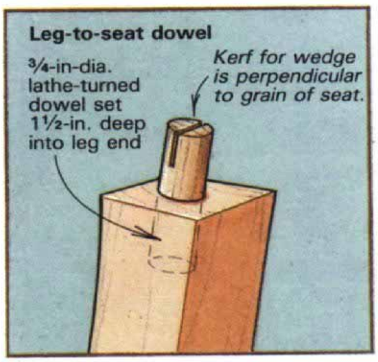
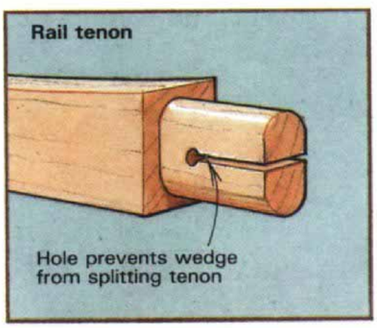
Building a Stool

Compound angled joints on drill press and tablesaw

by Gary Rogowski

Fig. 1: Rogowski's stool





It was not in the sometimes-a-great-notion category that I decided to build a stool a few years ago. I needed something sturdy to sit on. "How hard could it be to knock out a stool?" I asked myself. My first attempt ended in a three-legged triumph of material over maker. It was astonishingly ugly and so precarious that you could sit on it only with great caution. It did hold a plant very nicely though.

In the process of building my first stool, I learned a basic lesson. Effort, not luck, and planning, not good intentions, are required to successfully build a piece of furniture. This involves a thoughtful approach to design, accurate drawings and careful construction. Gone is the innocent notion that one relaxing weekend of humming and puttering is enough to concoct a piece with style, grace and strength. So, I started over.

Designing a chair or stool is a deceptive task, like setting up a model train. Kind thoughts blessed with the vision of an innocent invariably produce some degree of frustration. It only looks simple. You soon find the job involves more work than you expected. The process is a lot like designing other types of furniture in that it involves solving a series of problems, both aesthetically and structurally. Stools do present unique design difficulties, however. A stool's parts must strike a delicate balance between looks and weight. Stools look jaunty compared to chairs, are comparatively lighter and easier to move. Yet, looks can't come at the expense of strength. Thus, a stool is built with the strength of a timber-frame house even though its airiness gives the impression it is built of matchsticks.

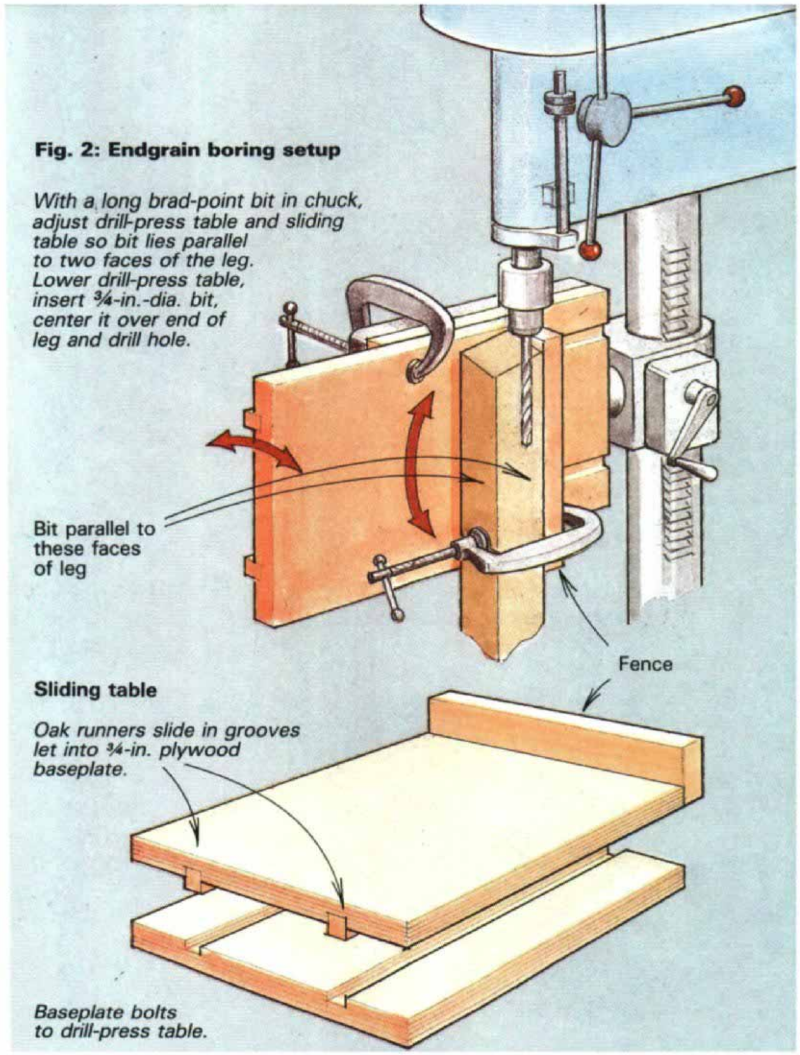
As if this didn't present enough of a challenge, recall that, by design, stools are meant to put you high off the floor or close to it. Generally, the former design is more popular because there are more reasons in this world for sitting at workbenches, counters and bars than there are for sitting a few inches off the ground. Thus, stools are generally higher than chairs and narrower in front and side profile. This makes for a weight distribution problem. Chairs are comparatively wider and more stable, so their legs can be perpendicular to or angled from the seat. Stools need all the stability they can get, are more stable and look best if their legs are splayed (i.e. they slope at a compound angle). A stool with splayed legs distributes a person's weight over a greater area than one with legs perpendicular to the seat. Thus, a person sitting on a stool with splayed legs must tip through a greater arc before falling over.

Splayed legs help, but don't entirely solve the stability problem. A stool's stability and attractiveness rely heavily on its proportions. In my case, these were quickly arrived at through an empirical method. I wanted to sit comfortably at my workbench and knew that chair height, about 17 in. or 18 in., would be too low. I put a chair on top of bricks, placed phone books on its seat and finally, sat myself on top of the phone books. I discovered the correct seat height was about 25 in. With the stool's height established, I went to the drawing board and made a series of drawings at ¼ in. scale, experimenting with various leg angles and spacing arrangements. I finally decided to locate the legs so they were 12 in. apart at the base and sloping 82°. Given the stool's height, the slope of the legs looked just right. I used a sliding protractor to copy the angle of the legs off the drawing.

Angled joinery—It soon occurred to me that although the sloping legs add to a stool's attractiveness and stability, they presented quite a challenge in joining together its parts—both in terms of rung-to-leg and leg-to-seat joinery. This was particularly troublesome in my case because, being influenced by James Krenov's work, I wanted to use exposed mortise-and-tenon joinery throughout. This meant the eight rung mortises would have to be cut to compensate for the slope of the legs, and the tenons on the ends of the rungs would need sloping shoulders. Furthermore, the compound angle does funny things to the geometry of the legs. The footprint seen in figure 3 shows an exaggerated view of what happens. Fortunately, the gentle curve I added to the legs had no effect on the joinery, because the legs curve only on their outside surfaces and were shaped after the joints were cut.

Joining the seat to the legs seemed similarly tricky, but after some head scratching, this problem was easily solved by letting a lathe-turned dowel into the top of each leg (I explain how to do this below). A dowel joint eliminated the need to cut a tenon with compound-angled shoulders on the end of the leg.

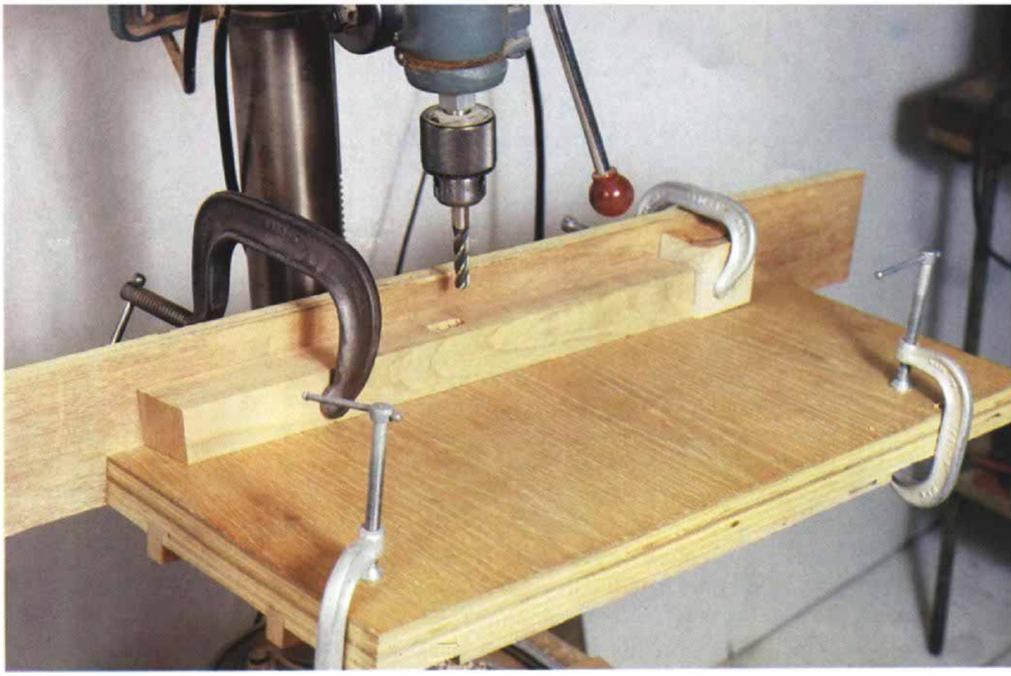
I started work on the stool by milling up my stock for the legs, rungs and seat. Cutting the compound angles on the ends of the legs seemed the trickiest job, so I started with them. I cut an accurate 8° compound angle on the ends of each leg on the tablesaw. With an extra-long fence on the miter gauge, I tilted the



blade over 8°, made a test cut and then checked it with the protractor. I repeated and tested the cuts until the saw cut a perfect 8° slope. To complete the compound angle, I set the miter gauge to 8°, make another test cut and check as before. When I can produce a perfect compound miter, I clamp a stop to the miter-gauge fence. Then, I cut one end, tip the miter gauge to 8° in the other direction, flip the leg over and cut the leg to finished length. Be sure to check that the top and bottom of the leg are parallel after it is cut to length.

To bore the dowel hole in the end of each leg, I clamp the leg to a vertical sliding table bolted to the drill-press table. The sliding table moves toward or away from the drill-press column (see figure 2, above). To ensure the leg is plumb to the bit, I swivel the drill-press table around until the leg butts up to a long brad-point bit chucked into the press, adjusting the drill-press table so the leg lies along the bit's length. I then reposition the sliding table so a second face on the leg lies along the bit's length (referencing off a face perpendicular to the first face). Once I'm sure the leg is plumb to the drill bit, I switch to a ¾-in.-dia. bit, center the leg's end under it and bore a 1½-in.-deep hole.

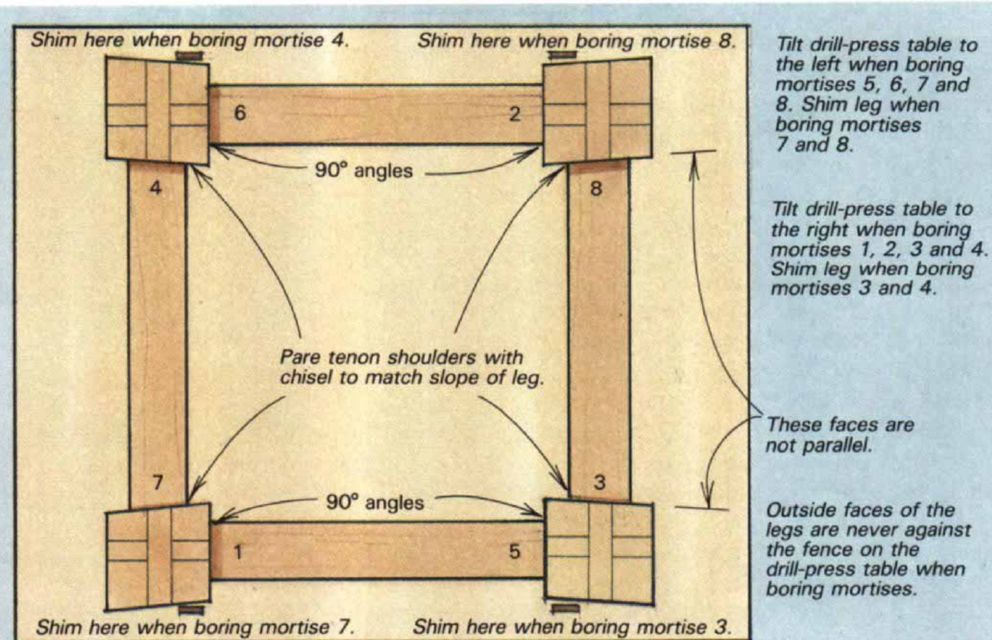
Next, I crosscut the rungs on the tablesaw with a plywood crosscutting jig with an 82° wedge tacked to its fence. With the wedge to the right of the blade and its narrow end pointed toward the" left, I cut one end of each rung. Then I positioned the stop block, flipped each rung over and cut it to length. Next, I lowered the blade and repositioned the stop block to cut the tenon shoulders. On each rung, I cut one shoulder, flipped the rung end for end and cut the shoulder on the opposite face. I then switched the wedge and stop block to the other side of



Tenons are cut square and then rounded with a file to fit the mortise, above. Their shape is checked with a template with a slot cut by the same end mill that bored the mortises. With addition of a shopmade sliding table, right, the author's drill press does double duty as a slot mortiser. Clamps under the table hold stop blocks to set length of mortises, which are first bored with a brad-point bit, then finished with an end mill. The sliding table is sloped to the left or right to angle the mortises, accounting for the legs' slope. A test leg to establish table angle and locate stops is shown in place.

Fig. 3: Boring mortises

This diagram of the legs and rungs, viewed from above, shows the geometric relationship between them. Since the legs lean in at a compound angle, they're diamond shaped in cross section. The rails are parallel to the seat and floor. The tenons on the rails and mortises in the legs must accommodate the diamond-shaped section of the legs. Rogowski put shims under the legs when boring four of the mortises and shaved the shoulders on the matching tenons.



the blade and repeated the procedure to cut the remaining two shoulders.

Next, I roughed out each tenon cheek on the bandsaw to prevent the offcut from flying back at me and finished sawing the tenon with a tenon jig on the tablesaw. Back at the bandsaw, each tenon was trimmed on its top and bottom edge to give it a shoulder on all four sides. Shoulders of two rungs must be pared, as described in figure 3, to compensate for the slight diamond shape of the legs. The tenons were rounded with a file to match the curve of the mortise and each was slotted on the bandsaw to receive a wedge. A $\frac{3}{16}$-in. hole was bored at the bottom of the slot to prevent the wedge from splitting the tenon.

Drill-press mortising—I moved on to cutting the leg mortises. I don't own a slot mortiser, but have the next best thing—a horizontal sliding table for my drill press (see photo above, right). I set the table's angle for the sloping mortises using the angle on a rung end as a guide. I chucked a long drill bit into the drill press to serve as a positioning guide, stood the rung up on the table, tipping the table until the rung laid flat against the drill bit.

Without changing the drill-press alignment, I removed the drill bit and chucked a four-flute end mill into the drill press. The end mill badly mauled a test leg at every speed I tried. The remedy was to bore out the bulk of the mortises with a brad-point bit. The mortises were cleaned up taking shallow passes with the end mill, running the drill press at 1,600 RPM. In boring with both the brad-point bit and the end mill, I prefer to stop $\frac{1}{16}$ in. or so shy of boring out the other side of the mortise. The leg's outside is shaped after the mortises are cut, so the remaining wood is cut away, leaving a clean opening. If you bore through the other side, you will have to put a piece of scrap under the leg to keep from cutting into your sliding table; you also risk tearing out the exit hole. The final shaping may not be able to remove the tearout if it's too severe. Mortises 1, 2, 3 and 4 are cut with the table sloping to the right; mortises *5, 6, 7* and 8 are cut with the table sloping to the left, as shown above. Remember to mark the table for two different sets of stops for boring the upper and lower rung mortises. When boring for mortises 3, 4, *7* and 8, I had to

Fitting rungs

by Jeremy Singley

I wish I had an extra 10 minutes for every time my mother told me not to tip back in my chair. I could retire. Mothers know a chair or stool's rungs are its weakest link; to the woodworker, rungs are a pain in the neck.

Not only do rungs have to fit tightly to the leg, in some cases they have to fit tightly to each other—double jeopardy. This requires rung holes be bored in the leg at the correct angles and cut to an accurate length. If these requirements aren't met, the assembled stool or chair will have legs sloping at different angles.

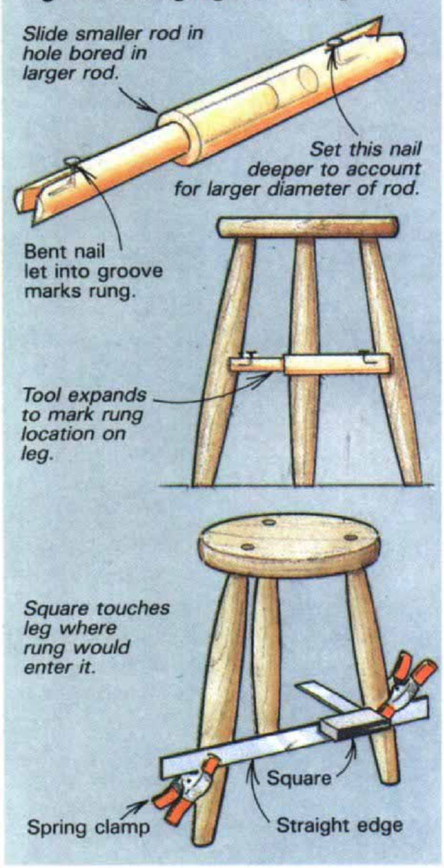
Fortunately, I've developed a bunch of techniques and jigs to make the job of fitting rungs to legs easier. For example, when I have just one or two stools to build, I bore the leg holes in the seat with a hand drill sighting along a sliding bevel gauge set to a leg axis line as a guide. I dry assemble the legs to the seat, then eyeball the alignment of the rung holes. The rungs are bored from inside the legs with an electric drill. If the room between the legs isn't enough to accommodate the drill and a full-length bit, I use a ground-off Powerbore, spade or twist bit.

The tricky part here is getting the rung holes centered. I solve this problem with a marking tool or a try square and straightedge, shown in figure 7. I bore on the marks and measure for rung length. I check that the legs are the correct distance between their ends, use an extension rule with a sliding tongue to measure the distance from the shoulder of one hole to the bottom of another, then add the depth of the second hole. If you find reading the ruler in this situation awkward, you can simply measure the depth of each hole and then measure the span between them. The rung stock is cut to this length, and its ends are shrunk to a snug fit with a heat lamp just prior to turning and reshrunk just before the stool is assembled. The tenons swell from the moisture in the glue, locking them firmly in their holes.

The eyeball rung-boring method works if you have only a few stools to build; if you have a large batch, it pays to set up a jig.

It's crucial to keep the legs organized as you bore. A box of 50 unmarked legs with two rung holes in each makes a fine solution to the leisure-time problem—you can spend your day off sorting legs. To avoid this, before each leg leaves the jig, I mark its end with a number from one to four, corresponding to the four clockwise designations of leg positions: 1—front left; 2—front right; 3—rear left; and 4—rear right. This system assumes the stool is flipped over (the position it will be assembled in) so its left, front leg becomes the leg sticking up at the left rear. I use a color code to keep track of rungs. I crosscut boards and paint their ends a color to match rung length. No further coding is necessary, because turned rungs are not handed—a top rung that fits on the right side of the stool would also fit the left side. Then I rip the boards into rung blanks.

Fig. 7: Marking legs for boring



A final question: What do you do if you botch a rung hole? First, act innocent. Why bother the world with more bad news than it has already? Usually, turning a new leg is more work than the following alternatives. If the hole location is wrong and you plan to paint the stool, simply fill the hole with a plug and sand it flush. If the angle is wrong, turn a rung and then whittle the oversized tenon at an angle by eye to fit the hole (see figure 8, below). You can also glue a lathe-turned dowel into the hole and rebore. Since you have to bore the new hole exactly on the center of the dowel, position the plug with the tail center mark facing up and bore into the center mark with a brad-point bit. □

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Fig. 8: Leg-boring jig

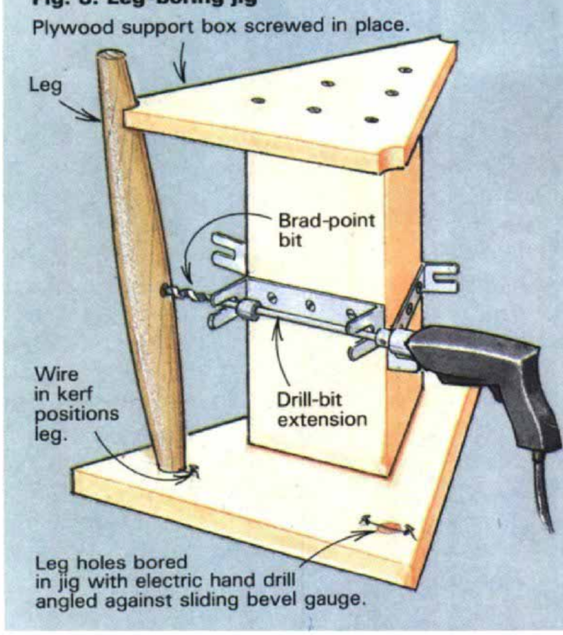
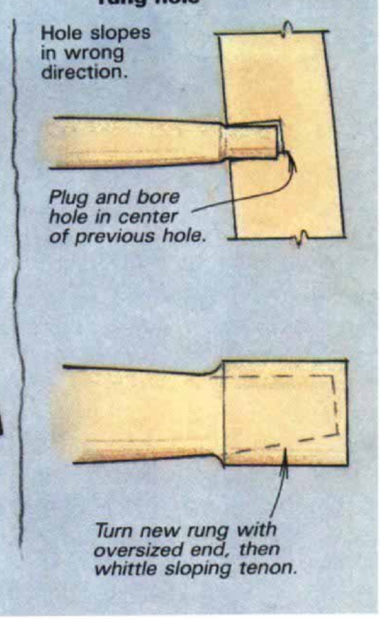
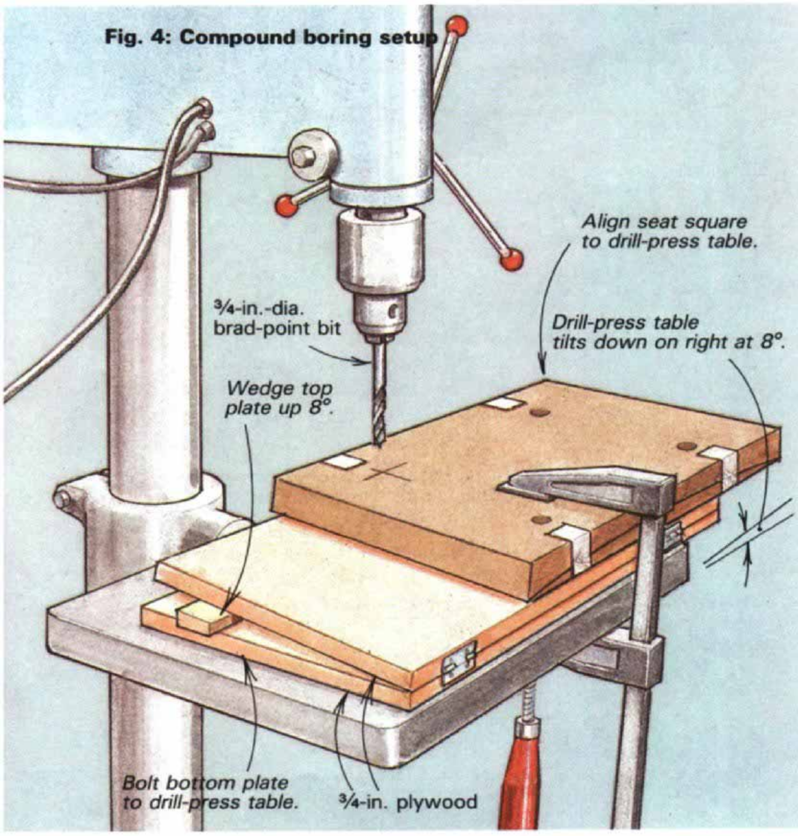


Fig. 9: Fixing a botched rung hole



The curves on the outside of the legs are roughed out on the bandsaw and then cleaned up with a straight bit and template on the router table. Note that the template curves in two planes to accommodate the curve routed during the first pass. Always test such a setup before trying an actual leg.



shim the legs with a slip of paper under the rear, back edge to compensate for the compound slope of the legs.

With the setup fine-tuned, I cut the mortises and moved on to shaping the legs. Working from a full-size drawing of the stool, I made Masonite templates shaped to the curve of the legs and seat. I transfered the marks from the Masonite leg template to one made of alder, which I curved in depth and plan view (see photo, above) to match the curve of the legs. I marked the legs out, rough sawed them on the bandsaw, then taped the template on top of one leg and finish shaped it on the router table with a straight bit and ball-bearing pilot bearing against the template. I then flipped the .leg over 90° and used the alder template to guide the straight bit while cutting the second curve. As can be seen in the photo, the curve in the template's depth accommodates the first curve cut in the leg.

I sand the legs and rungs before assembly because it's impossible to do a quick and neat job after the legs are assembled. There is no way of simultaneously assembling all four legs and rungs on a stool single-handedly. Because I work by myself, I had to glue and clamp the stool in subassemblies. I glued up the front and back pairs of legs and rungs (the legs perpendicular to the long axis of the seat) and hammered the wedges into the tenons. When the glue was dry, I inserted the remaining two rungs and then glued and clamped the two pairs together.

Seat shaping—I was moving into the homestretch and started work on the seat. To save time shaping, I wanted to saw out the curve in the seat, but my bandsaw wasn't large enough to accept the seat blank turned up on edge. I solved this by making the seat from two narrower halves; I sawed the curve in each half then glued them together. I don't cut to the curved line, but leave a slight amount of wood to allow for tearout when boring the leg holes. Save the curved offcuts, you'll need them later to back up the seat when you bore the holes through it.

To mark for boring, I set dowel centers into the top of each leg, placed the seat top down on the bench and set the legs with dowel centers against the seat's bottom. After checking that the seat was positioned correctly relative to the leg, I tapped on top of each leg to mark the seat bottom and then returned to the drill press.

I use a hinged jig that bolts to the drill-press table to bore the leg holes (see figure 4). This is simply two pieces of plywood connected by a piano or butt hinges. The jig is placed with the hinge knuckle opposite the drill-press column and the jig's edge parallel to the drill-press table. The top plate is wedged up from underneath until it's at an 8° slope, then clamped in place so the wedges can't move. Next, I tilt the table 8° to the left or right, using a rung, as before, to align the table relative to the bit. I rest the seat top down on the table with the offcuts taped together underneath the seat. The brad-point bit enters the offcuts as it exits the seat, reducing tearout on the top of the seat. The seat is parallel to the edge of the jig.

Assembly is relatively easy compared to the rest of the project, but it takes considerable clamping force to bring the stool parts together. I set concrete blocks on the shop floor and then put a piece of plywood that is slightly larger than the area covered by the stool's base on top of the blocks. I set the legs on top of the plywood and the seat on top of the legs, then rest cauls on the seat's long axis (the cauls are notched to allow the leg dowels to project through the seat). I bring the seat and legs together with bar clamps running from the plywood to the cauls. I have to flex the legs a few degrees to get them into the holes; this requires a fair amount of force. Once the legs fit in the holes, a generous amount of clamping pressure is required to bring the legs and seat together. Once the legs butt up to the seat, I take the clamps off, spread some glue on the wedges and bang them in place.

After the glue has dried, I file down the seat dowels and spokeshave and sand the seat to its final curve. I file down any remaining projecting tenons. I lightly sand any areas that require it and then finish the stool with Watco or a similar oil. I prefer oil finishes because stools are prone to being roughly handled, and oil finishes are easy to retouch.

Through the years, I have made a number of variations of these stools to suit the customer's needs. Their heights have ranged from 24 in. to 27 in. and with different rung heights, but I haven't changed the basic design; neither have I changed my attitude toward building them—another relaxing, uncomplicated weekend project. I'll get started after brunch. □

Gary Rogowski builds stools and other intriguing projects in his Portland, Ore. shop.