Framing a Barrel-Vault Ceiling

To simplify the layout, think in terms of a hip roof

by Tim Uhler

The company I work for builds spec homes. One of the ways we dress them up is by adding barrel-vault ceilings. Except for the layout, these impressive architectural details are not that hard to frame. A carpenter and helper can do it in four to five hours.

Our vaults are typically installed in a rectangular opening in a hallway or master bathroom. As a result, the opening is rarely more than 6 feet wide or 12 feet long. Framing a larger vault wouldn't be any different, but we've never had the space.

Geometry of a Barrel Vault

The surface of the barrel is part of the inside surface of a cylinder; a section through it is an arc of a larger circle. The ends of the vault can be plumb and flat, or curved like the barrel itself. We usually make them curved.

Like a hip roof. The layout for this kind of barrel is similar to that of a regular hip roof — one where all the pitches are equal. On a hip roof, common rafters run up from the sides and meet at the ridge. On a barrel vault, half-arc segments run up from the sides and meet at the high point of the vault (see Figure 1, next page). If the vault is small enough, you can make the entire segment from a single piece of plywood.

A hip roof has a single common rafter, called the king common, at each end. The king common runs from the top plate to the ridge board. The same is true of a barrel vault except that the end piece is half of an

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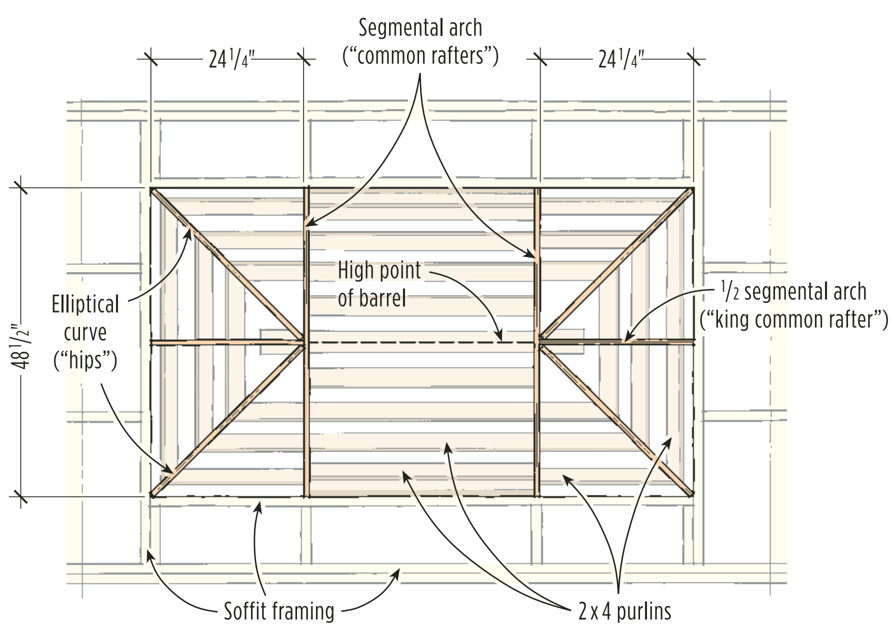
Figure 1. The vault framing (left) consists of radiused plywood "rafters" at the sides and ends, and elliptical plywood "hips" at the corners (drawing, bottom). Two-by-four "purlins" run between the plywood pieces. The surface is finished later with a double layer of 1/4-inch drywall (below).



arc segment, and instead of hitting a ridge it meets the midpoint of the last full arc segment in the barrel.

The hip is an ellipse. The vault framing also includes hiplike pieces that come in from the corners at 45-degree angles. In plan, they look exactly like hips, but from the side you can see they're curved. Because they're formed by the 90-degree intersection of two cylindrical curves, their shape is actually an ellipse.

Ceiling Opening

The first step in framing a barrel is to create an opening for the vault to go into. If it's on the top floor, we'll cut out some ceiling joists and head off the opening. That may not be possible on a lower floor, in which case we'll drop the surrounding ceiling by framing in a soffit (Figure 2). The size of the opening might be specified by the designer; if not, we'll come up with a size that seems proportionate to the room. In the project photographed for this article, we framed the opening about 12 inches off the main walls of the room.

After the opening is framed, we double-check to make sure it's square and the sides are reasonably parallel. Then we measure the distance across the opening at several points and use the average distance to determine the curves for the barrel.

Determining the Radius

Once we know the size of the opening, we decide how tall the vault should be at its highest point, then calculate the radius required to hit both edges of the open-

Figure 2. On upper floors, the opening for a barrel vault can be created by heading off ceiling joists (left). In rooms with high ceilings, the vault may fit in a dropped soffit (below).

ing while passing through the high point. To put it mathematically, we know a chord length (the width of the opening) of a given circle, we know the plumb distance from the center of the chord to the circumference of the circle (the height of the barrel), and we need to find the radius of the circle.

The easiest way to get the answer is to use a construction calculator that has a trig function. I use the Construction Master Pro Trig Plus III. For the vault shown in this article, which is 48½ inches wide and 12 inches high, I punch in the following sequence:

48½-INCH RUN
12-INCH RISE
CONV DIAG

The screen displays the radius of the arc, in this case 30½ inches. You can also use algebra to calculate the radius (Figure 3).

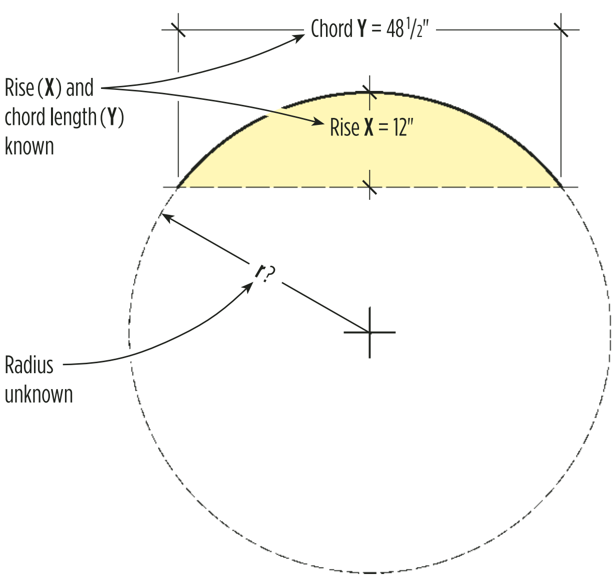
Making Arc Segments

We make the arc segments out of plywood. You could use OSB, but that would make it harder to see the layout and make clean cuts. Whenever possible, we try to gang-cut the pieces with a jigsaw (Figure 4, next page). We then cut one in half to make the king commons for the ends.

Laying Out the "Hips"

The first time we framed this kind of vault, we didn't fully understand how to lay out the ellipses. When our initial efforts failed, we installed the segmental arches, or "commons," then scribed the ellipses by taping a pencil onto a 4-foot level and sliding the level along the plane of the barrel to mark the shape onto an oversized piece of plywood that had been inserted where the "hip" was to go. The method worked, but it was time-consuming and the curves weren't as fair as they should have been.

Finding the Radius of an Arc



$$r = \frac{X^2 + \left(\frac{Y}{2}\right)^2}{2X} = \frac{12^2 + \left(\frac{48.5}{2}\right)^2}{24} = 30.5$$

Figure 3. If the width and the height of a barrel vault or segmental arch are known, you can use this formula to calculate the radius of the curved arch pieces.

Figure 4. The blanks for the arc segments are as long as the opening is wide. After marking the radius on the top piece (left), a carpenter cuts three arcs at once (below).

The next time around, I called Joe Fusco, a cabinetmaker I know in New York, to ask what we were doing wrong. He sent me a drawing that explained how to lay out the ellipses; without it I'd probably still be tracing the curves.

There are two numbers you need to know to lay out an ellipse: the length of the major axis and the length of the minor axis. If you have these numbers, you can also locate the two focus points. Once you have those points, all it takes is some picture-hanger wire and a pencil to draw the curve (see "Laying Out the Elliptical Hips," next page).

In a vault of this type, the minor axis matches the diameter of the cylinders from which the barrel is formed. Since we needed to draw only the top half of the ellipse, we used half the diameter, the radius of the circle — 30 1/2 inches.

The major axis was a little trickier, but treating the elliptical "hips" like regular roof hips helped. Just as a hip runs 17 inches — actually 16.97 inches — for every 12 inches of common run, so does the elliptical hip. Using a calculator, we multiplied the common run, 30 1/2 inches, by $\sqrt{2}$ to get the hip run — 43 1/8 inches. Twice this would give the major axis of the ellipse, but

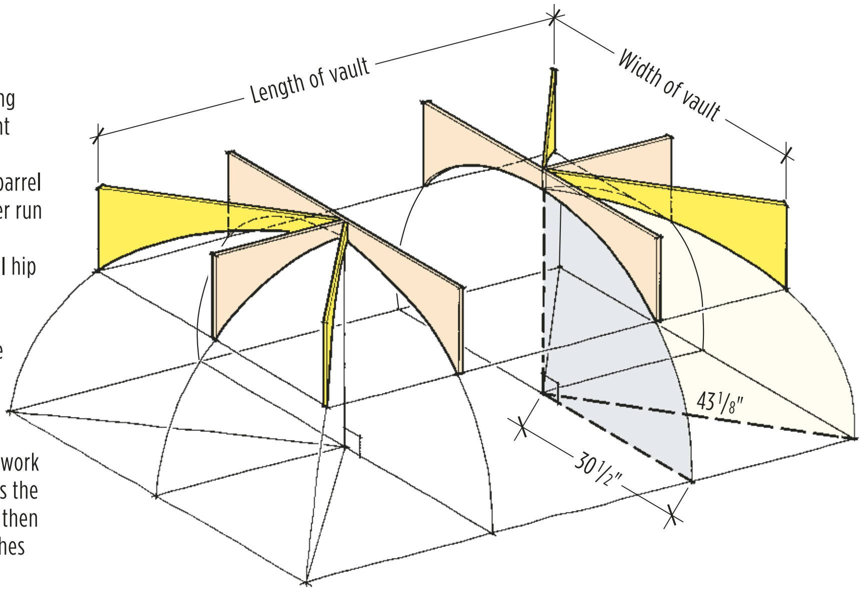
Laying Out the Elliptical Hips

1

The "common rafters" of the barrel-vault ceiling featured in this article form a 12"-high segment of a circle with a radius of 30 1/2". The "hips" are elliptical, and extend from the end of the barrel at 45-degree angles. Just as a regular hip rafter run can be found by multiplying the common run by the square root of 2, the run of the elliptical hip is 30 1/2 x $\sqrt{2}$, or 43 1/8".

These two numbers — the circle radius and the hip run — are the basis for the minor and major axes needed to scribe the ellipse.

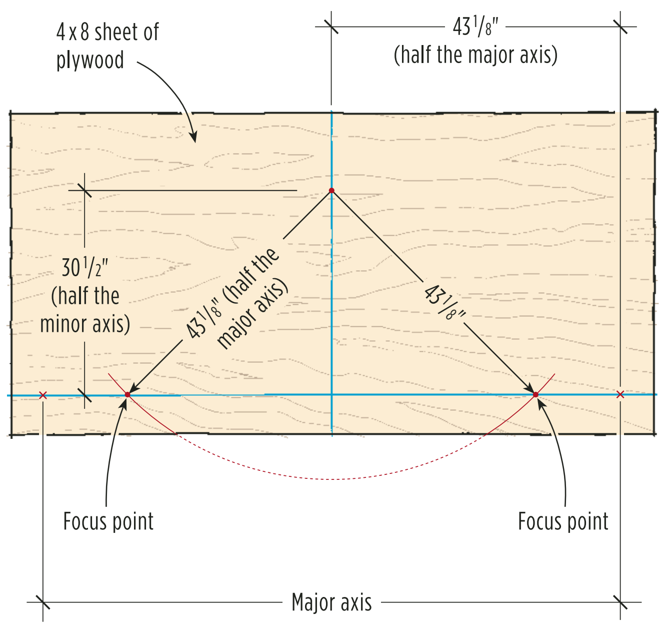
Note that for laying out this elliptical hip, you work from the full diameter of the circle that defines the ceiling's shape. After the ellipse is drawn, you then use only the top 12" of the ellipse, which matches the actual height of the vault.



2

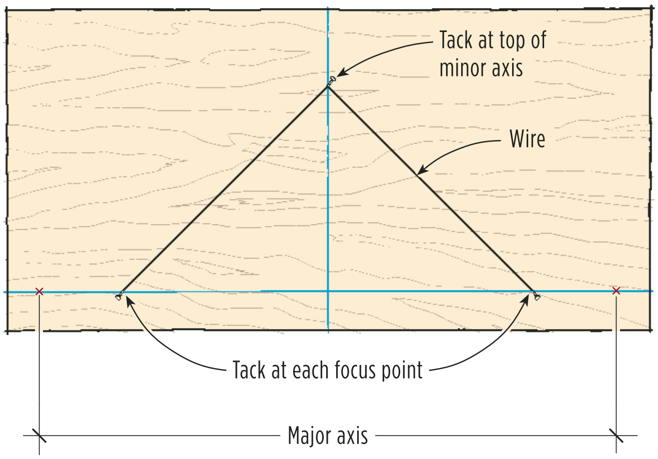
Two numbers are required for laying out an ellipse: the major axis (the length of the ellipse) and the minor axis (its overall height). In this case the major axis is twice the run of the elliptical hip, and the minor axis is the diameter of the circle that defines the vault. But for scribing what's essentially an elliptical arch, as in this case, you use half of each number — the 30 1/2" radius and the 43 1/8" hip run.

After snapping perpendicular lines to represent the major and minor axes, measure 30 1/2" up the minor axis to locate the top of the ellipse. Using that as a fixed point, swing two 43 1/8" arcs across the major axis to locate the focus points.



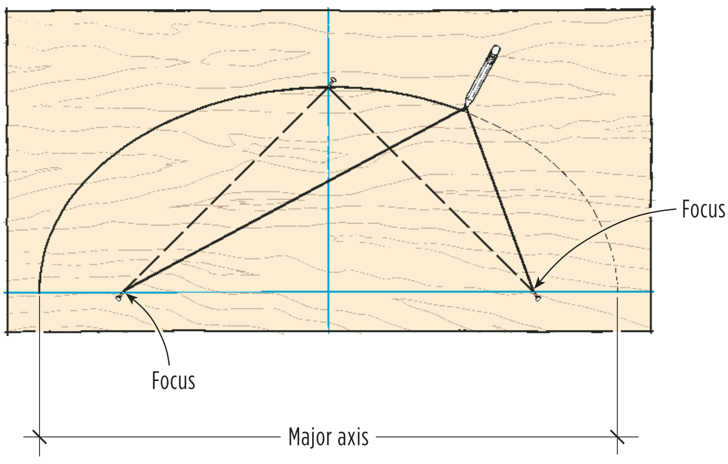
3

Picture-hanging wire works well for scribing an ellipse because it doesn't stretch like string does. Put a tack at each focus point and at the top of the minor axis, then run the wire from focus point to focus point over the top tack.



4

Pull the top tack, then scribe the ellipse by pressing a pencil firmly against the wire and pushing it from one end of the major axis to the other.



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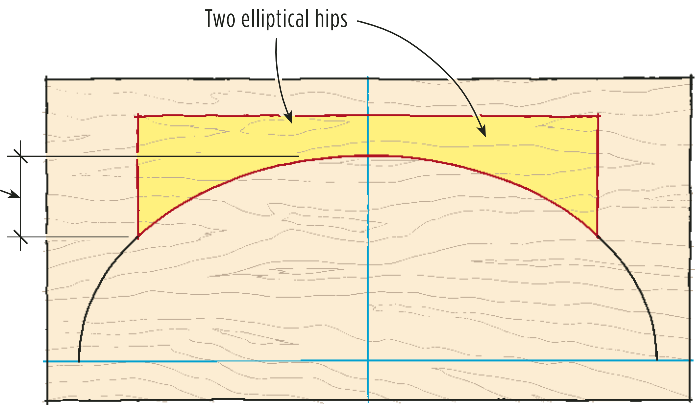
Because the barrel vault is 12" high, the elliptical hips are cut out of the top 12" of the ellipse. Cutting the "arch" in half yields two hips.



since you use half the major axis to locate the focus points that allow you to scribe the ellipse, 43 1/8 was the number we needed.

Scribing and Cutting the Ellipse

We used picture-hanging wire rather than string to scribe the ellipse. We made sure to stretch it very tightly over the nail at the top of the minor axis when securing it to the nails at the two focus points. The final step was to pull the nail from the minor axis, then slide a pencil against the taut wire to scribe the curve (Figure 5).

Because the arch segments for the vault were 12 inches high, we needed only the top 12 inches of the elliptical arcs. This curve was flat enough to cut with a circular saw (Figure 6, next page). To save time, we doubled up the plywood and cut two arches at the same time, then cut those in half to get the four hip pieces.

Putting the Pieces Together

Before building the vault, we needed to know the length of the barrel section. Again, I treated the opening as a hip roof, dividing the width of the vault in half (48 1/2 inches ÷ 2) and measuring that distance

Figure 5. After pulling the temporary tack, a carpenter inserts a pencil where the picture wire passes over the top of the minor axis (left). He then scribes the ellipse by sliding the pencil firmly against the wire, which he is careful to keep taut (below).

Figure 6. In this case, the elliptical curve is shallow enough to be cut with a circular saw. Only the top 12 inches of the ellipse — the height of the barrel — is needed.

Figure 7. The barrel portion — or the arch — is framed like an arched door opening with flat 2x4 purlins sandwiched between curved plywood pieces (left). This barrel was small enough to be lifted into place by two men (below).

in from each end of the opening.

Because it was small enough to be lifted into place easily, we built the barrel — basically flat 2x4 "purlins" sandwiched between a pair of $^1/_2$-inch plywood arches at each end — on a bench (Figure 7). We nailed temporary 2x4 cleats across each end of the barrel, high enough up so they would land on the top of the framing and support the barrel while we positioned it and nailed it off. This barrel was small enough for two guys to handle; we've framed some that took six guys to lift.

Once the barrel was up, we installed the king commons and the elliptical hips, checking for alignment with a 4-foot level (Figure 8, next page).

End purlins. Though the purlins in the middle of the vault were cut square, the ones at the ends had to be compound beveled where they hit the hips

Figure 8. After the barrel is positioned (left), the king common and the elliptical "hip" are installed. Here, a carpenter uses a straightedge to verify that the barrel surfaces are in the same plane as the hip end (below).

Figure 9. The purlins at the ends of the vault have straight cuts on one end and compound miters on the other.

(Figure 9). To get the miters and bevels, I simply held up a test piece where the lowest purlin would go and scribed the miter. Then I eyeballed the bevel and made the cut. After a couple of tries, I got it to fit and used a Speed Square to measure the two angles.

I knew the very top purlin would have a 45-degree miter with a 0-degree bevel, and I now knew the compound angle for the bottom piece. So, to get the angles for the rest of the purlins, I took the difference between the top and bottom angles and divided by the number of purlins. This gave me the number of degrees by which the bevel and miter angles would change as the purlins moved up the vault.

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