Production Chairmaking

Jigs and loose tenons simplify angled joinery

by Terry Moore

Chairmaking seems to intimidate many an accomplished craftsman. I must admit, I shied away from all that angled joinery for years. However, my fears subsided when I eventually realized that people were buying someone else's chairs to go with my tables and desks and there was a risk that those chairs might detract from the beauty of my work. My other consideration was financial: I was losing money by letting all the chairmaking work go to other craftsmen.

Fussing with the angled joints in a typical chair can be a costly chore for many builders, but I simplified the process by basing the joinery on loose tenons, as shown in figure 1 on the facing page. After the parts are shaped, I cut mortises in both halves of each joint, and then join the two pieces with a loose tenon. Angled mortises are easily and accurately cut on the slot mortiser, once it's fitted with a wedge-like fixture, as shown in the top photo on p. 42; the loose tenon stock is ripped out on the tablesaw and the edges rounded over with a router bit. The joints are strong and don't require a lot of hand-fitting. However, the real beauty of this system is that it doesn't constrain my design creativity. Since even the most complicated angled joints can be easily made, my hand is free to design the form most appealing to my eye.

Writing a plan—Before beginning construction, I make mil-size drawings of my chair and mentally formulate a preliminary step-by-step construction plan (see the sidebar on p. 45). I outline each step, including preparing the stock, cutting parts to length, mortising, milling tenon stock and assembling the piece, trying to anticipate any possible construction problems. I further refine my plan and modify procedures as needed when I build a prototype of the design. Once I'm actually ready to manufacture the set of chairs, most of the thinking work is finished and nearly all dimensions and angles can be picked up from the full-size drawing without using a ruler.

Photo: Thomas Ames, Jr.

The curved lines of this trestle table are complemented by the walnut chairs that Moore built with a series of jigs.

I begin production by planing, jointing and ripping stock for all the legs, seat rails and backs, as shown in figure 1. Extras of each part are prepared to avoid having to reset machines to remake damaged or defective pieces. Except for the profile shape of the back legs, I leave all parts square and parallel until the joints have been machined.

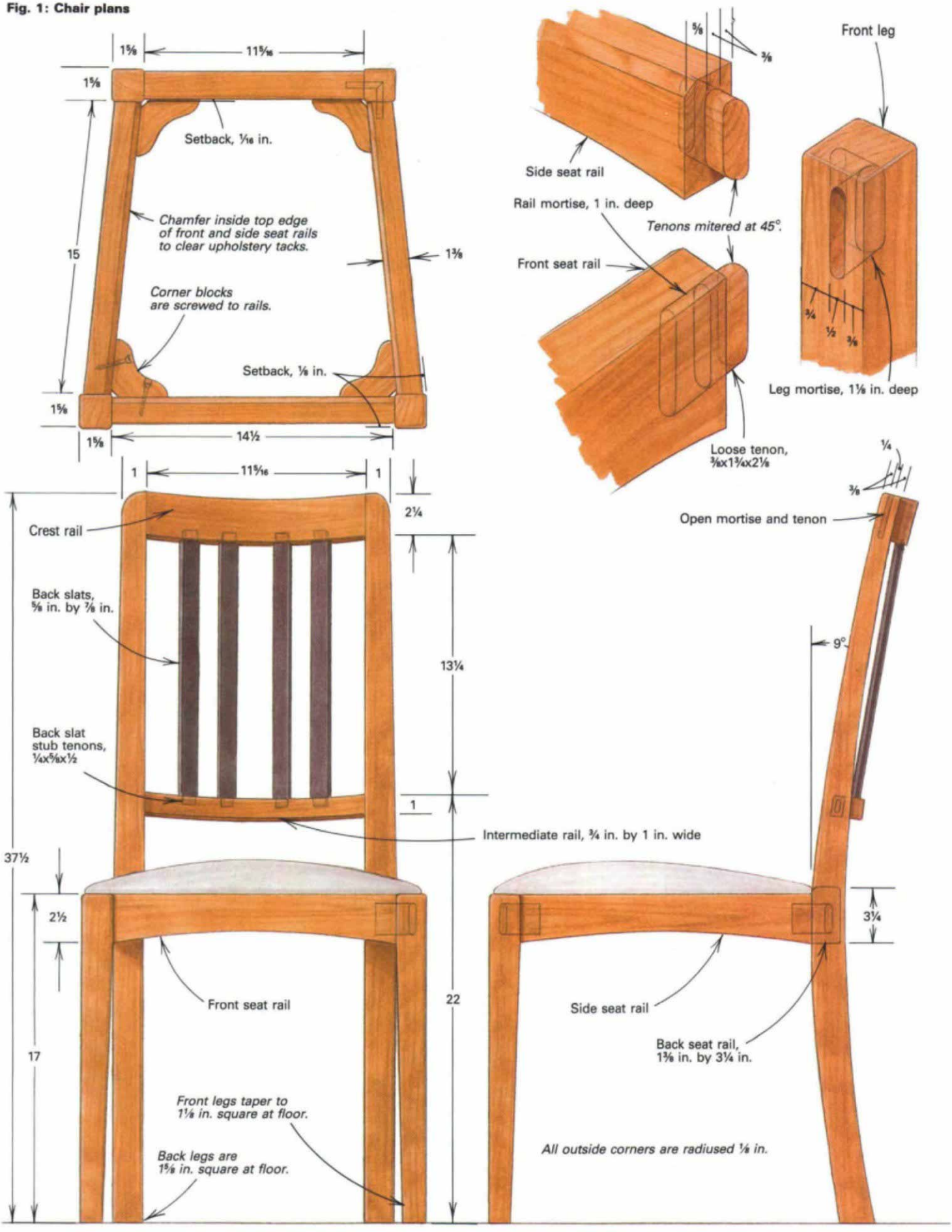
The 1⅝-in.-square blanks for the front legs are simply ripped and planed from ⅝ stock and crosscut to 17 in. using a miter gauge on my tablesaw. Stock for three of the seat rails on each chair is ripped and planed 1⅜ in. by 2½ in.; the back seat rail is cut 1⅜ in. by 3¼ in., wide enough to cover the back edge of the seat cushion. The stock for each crest rail and intermediate rail is planed on one side and jointed to 1¾ in. by 2½ in. Using a plywood pattern, lay out as many pairs of back legs as possible on a single piece of 1⅝-in.-thick stock. By choosing the widest stock available, you can orient the pattern so the grain follows the leg's shape and still make the most economical use of the board. The "waste" from cutting the back legs may be used later for back slats, thus ensuring that the grain and color will match throughout.

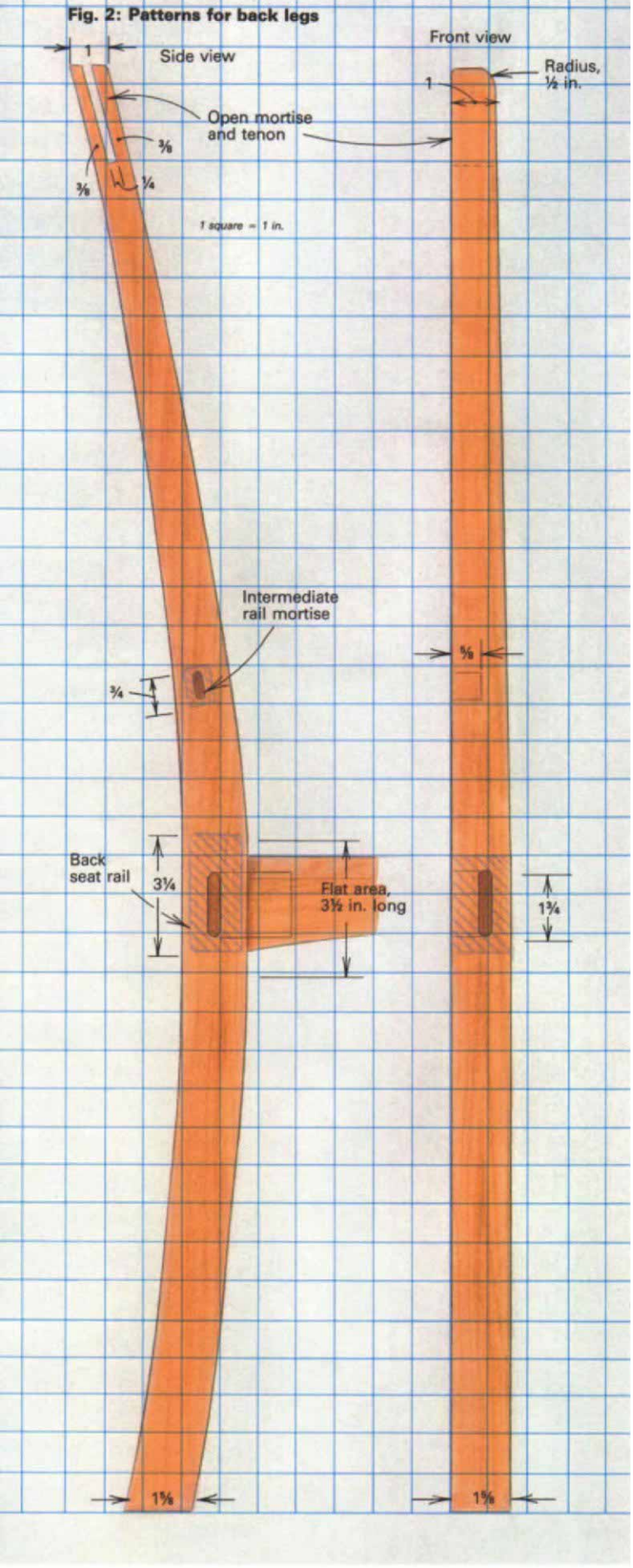
Shaping from patterns and jigs—Working with patterns and jigs eliminates the need to measure, so I can almost put my ruler away. The back legs, for example, are laid out with a ¼-in. plywood pattern, shown in figure 2 on p. 42, which was taken from the full-scale drawing. The pattern has a mark that, when transferred to the stock, aligns the roughsawn leg to my profile shaping jig (shown in the bottom photo on p. 42). After bandsawing the legs to within 1/16 in. of the pattern line, I clamp them in the profile jig and run the assembly over my shaper to finish the curve shown in the drawing.

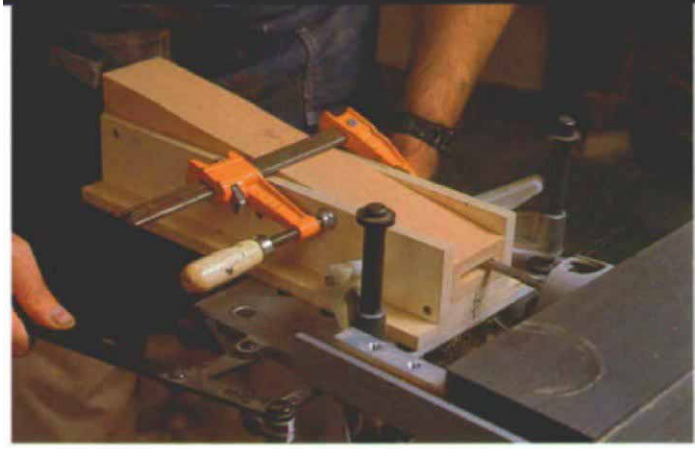
The shaper operation is straightforward. The jig holds the roughsawn back leg securely, while the jig's front edge, which is actually a profile template of the finished leg, follows a guide collar fit in the shaper's table. As the jig's template is run across

Drawings: Roland Wolf/Bob La Pointe

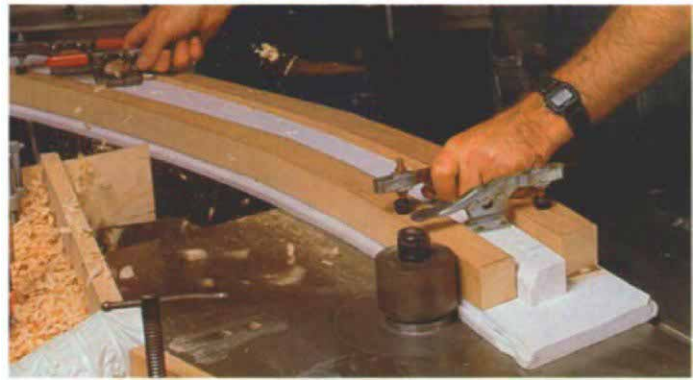
Fig. 1: Chair plans







To cut angled mortises on the ends of the side rails, the author equips his slot mortiser with the auxiliary fixture shown. Note how the centerlines of the fixture and table align during the cut.



To shape the back legs, Moore clamps both roughsawn pieces to a jig that rides on the stationary collar in the shaper. The guard has been removed for the photograph.

the collar, the shaper's straight cutter precisely finishes the leg's profile. Because my shaper's collar is smaller than the cutter, the jig template must be larger than the finished back leg. If you don't have a shaper, you can clamp the back leg in a vise and shape it with a 2½-HP to 3-HP router using a straight bit and bearing that follows a template.

A back leg sizing jig, which looks a lot like the back leg shaping jig, is clamped to the fence on my radial-arm saw to secure the rear leg at the proper angle while it's cut to length.

Angled tenons and straight mortises—My mortising system, which is based almost entirely on machines, relies on 90° mortises cut in legs and loose tenons fit into angled mortises in side rails. Gluing these tenons into the rail mortises in effect creates an angled tenon that is very strong because it doesn't have any weak, short grain areas possible on tenons cut at an angle. Both leg and rail mortises are cut to the same width on my Inca slot mortiser (available from Garrett Wade, 161 Ave. of the Americas, New York, N.Y. 10013; 800-221-2942, in N.Y. 212-807-1757), although other mortising machines or a router will work. Since the mortises are cut to uniform width and depth, tenon stock can be milled to uniform thickness and width and rounded over with a router bit. For strength, the tenons meet in a miter, shown in the loose tenon detail in figure 1 on the previous page, which strengthens the joint more than one long and one short tenon would.

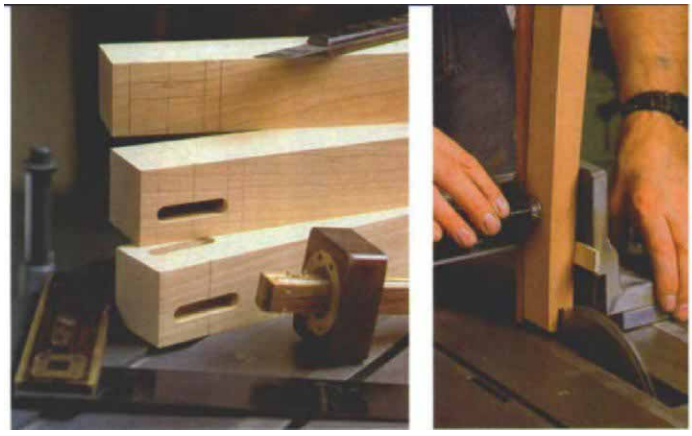
Once I've laid out the first mortise of each batch of parts and set up the machine, my job is similar to that of a production worker. When you get the first rail of a batch to fit accurately, the rest are easy. The mortises are laid out on the rail ends with a ⅜-in. shoulder at the top, bottom and outside, and a ⅝-in. shoulder on the inside. The mortising of the front and back legs and front and back

rails, which join the legs squarely, is done directly on the slot mortiser table, which is set at 90°. I use an auxiliary side rail fixture, which is shown in the top photo on the previous page, to align each end of the side rails to mill 7° angled mortises. The side rail mortising fixture is quicker to set up and more accurate than changing the angle of the mortiser table. The rail fits snugly on the fixture's 7° bed, which supports the rail so its end is perpendicular to the cutter. After aligning the centerline on the fixture with the centerline on the table and clamping the fixture in place, the mortise width is set with the table-movement-limit levers. The table height can then be adjusted and the first side rail mortise bored.

The 1⅛-in.-deep leg mortises are laid out by holding the appropriate seat rail in position on the leg, tracing the outline of the rail and then marking the mortise. The mortise should be located about ⅜ in. from the top of the front leg and ½ in. from its outside face; this will set back the side and front rails about ⅛ in. Finally, mark the centerline of the back leg mortise, as shown on the three legs in the left photo at right, so you will be able to align the pieces on the mortiser table. Clamp the first leg to the table and adjust the stop collars in the mortiser table's surface so the remaining legs in the series can be accurately placed on the table. Then with the handwheel, set the table height in relation to the cutter, but leave the mortise width set the same as for the rails. After making sure the seat rail tenon fits the first mortise, you can mortise the remaining legs with the same setup by simply marking and aligning the mortise centerline.

After mortising the front and back legs and all four seat rails, I taper the front legs and cut and shape the curve in the bottom of the seat rails, as shown on the patterns in figure 3 below. The straight tapers, on the front legs are rough cut on the tablesaw, with a taper jig, and cleaned up on the jointer. Curves in seat rails are bandsawn from patterns and finished on the spindle shaper with jigs.

Chair backs and crest rails—The crest and intermediate rails are curved to conform to the roundness of the human back. Before sawing them to shape or cutting mortises in these rails for vertical back slats, I set up the tablesaw and cut the open mortise and tenon joint on the rail ends and on top of the back legs (see figure 1 on p. 41).



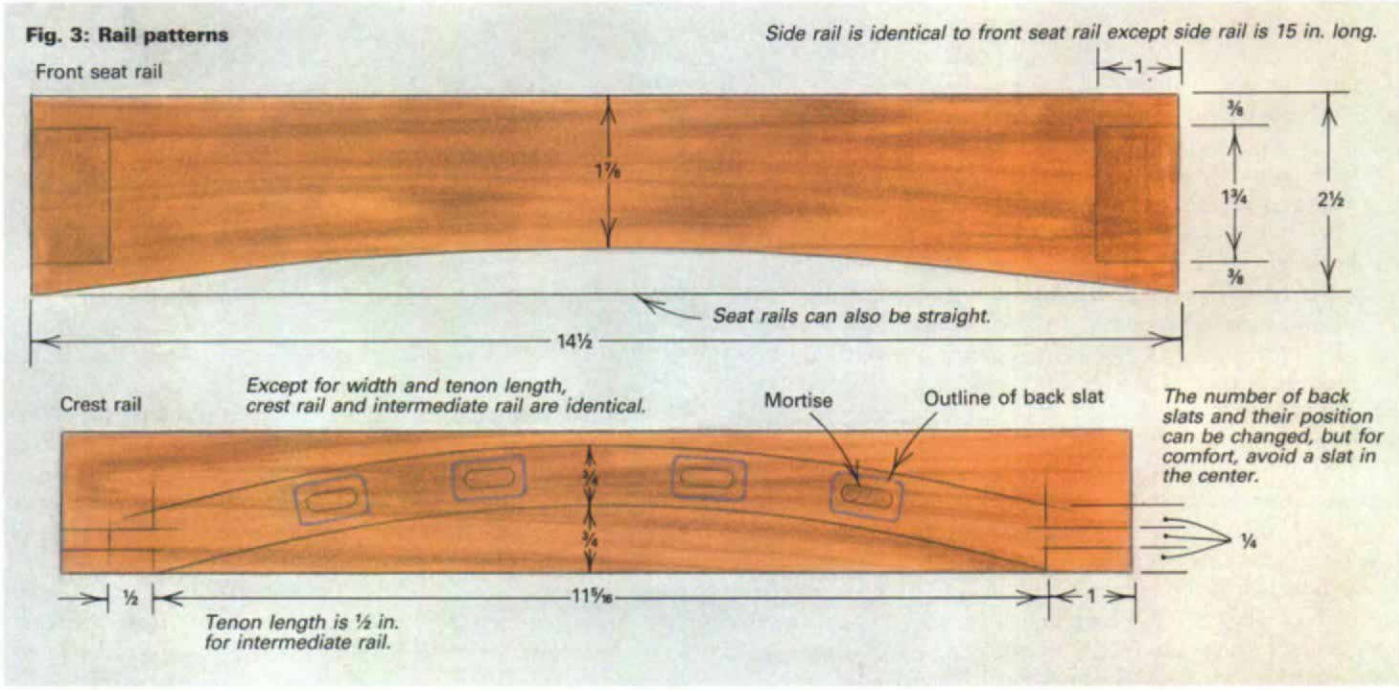
Left: Slot mortising is simple after careful preparation on the first leg (top). Moore has laid out the mortise on the joint's centerline. After cutting one (middle) and checking its fit, he can mortise the remaining legs by using only a centerline for reference (bottom).

Right: The author cuts the ¼-in. open mortise in the top of the back leg with a tenon jig on the tablesaw. After squaring the leg's end to the table, a shim is temporarily taped to the jig to align the remaining legs.

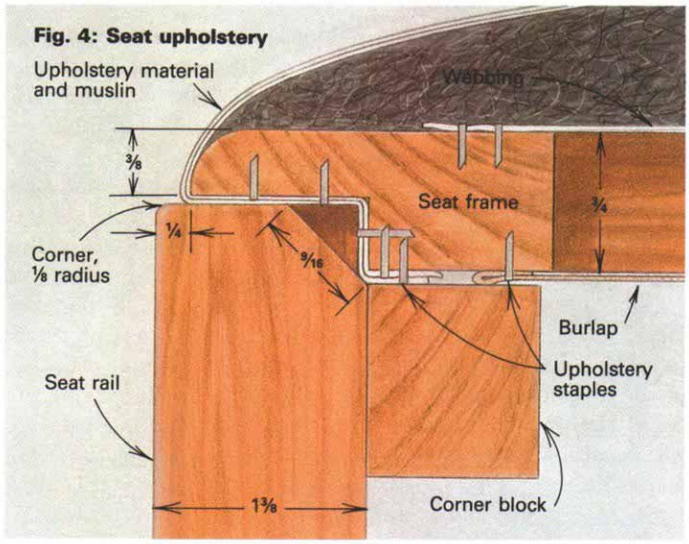
I use the tablesaw tenon jig and a dado blade to cut both back leg mortises as well as the shoulders on the crest- and intermediate-rail tenons. I set the blade 90° to the table and angle the back leg in the tenon jig to cut the open mortise parallel to the front of the back leg. Use a try square to check that the front line of the crest rail mortise is perpendicular to the saw's table, and tape a shim to the tenon jig, between it and the leg, as shown in the right photo above. If the setup is correct, cut the mortises in the top of all the back legs.

Then, in order to cut straight, parallel tenons on the crest and intermediate rails, remove the shim and reset the jig. Since the crest rail stock is still straight and unshaped, it's simply clamped in the jig perpendicular to the saw's table. You can eliminate considerable handwork and ensure that each intermediate rail will be of uniform curve if you use stock wide enough for two rails. I simply cut both crest rails and intermediate rails to the same dimensions, and then cut a single, continuous tenon on both ends of the stock; later I rip an extra crest rail in half to

Fig. 3: Rail patterns



The author mortises the crest and intermediate rails to accept the back slats with this simple plunge-router jig. Each shaped rail is fit into the curved slot in the jig and the whole assembly is clamped in a vise; the slots shown guide the router's collar during the cut.



produce the two intermediate rails.

Next, lay out the curve in the crest and intermediate rails from the pattern in figure 3 (see the previous page) and bandsaw them to shape. After sawing to the line, I use a compass plane to true up the front, concave curve and a smoothing plane to finish the back, convex curve before scraping and sanding. Then I rip intermediate rails from crest rail stock, and cut their tenons to ½ in. long by ¾ in. wide, with a ⅛-in. shoulder on the top and bottom. In each case, check the first tenon's fit in a leg mortise before cutting the rest of the tenons. Leave the crest rail tenons full width.

Mortises on the inside of the back legs, for intermediate rails, are cut with a plunge router and a ¼-in. straight bit guided by a slot cut in the leg profile pattern. To shape the outside of the rear leg, which tapers from the top of the seat to the top of the leg, I trace the pattern, shown in figure 2 on p. 42, rough-cut the shape on the bandsaw and finish with jigs on the spindle shaper.

Back slat tenons and their mortises—I use a plunge router and simple jig to plunge-cut the mortises in the crest rail and intermediate rail to accept the stub tenons on the back slats. The router jig, shown in the photo above, registers and holds the curved crest and intermediate rail stock, while the router's collar is guided by the holes in the jig's thin plywood template. Locate the collar in the hole, and plunge a ¼-in. straight bit into the rail as you move the bit in the slot and gradually plunge-cut to the ½-in. mortise depth.

The back slat tenons must be angled—about 1½° for the intermediate rail and 4½° for the crest rail. To measure these angles, dry-assemble the back legs, intermediate rail and crest rail; then, hold a straightedge against the rails at the chair's centerline and set a bevel gauge to the angle between the rail edges and straightedge. I cut the tenons in one pass on the spindle shaper, which is set up with two straight ½-in. cutters separated by a ¼-in. spacer. The stock is supported during the cut by a sliding-table jig that rides in the table's slot. Begin with stock that is wide enough for multiple slats and cut the pieces to length. Wedge up the tail end of the stock in the jig until the end to be cut is at the proper angle to the cutter, and then clamp the stock against the jig's fence. Once a continuous tenon is cut in both ends of the back slat stock, the stock is ripped into multiple slats, which are rounded over and finished.

After the mortising and shaping is done, I crosscut and miter the loose tenon stock to length and glue the pieces into the rail mortises.

Assembling the chair—Before assembly, I round over all corners with a ⅛-in. radius bit, sand and carefully apply a sealer coat of Watco oil (available from Minwax Co., 102 Chestnut Ridge Plaza, Montvale, NJ. 07645), making sure not to get it on joint surfaces. Sealing with oil helps keep parts free of glue during assembly.

A systematic approach to assembly is a must. After a dry run to check the joinery for fit, I glue up the 90° joints first, which are the front and back subassemblies. The front subassembly is the two front legs and the front seat rail and the back subassembly is the two back legs, back seat rail and intermediate rail. The crest rail and back slats, because of the open mortise-and-tenon joint at the top of the back legs, are added later. Try to match wood color and grain during assembly and clean up glue with a damp rag as you go.

When the glue has dried, dry-fit the front and back subassemblies together with their side rails. Pare shoulders and tenons as needed to ensure a good fit and then gather tools and parts for final assembly: two bar or pipe clamps, some clamp pads and a damp rag. Working on one chair at a time, I glue the side rails to the back subassembly and then the front subassembly to the side rails, working quickly so any needed adjustments can be made before the glue sets up.

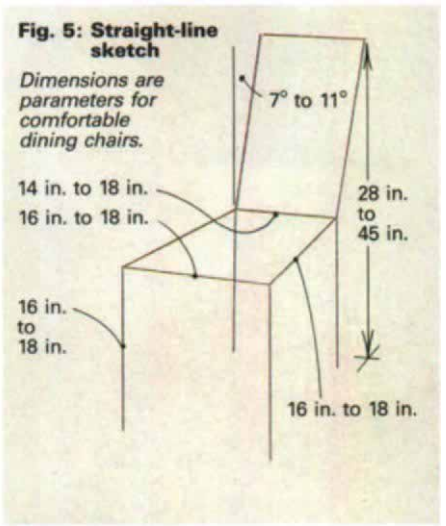
The chair isn't complete until I have installed corner blocks on the inside of the seat rail frame and made a slip cushion seat frame, which will be padded and covered. Since my chairs are built of strong components joined with well-fit mortises and tenons, corner blocks serve only to secure the seat. Regardless, they are tightly fit and fastened to the inside of the seat rails with screws.

Traditionally, the seat is an upholstered hardwood frame with webbing and horse-hair padding, but I use a piece of well-padded ¾-in. plywood on some chairs. For more on upholstering a seat, see *FWW* #79, pp. 78-81. I allow room for the fabric and padding, which is stapled to the underside of the slip cushion, by routing the inside of the seat frame, as shown in figure 4 at left, with a chamfering bit. While I apply the oil to the chair frame, I send the slip seat frame out to be upholstered.

Finally, place the chair on a flat surface, check if it sits flat on all four legs; if one leg is long, mark it and cut or sand it to length. Now you're ready to rump test it and move on to the next chair or set of chairs.

Terry Moore was brought to Newport, N.H., from Wales, Great Britain, as his wife's "souvenir" 15 years ago. He's been a cabinetmaker and furnituremaker there ever since.

Designing a chair



When I set out to develop this chair series, it was not my intention to design something new or flashy. I simply wanted to develop a sound construction process that would leave the final design of the chair variable. When designing chairs, you must reconcile comfort, strength and aesthetics, but my foremost consideration is comfort. After all, if a chair isn't comfortable, its design fails. Secondly, it must be strong and durable, or it will fall apart. And if the chair isn't attractive, nobody will want it in their home. All three aspects are important and must be dealt with.

I studied dining chair comfort by analyzing and critiquing many different types of chairs and querying other adults of various sizes about their comfort requirements. The results of my research are the parameters listed for the chair in figure 5 above. The height of the back, often an aesthetic consideration, can be as little as 28 in., as in a Sam Maloof type low-back chair, or as great as 45 in., as in a Charles Rennie Mackintosh type high-back chair. My dining chairs have higher-than-average backs to provide comfort and upper-back support when reclining after a meal.

Once I established basic seat dimensions, I studied how other chairmakers blend comfort with aesthetics and sturdy construction. Excellent sources of information and inspiration were museums and galleries. I brought a measuring rule and notebook and remembered to ask permission before taking measurements. Taking special note of what I liked and disliked about a particular design, I tried not to be intimidated by what I saw while making rough sketches of designs and noting construction details.

At the drawing board: With sketches in my notebook and ideas fresh in my head, I drew simple, straight-line sketches, such as those in figure 5. Once I liked the basic dimensions, I refined the lines so the chair would blend with its accompanying table. Then I worked the simple sketches into detailed, measured drawings, like those in figure 1 on p. 41, with side and front elevations and a plan of the seat, along with any curvature designed into the back. At this point it's not necessary to draw many construction details, except you must remember to provide enough wood for joint construction and to show joints that will be visible, such as the open mortise and tenon at the top of the back legs in figure 1.

The crest rail, along with the space beneath it and the seat, is the designer's focal point of the chair. The chairs in the photo below are from the same design series, but each have different backs. In each successful variation, every aspect of the design must blend together to convey consistency.

Full-size drawings and prototypes: My last design steps are to draw the chair full size to show the front, side and plan views as well as joinery details. Full-size drawings have X-ray details of joints; unless I need to visualize construction details, I don't bother with perspective drawings.

Before building a prototype, I pick up patterns, dimensions, angles and joinery details from the full-size drawings, as well as information to design jigs and fixtures that make construction faster and more accurate.

I build the prototype from oak with the exact dimensions and joinery details as shown on the full-scale design. The chair isn't a mock-up, built of glued-together cheap material; it's identical to finished chairs in every detail, so it becomes a tool for working out assembly details. I use the prototype's disassembled parts to set up machines for difficult cuts and to test my assembly procedures. Once the prototype is assembled without glue, I can see and sit on a real chair and affirm whether the design does or doesn't work. This is my last chance to make changes before beginning the production run. Once finished with a set of chairs, I save the knocked down prototype as a model to show prospective customers and to refresh my memory when building the next set.

If the first chairs are comfortable, sturdy and attractive and if the design sells, the model can be changed and elaborated upon in future chair sets. Maintaining the same joinery details, I have changed leg and seat rail profiles, back heights, crest rails and other elements of a design series to produce different chairs that complement different table designs, such as the three chairs shown in the photo below. —*T.M.*

These chairs are from the same design series developed by Moore. Although each is different, they all share the same construction methods based on a series of shop-built patterns and jigs. The chair on the left is of Honduras mahogany, the chair in the middle is curly maple with rosewood inlay and the chair on the right is cherry with ebonized back slats.