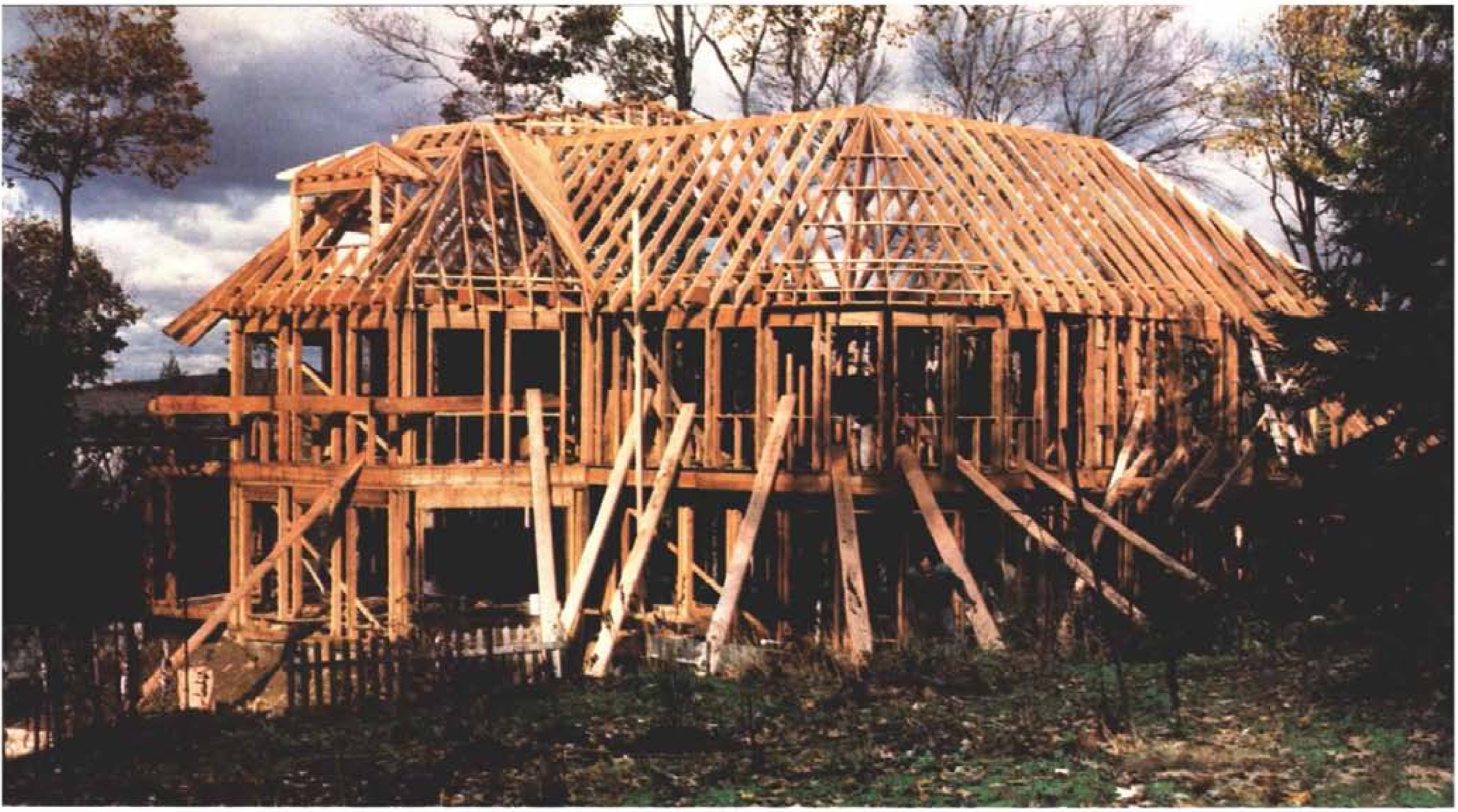
The first step is to develop the unit rise and the unit length of the rafter on the plan, using the same graphic procedure as for common rafters and the regular hips. Again, you will need to draw a measuring line parallel to the edge of the rafter stock, offsetting it by the same raising distance (X) used on all the other rafters. The raising distance is measured along the plumb cut, which is made using the angle shown in blue on the plan for QG. The seat cut for QG is made using the yellow-shaded angle from the plan. Remember that when using this graphic system, the plumb-cut angle is always opposite the run, and the seat-cut angle is always opposite the rise.

Dropping an irregular hip is done as on a regular hip, except that in this case, bisecting the irregular plate angle of this bay means orienting the scrap block at 67½° to the plates, not at 45°. The amount of drop is then measured up from the edge of the plate to the top edge of the scrap block as before.

Next, the unit rafter length from the drawing needs to be stepped off 12 times on the rafter stock to determine the unadjusted rafter length. However, the top plumb cut does not have to be shortened as the regular hip did because the face of header GH, against which QG frames, coincides with its theoretical layout line.

To make the plumb cut at the top end of the rafter, I set a 22½° bevel on my saw (the difference between 90° and 67½°), and cut away from the line. The resulting cheek fits against header GH, and a mirror image of this rafter fits header DG. Spiking these two together formed a V-notch at the top of the double rafter that straddled the 135° angle of the deck corner.

**Adding the edge cut**—The real challenge of an irregular plan comes when the bevel you are cutting is less than 45°. The bottom cut of valley KR is a good case in point. The bottom end of this rafter frames against the side of hip rafter JR, forming an angle in plan, KRJ, which is sharper than 45°. The solution is to lay out a



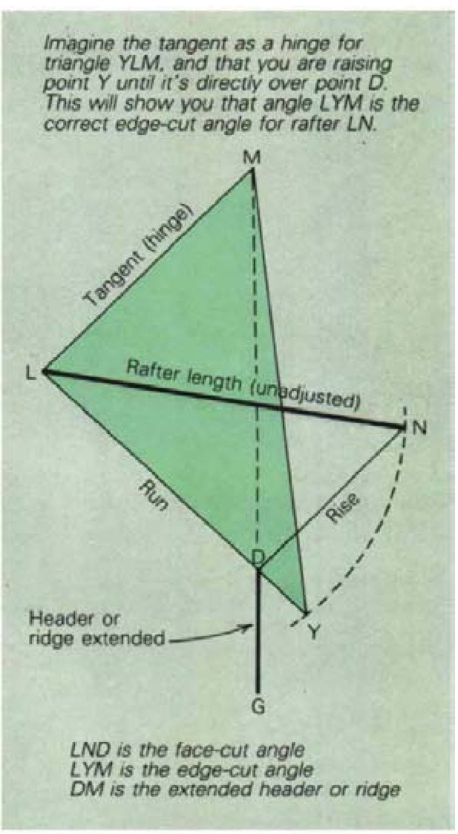
**Facing page: The author began with the common rafters and the ridges and headers they frame against, and worked up to the more complex parts of the roof, like the dormer and bays (on the left in the top photo), the irregular valley that joins them to the common rafters (in the center of the photo). The bottom photo shows a convergence of two hipped bays, two dormers, and a doubled valley that connects this area to a run of commons.**

face cut *and* an edge cut; and then to use either a handsaw or a chainsaw to make the cheek cut through both lines simultaneously (see the sidebar at right). It is in laying out the edge cut that things get a bit rough. I like to understand what I'm doing instead of just using a set of tables on a square, so I turned to Siegele again. His explanation relies on a line he calls the *tangent,* but its not the tangent you learned about in geometry class.

**The tangent**—This line is used in graphic constructions to find the edge bevel of roof members, roof sheathing, hopper boards, and other compound-angle cuts. Unfortunately, at no point in his books does Siegele give a concise definition of tangent. It's best understood in context, but I've assigned my own definition to the word just to introduce it. Basically, the tangent of a given rafter is an imaginary horizontal line, perpendicular in plan to the run of the rafter, extending from the heel of the rafter to the plane containing the vertical face of that member (ridge, header, or other rafter) against which the cheek cut of the rafter frames. Whew.

As an example, refer to the regular hip rafter LN, seen from above as LD (drawing, below). To construct the tangent for this hip (LM), I have to draw a line perpendicular to the run of the hip LD that emanates from the heel of rafter LN. The tangent ends at point M, where it intersects the face of extended header DG. This imaginary plane is seen from above as a dotted line—DM—which extends from line DG.

To find the angle for the edge cut, I set the steel point of my compass at L and the pencil point at N and swing an arc down to intersect the extended line LD at Y. Now the extended run LY equals the rafter length. By connecting M to Y, I make angle MYL, which is the edge cut for the hip where it frames against header DG.




**Why it works**—I'll attempt to explain why this geometric construction works. Imagine that tangent LM, magnified now to full scale, is a sort of giant hinge. Slowly, triangle LYM (colored green in the drawing at left) starts to rise upward, led by point Y, while line LM remains anchored where it is. Your perspective on this is looking straight down.

When line MY coincides in your vision with the plane represented by line DM, and point Y coincides exactly with point D, the plane LYM is inclined at the right pitch for the hip LN. Only at this pitch is the rafter length LY seen as equal in length to the run LD.

With plane LYM in this angled position, imagine a T-bevel applied with its stock along LY and its blade along YM. Now imagine a hip rafter, with its seat cut already made, raised up into position so that its top edge runs right along the raised-up line LY. If you survived these visualizing gymnastics, you'll begin to see why the angle LYM on the T-bevel gives the correct edge cut on the hip.

Here is another way of describing this concept: Construct a right triangle with legs equal to the tangent and rafter length—the angle opposite the tangent gives the edge cut.

For regular hips and valleys, the tangent is equal to the run. So by substituting the word run for the word tangent, we get a useful corollary: In all regular roof framing, use the unit run of the rafter on one arm of the square, and the unit length of the rafter on the other—the latter gives the edge cut. □

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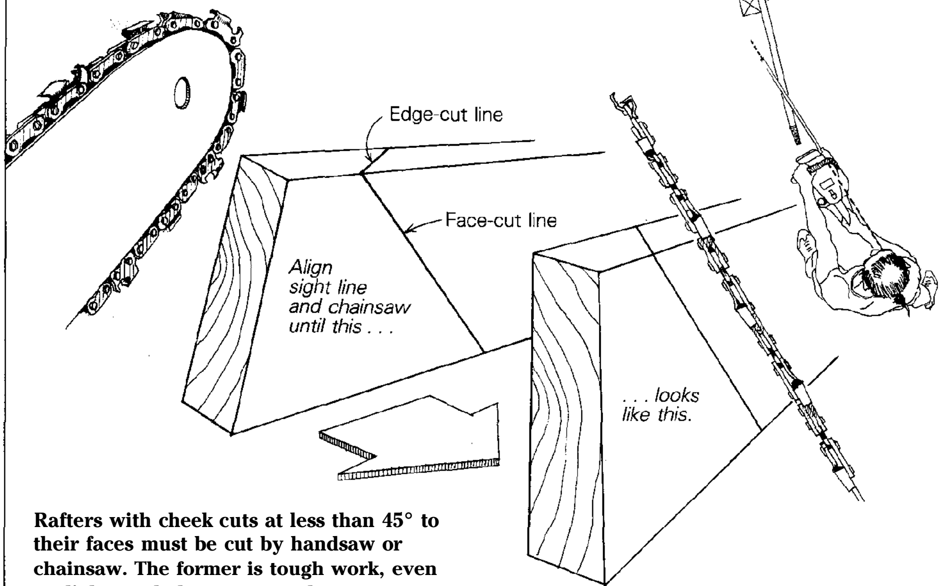
## *Cutting rafters with a chainsaw*




**Rafters with cheek cuts at less than 45° to their faces must be cut by handsaw or chainsaw. The former is tough work, even on light stock, because you have to cut through the wood at a miter *and* a bevel. This means cutting a cross section greater than the area of the same stock cut square.**

**To cut rafters with a chainsaw, you must line up the face cut and the edge cut with your eye so they appear as a single line, and then introduce the bar of the chainsaw so that it also lines up along this plane of vision. When everything coincides, you can make the cut.**

**This all sounds simple enough until you consider that holding the saw as I just described violates the first rule of chainsaw safety: Keep your face and shoulder out of the plane of cut, because that is where the saw will go if it kicks back. But lining up like this is the only way I know to produce a cheek cut that fits precisely. As a result, I use extra caution when I'm cutting this way. I spike the rafter stock to a post or some other solid object, leaving the end to be cut sticking well out in mid-air. Then I check the stock carefully for nails. I give myself plenty of working room, especially behind me. I keep my arms firmly locked and my legs spread, and drop the saw smoothly through the cut, without twisting. The chain must be kept sharp, well lubricated, and fairly tight on the bar; ripping chain works best.**

**After sawing, you'll probably want to smooth out the cut you just made with a plane. I use the 6-in. wide Makita 1805B and get excellent results. —*S. M.***