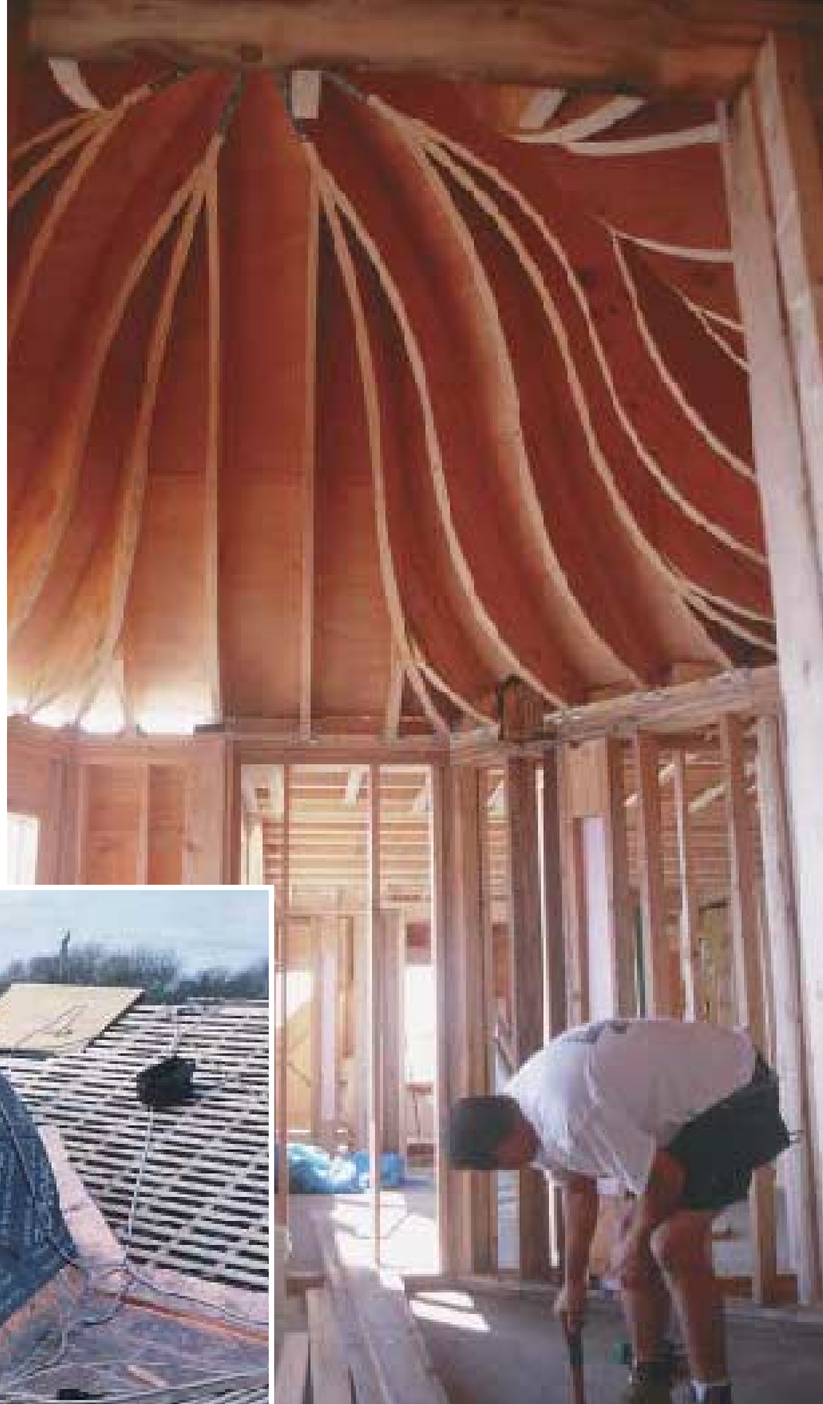
FRAMING AN Octagonal Roof



Bell-shaped rafters call for full-scale layout

by Jeff Davis

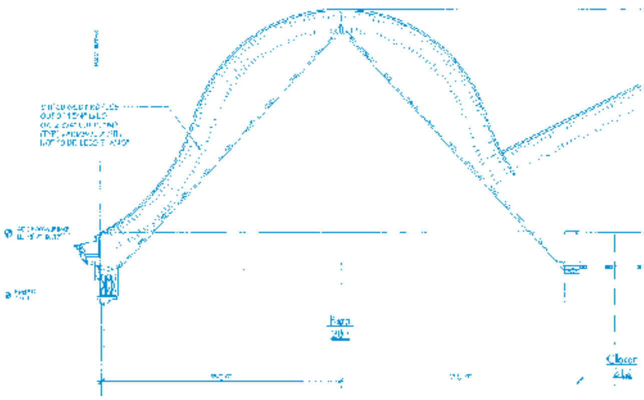
Last summer, contractor Scott Babcock asked me to frame an eight-sided, bell-curve cupola roof as part of a large home he was building. Given a choice, I'll take roof framing over any other project, and a roof like this one doesn't come along every day. I jumped at the chance.

The nearly 15-foot-diameter roof would cap a three-story "turret" situated at the ell between the two major wings of the shingle-style home. Considering the complexity of the framing job and the elevation — about 30 feet above grade — we decided to frame the roof on the ground and lift it into place with a crane as a unit. While I finished up another project, I asked Scott to provide me with a temporary, dead-level, 16-foot-square platform on which to build the roof in the yard.

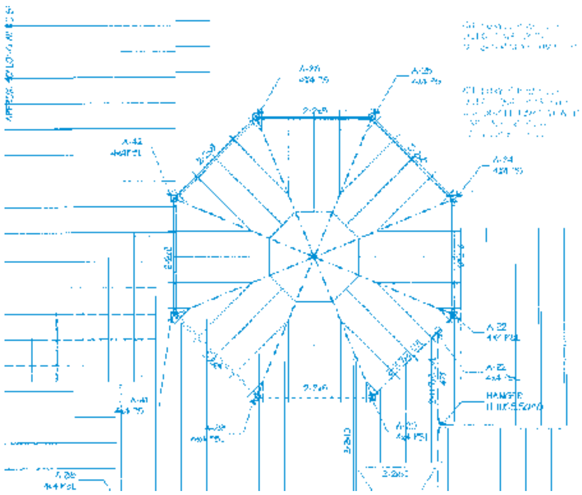
Sketchy Plans

The plans weren't exactly generous with detail. The architect provided a section drawing of the rafter profile, which featured an ogee curve on the

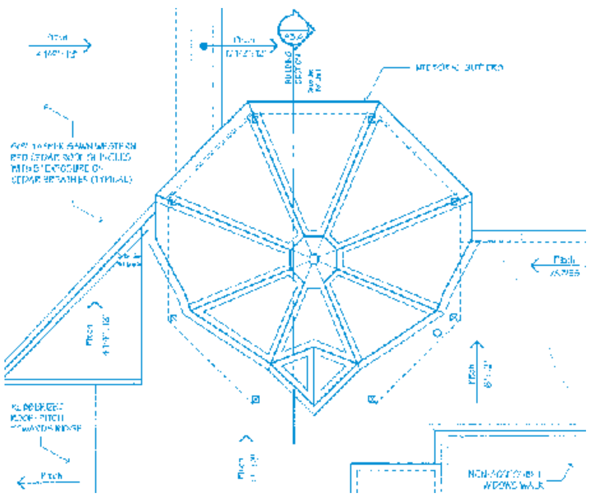
Octagonal Roof As Drawn



Ceiling Section



Framing Plan



Roof Plan

Figure 1. The architect's plan presented an octagonal framing scheme of eight hip rafters bridged by a ring of blocks that would support a centered common rafter. The author replaced the ring blocking and instead added common jacks.

exterior side and a straight interior line to be framed as an open, cathedral-style ceiling. The roof framing plan outlined a simple scheme of eight hip rafters converging at a common center, with a "common" rafter and a pair of jacks filling in each plane of the roof. The common rafters were shown landing against an octagonal "ring" of blocking between the hips near the peak, to minimize the convergence of framing members at the actual center (see Figure 1). Little additional information was provided, which was fine with me. In a situation like this, I'd rather begin with a clean slate than reverse-engineer someone else's framing vision. I determined the pitch of the roof from the architect's drawing of the interior ceiling. It worked out to around 13-in-12.

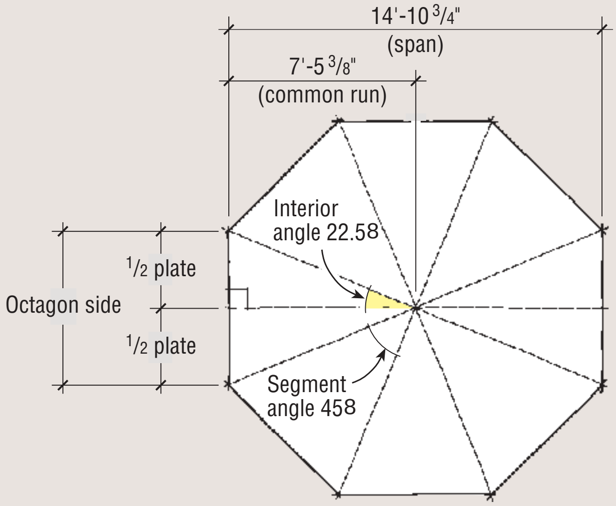
Dimension check. To accurately map out the plate on my temporary work surface, I carefully checked the supporting wall framing for level, plumb, and dimensional uniformity (see "Determining the Sides of an Octagon," next page). The wall sections were within $^1/_8$ inch of each other in length — close enough — but they needed a little tweaking for plumb. I made the necessary adjustments and added temporary interior bracing to hold the lines firm. Four of the eight supporting walls were interior partitions, three were exterior walls, and one was partially interior and partially exterior. The main roofs met in a complex junction of valleys, gables, and crickets behind the turret, supported in part by a steel girder from which I'd have to face-hang one section of rafters. For the time being, the main roof framing surrounding the turret had been left incomplete, to be filled in after placing the octagon. Several framing features would affect the placement of the preassembled roof, and I made countless trips from the ground, up three flights to the top floor to check and recheck various details. Tiring as it was, the time was well spent. I was determined to drop the roof neatly into place on the first try, rather than end up remodeling the heavy structure as it dangled above my head from the crane's cable.

Layout

After snapping an exact duplicate of the wall layout on our work platform, we framed a double-thickness 2x6

Determining the Sides of an Octagon

When I was called in to frame this octagonal roof, the walls were already standing. Because the plan was to build the roof on the ground and lift it into place, I needed to check the accuracy of the wall plates so that I could duplicate them on the ground. I used an approach that involved some simple trig.



1. First, I measured across the octagon to determine the total roof span: 14 ft. $10^3/4$ in. Dividing this in half gave me the run of the common rafters: 7 ft. $5^3/8$ in. (89.375 in.). In plan view, the common rafter run is one side of a right triangle. The other side is half the wall plate; the hip rafter is the hypotenuse. If you know one side of a right triangle and one angle, you can use trig to solve for the rest.

2. The hips of an octagonal roof form eight 45-degree angles. The angle between the hip and the common is half that, or 22.5 degrees.

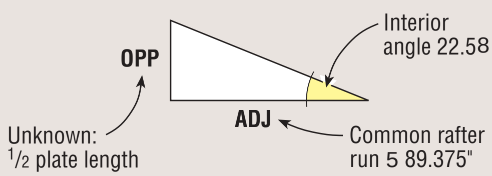
$$\frac{360 \text{ degrees}}{8} = 45 \text{ degrees} \qquad \frac{45}{2} = 22.5 \text{ degrees}$$

3. I plugged the angle and the side — the common rafter run — into the most basic trig function:

$$\text{tan of angle} = \frac{\text{opp}}{\text{adj}} \quad \text{or in this case:} \quad .4142 = \frac{\text{X in.}}{89.375 \text{ in.}}$$

Rearranging the numbers,

$.4142 \times 89.375 = X = 37.02$ in.



4. Since half the plate length is 37.02 in., the full plate length is 37.02 x 2 = 74.04, or $74^1/32$ inches.

Figure 2. A temporary work platform served as a base for a double construction plate built to the exact dimensions of the existing wall plates. Stand-blocks maintain its position; 2-by blocks elevate the structure to aid the final lift.

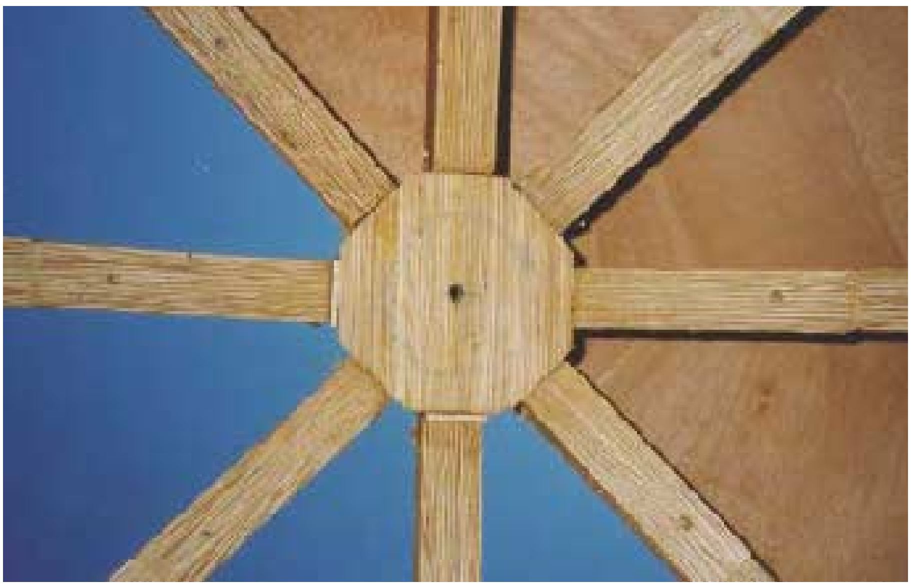


Figure 3. A beveled center block laminated from 18-inch LVL cutoffs provides support where the hip rafters intersect at the roof center.

octagonal base, overlapping the corner joints for strength. To help with lifting, we slid 2-by blocks under the assembly to hold it 3 inches off the deck. Stand-blocks fastened to the platform held the double plate's outside dimension to the reference lines (Figure 2). (I had to subtract the thickness of the extra double plates from the common rafter height-above-plate to ensure that the fascia would align with that of the adjoining roof planes.)

I marked the rafter layout directly on the plates. Instead of working to the blueprint layout, I simplified the framing by eliminating the ring blocking and centered "common" rafters. The spaces between hips would be framed with common jack rafters.

To support the framing at roof center, I glued together several layers of 1^3/4x18-inch LVL scraps to make a cube, then cut its corners at 45 degrees to make an eight-sided center block to catch the tops of the hip rafters (Figure 3).

Building the Bell

To develop the shape of the bell, I had to start with a common rafter pattern, which would be recut later as jack rafters. I worked out the common length using the common run and a calculator — just as I would for a straight 13-pitch rafter.

Cutting the rafters. I snapped lines on the work platform to represent the rafter in elevation as seated on the plate. The rafters were cut from 1^3/4x18-inch LVL stock. After cutting a rafter "blank" to length, I laid it on the pattern line and struck scaled-up radius curves using a site-made trammel stick (Figure 4, next page). At the outer curve, the radius exceeded the width of the LVL, so I piggybacked a block of LVL on the rafter to fill the break and secured it with PL Premium construction adhesive (OSI Sealants, 800/321-3578, www.osisealants.com) and screws.

Curved Rafter Layout

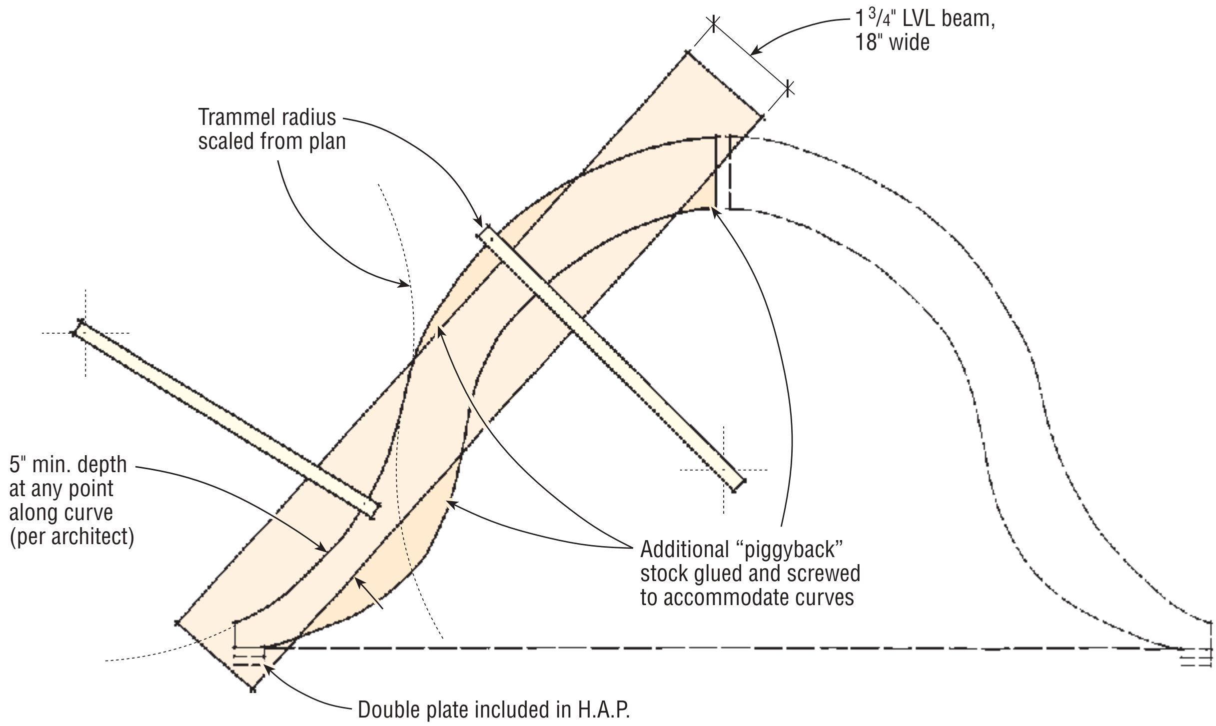


Figure 4. Where the rafter curves exceeded the confines of the 18-inch LVL beam stock, the author secured piggyback blocks with adhesive and screws.

Rather than going with the flat ceiling planes specified by the architect, Scott wanted to replicate the curves on the interior surface as well. After getting the go-ahead from the owners and the architect, we piggybacked additional blocking onto the undersides of the rafters to pick up the bottom curve. At first, we used a simple 12-inch gauge block to transfer the outer profile directly to the interior edge. But ever creative Scott wanted the ceiling line to travel horizontally out from the wall before turning upward.

To alter the ceiling profile, we used a thin poplar ripping and flexed it across the rafter face until we found a pleasing line. We traced the arc and carefully cut the rafter to shape with a saber saw. This rafter became the pattern for the rest of the commons. We initially cut 16 rafters, leaving the shorter jacks until later. Bosch #T144D blades proved to be excellent performers throughout this intensive cutting session.

Curvy hips. Although this roof was essentially no more than a fancy eight-sided hip roof, the unusual shape literally threw a curve into the hip rafter design. I don't know of any practical method for calculating the ratio of the common rafters' curved profile to that of the elongated hips. Fortunately, the common rafters provided a ready solution. We extended the wall line where the commons would sit, and set up a temporary ridge board parallel to the line, centered at the correct distance away (the common run distance, or 7 feet 5 3/8 inches). We built the ridge out to match the thickness of the center block and supported it at the proper height (Figure 5, next page). Working directly on the platform, we installed four profiled common rafters against one side of the ridge and two against the other for bracing, as if framing a gable roof.

After cutting and accurately setting a "blank" hip rafter against a common at one end of the frame, I used a straightedge with an attached pencil to transfer the correct profile from the commons to the hip.

Where the curvature exceeded the width of the hip rafter, we again added LVL blocking, attached with screws and adhesive. We developed the interior ceiling profile the same way.

With the hip and common patterns completed, we fabricated the rest of the rafters. We first set the hips, securing them at the plate below and the

Scribing the Hip

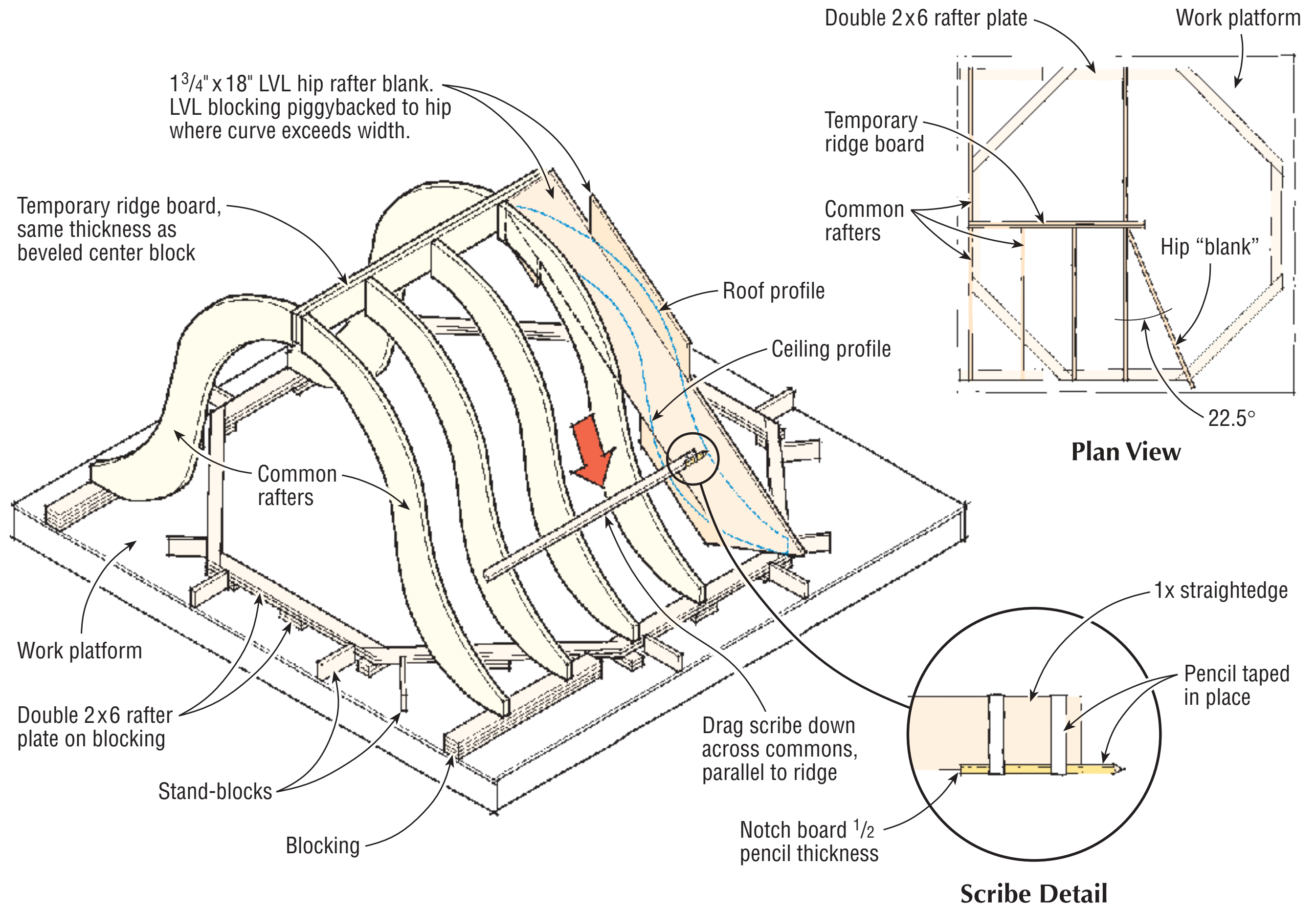


Figure 5. After cutting and accurately setting a hip rafter "blank" against a common at one end of a temporary frame, the author fashioned a scribing tool from an 8-foot length of 1-by pine that had been notched at one end to accept a carpenter's pencil. Held parallel to the ridge, the straightedge was dragged across the curved backs of the common rafters to transfer the correct profile to the hip.

center block above. The common jacks were a little trickier. Each octagonal section had four jacks, two longer and two shorter ones. There was an equal number of rights and lefts. The level cut at the bottom was already made, but the rafters needed to be shortened at the top. With no straight edge to work from, we needed a way to make an accurate plumb cheek cut.

Rather than fuss with a mathematical approach, I cut a 14¹/4-inch-long gauge stick to represent the standard spacing between 16-inch-on-center LVL rafters. I positioned this stick between a pair of hips an equal distance down from the top. At the points where the gauge just contacted the face of each hip, I made pencil marks to target with my LeveLite plumb laser, set up on the deck. The laser line, marked with pencil, became the long point of the jack rafter cut. I then set a short full-scale heel pattern on the plate to measure from, up to the mark, to find the overall jack length. I cut 16 of these longer jacks, half lefts and half rights (see "Cutting Acute Rafter Angles," next page).

A series of shorter jacks completed the layout; these were simply traced from the lower end of the common pattern.

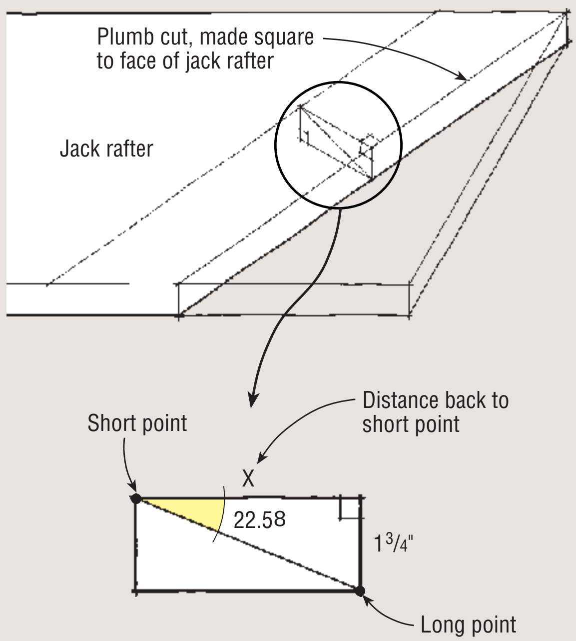
The framing members went together neatly with a little belt-sanding and power-planing here and there to fine-tune the cheek cuts. We shot the cheeks in with 3¹/4-inch gun nails following a liberal application of PL Premium. On the side of the roof that would coincide with the steel girder, I shortened the rafter tails to butt against the face of a double 2x10 let-in header that replaced one side of the plate, and connected the rafters with metal Simpson hangers (Figure 6, page 8).

Cutting Acute Rafter Angles

When cutting acute angles on jack rafters, I first make the plumb cut square to the stock. (I make sure that I'm cutting to the long point of the compound angle.) Then I find the distance back to the short point of the bevel using a calculator and the tangent method:

$$\text{Tan} = \frac{\text{Opp}}{\text{Adj}}$$

I know the length of the opposite side — the thickness of the LVL rafter, $1^3/4$ in. — as well as the rafter angle in plan — 22.5 degrees.

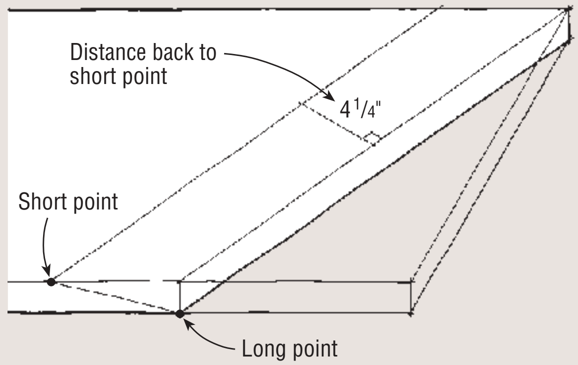


Plugging in the numbers, the formula looks like this:

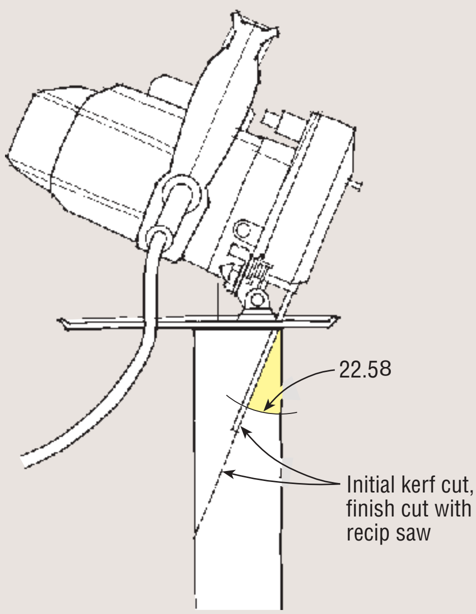
$$\text{Tan } 22.5 \text{ degrees} = \frac{1.75}{X} \qquad .4142 = \frac{1.75}{X}$$

$$X = \frac{1.75}{.4142} = 4.225, \text{ or } 4^1/_4 \text{ in.}$$

This is the distance I measure back from the plumb cut to find the short point of the compound angle. Because we're working in plan, I have to measure perpendicular to the plumb cut. I then transfer this dimension to the edge of the rafter stock.



Finally, I secure the rafter on edge across a pair of sawhorses, with the short point of the angle facing up. Setting the circ saw at the correct bevel — 22.5 degrees — I cut down the face of the angle, with the shoe riding on the plumb cut.



The circular saw will only cut deep enough to establish an initial kerf, so I finish up with a recip saw. To make sure I'm getting an accurate cut, I typically draw the cut line all the way around the rafter and cut a little strong, preserving the line. If need be, the cut cleans up perfectly with a power planer, if you're careful to keep the edge mark visible as a guide.

Remember to keep track of left and right side jacks; the octagon requires an equal number of each.

Figure 6. A steel beam in the main roof forced the author to face-hang the rafters from a header on one side of the octagon.

Figure 7. The author used glue and screws to sheathe the roof with 3/8-inch-thick "wacky wood." The plywood can be ordered to bend either across or along the sheet but not both. Bending requires an extremely uniform framing surface for solid contact at all points.

Figure 8. A custom-welded steel "star" plate distributed the lifting forces to each hip rafter. The plate was welded to a central eyebolt that penetrated the roof's crown (inset).

Figure 9. Thanks to meticulous calculations and cooperative weather, the roof sailed into place on lift day.

Sheathing

The roof was sheathed with a double layer of 3/8-inch-thick "wacky wood," or bendable plywood, made to flex and bend along one axis or the other, parallel to the face grain (Figure 7). It can be ordered to bend either across the sheet or along its length but not both. Small discrepancies in contour from one rafter to the next interfered with a smooth bend, so we had to spend a considerable amount of time fine-tuning the curves with a belt sander before the bendable ply would cooperate. Next time around, I'll stack all the common rafters and belt-sand them together to a perfectly uniform surface — the slightest bumps and discrepancies created problems at the hips. When building a complex shape like this one, you can't be too precise.

Wacky wood does very wacky things if it gets wet, so we immediately covered the sheathing with a layer of Ice & Water Shield. A custom copper roof would go over it later.

Lifting. We decided that the best way to lift the roof into place was via a central lift ring. We had Rob Crowell, a talented local welder, make a custom "star" plate that tied into the underside of each hip to prevent possible spreading (Figure 8). The plate was welded to a long eyebolt that rose through the top of the center block. Somehow, the wind failed to notice what we were up to, and the actual lift went off without a hitch (Figure 9). I'd already checked and rechecked all the protrusions and other critical points of interest and notched and adjusted the roof accordingly. The roof settled into place as nice as can be, and we secured it with three 5/8-inch-diameter machine bolts per side, drilled up through the plate and drawn up tight.

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