Making Window Sash

How to do a custom job with ordinary shop tools and a router

by John Leeke

On a historic-restoration project I worked on not long ago, the house's window sash were in poor shape. The original plan for the sash was to repair the worst of them and then replace them all sometime in the future. But before the window work started, the owner decided to have new sash right off. I didn't have enough time to place an order with a custom millworks; so I decided to make the sash in my own small shop, even though it lacks specialized sashmaking machinery. This meant I'd have to match the joinery and molding profile of the originals, and I'd have to work quickly enough to make money on the job without overcharging my customer.

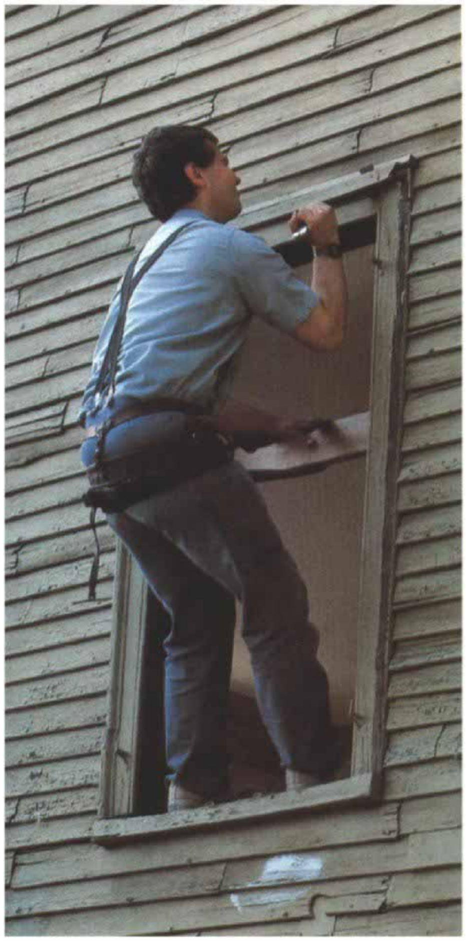
The old sash were hand-made over 150 years ago. One had been without paint for many years, so its joints came apart easily. All I had to do was see how it was made, and reproduce each part. The challenge was to keep track of all those parts, and to make the joints fit properly so the sash would get as much rigidity from its mechanical integrity as from the glue in the joints.

It takes me about 5¾ hours for all the setups needed during a run of sash. The production time for the kind of sash described here on a short run of three or four double units is almost six hours per unit. Considering my time and the cost of materials, the final price was about 20% higher than ordering custom-made sash from the local lumberyard. Not too bad for short-order work that met my specific requirements exactly.

Of course, I could lower these time figures by keeping specialized machinery set up for sash work. If I did, my shop rates would be higher. I'd rather keep my capital expenses low and have more hourly income.

I use white pine for all my sash because it strikes a good balance between machinability and durability. Straight-grain, knot-free wood is essential because the thin, narrow muntins need to be as strong and stable as possible. Also, the outer frame can twist if it's made from wood with unruly grain. I try to use all heartwood, which is stronger and more rot resistant. It's best to cut all the rails and stiles from parts of the board that have vertical grain. These quartersawn lengths of wood are less liable to warp and twist.

John Leeke is an architectural woodworker in Sanford, Maine. Photos by the author, except where noted.



To replace old frames, first remove the exterior casing, as shown above, then remove the interior casing. This exposes the casing nails that hold the jambs to the rough framing. These can either be pulled or cut with a hacksaw blade.

Two kinds of sash—Here I'll describe how I made double-hung sash for jambs that don't have parting strips. So the sash shown in the photos don't have weather stops. *(Parting strips, weather stops* and other sash terms are explained on the facing page.) However, many older sash are made for jambs that have parting strips, and so require meeting rails with weather stops, as shown in the drawing. Meeting rails with weather stops are thicker in section and narrower in elevation than ordinary rails, and are mortised to receive tenons on the stiles, rather than the other way around. If you have to make meeting rails like this, the joinery is the same, except that the stiles are tenoned and the rail is sized to overlap (with bevel or rabbet) the other rail. You can avoid this trouble altogether, if you wish, by applying the weather stops (with brads and waterproof glue) after the sash are assembled. The instructions that follow are for simple sash.

Sequence of operations—I did all the work on this job with ordinary shop equipment—a table saw, a drill press and a router, which I mounted on the underside of my saw's extension wing. The techniques described in this article can be adapted to produce sash in new construction, casement windows and fixed-glass windows.

I begin by disassembling one of the old sash to determine how it went together, and to get familiar with its decorative and structural details. Then I measure the inner dimensions of the old jamb, and make a drawing of the sash that shows the important features. From the drawing I compile a list that itemizes the parts and tells the dimensions of all the separate pieces.

The sequence of operations in the shop goes as follows: I thickness-plane all the stock (this can be done on the table saw since all the members are fairly narrow), and then cut the tenons and copes on all of the rails and horizontal muntins. Next, I cut the mortises in the stiles and vertical muntins. After this I set up to mold the inner edges of all the frame members on their inside faces, and then I rabbet the same pieces on their outside faces (for glazing). At this point I usually frank the tenons on the rails. Finally, I assemble the sash.

Measurements, drawings, cutting lists— After I take out the old sash, I clean off paint buildup and dirt. If the stiles of the frame are not parallel, I size the sash to the widest measurement and allow a little more time for trimming during installation. If the overall dimensions from sash to sash vary less than ¼ in., I make all the new sash to the largest size and then trim down those that need it after assembly. If the variation is more than ¼ in., I plan to make more than one size of sash. Too much trimming can weaken the frame members.

You can usually make a good guess about the joinery of the original, but if you're doing a precise reconstruction you have to take one of the sash frames apart so you can measure the dimensions of its tenons and mortises.

On my first sash projects I made complete drawings to keep the various parts and joints

Photo: Andrew Edgar

Sash anatomy

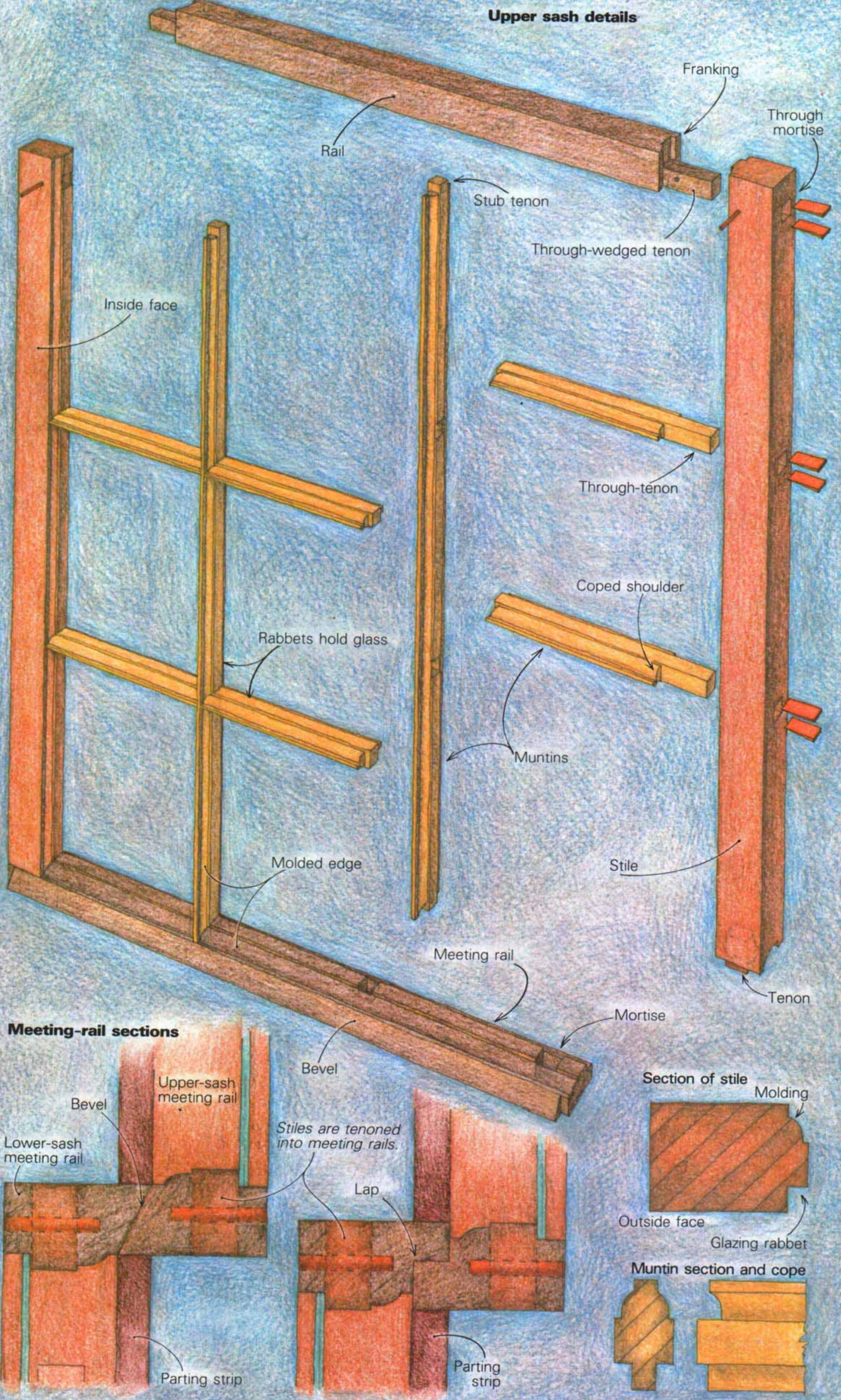
A basic sash for a double-hung window consists of an outer frame and an inner framework of smaller members that hold the separate panes of glass. The outer frame is made of vertical members called *stiles* and horizontal members called *rails*. The bottom rail on the upper sash and the top rail on the lower sash are called *meeting rails*, and these are often made to interlock when the windows are closed. This interlock can be a mating pair of bevels or an overlap (see section drawings below), and it helps keep out cold drafts. *Plain-rail sash* have meeting rails that lack the interlock feature; their meeting rails simply abut one another. The lower rail of the bottom sash has to be beveled to fit flush against the sill, which should slope toward the outside to shed water.

In the best construction, frame members are held together by wedged through mortise-and-tenon joints; as a general rule rails get tenoned, stiles get mortised. In some traditional sash, though, the meeting rails are rather narrow and so are mortised to house tenons cut onto the stiles. You can use slip joints, but these lose much of their strength if the glue in them fails, whereas wedged through tenons hold firmly even without glue.

The members of the inner framework or grid that holds the glazing are called by several names. I call them *muntins*, though they're variously known as *mullions, sticks, sticking, glazing bars* or just *bars*. Like the outer-frame pieces, the muntins should be tenoned into the rails and stiles, and into one another.

All the frame members—rails, stiles and muntins—are molded on their inner faces and rabbeted to hold glazing on their outer faces. This arrangement requires that tenon shoulders be made to conform to the molded edge of the mortised member.

In traditional sashmaking, there are two ways to shape the tenon shoulder. The first method involves cutting away the molded wood and shaving the shoulder on the mortised piece flat to receive the flat shoulder of the tenon. This means the beads are mitered on both members. The second, and easier, way is to cope the tenon shoulder. Simply stated, a cope is a negative shape cut to conform precisely to the positive shape that it fits up against. —*J. L.*



Illustrations: Christopher Clapp

straight in my mind. From these drawings, I made a list of all the pieces I'd need. Each part has its own line, and each line is keyed with a letter to the corresponding part on the drawing. Also on the line is the size, the quantity needed, the name of the part, and its location in the sash.

Router-table joinery—In millwork shops and sash-and-door plants, tenons are cut by single-end or double-end tenoning machines, which cope the shoulder of the joint at the same time they cut the tenon. In smaller custom shops, spindle shapers do the same job. But these are expensive machines, and they take up a lot of space, which I don't have much of. And I was in a hurry. So on this job I improvised a router setup to cut the tenons and copes.

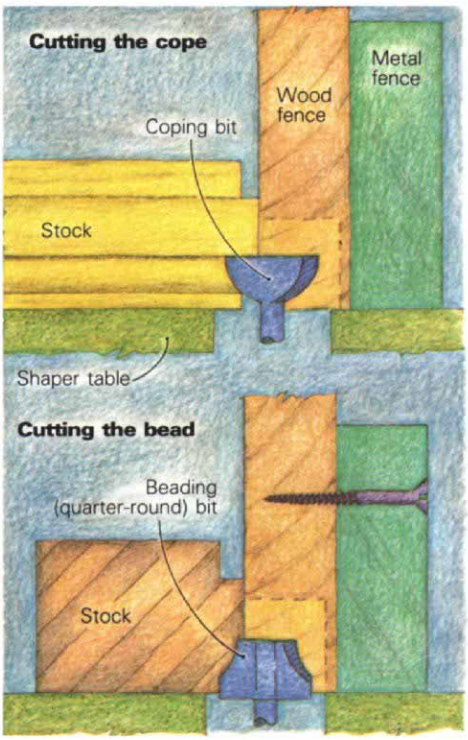
Instead of building an extra table in my already crowded shop, I mounted a router under one of my table-saw extension wings. This arrangement lets me use the saw's rip fence and miter gauge as working parts of the router setup. To keep from drilling needless holes in your saw table, be careful when you lay out and bore the hole in the cast iron for the arbor and cutter and the tapped holes that will let you attach the router base to the underside of the wing with machine screws.

I made a wooden auxiliary fence 2 in. thick and 5 in. high to attach to my saw's metal fence. To suck up chips and dust from around the cut, I bored a hole through the fence and carved a socket to accept the end of my shop vacuum hose (photo top left). This keeps the chips from clogging in the bit during cutting and from building up against the fence.

To guide the workpiece, I use a rectangular push gauge made from a block of pine. By holding the edge of the block against the fence, I stabilize the stock, and square it to the line of cut. Also I notch each corner of the push gauge to each size tenon and to the copes. This way the block backs up the workpiece and keeps the cutter from tearing and splintering the wood as it leaves the cut.

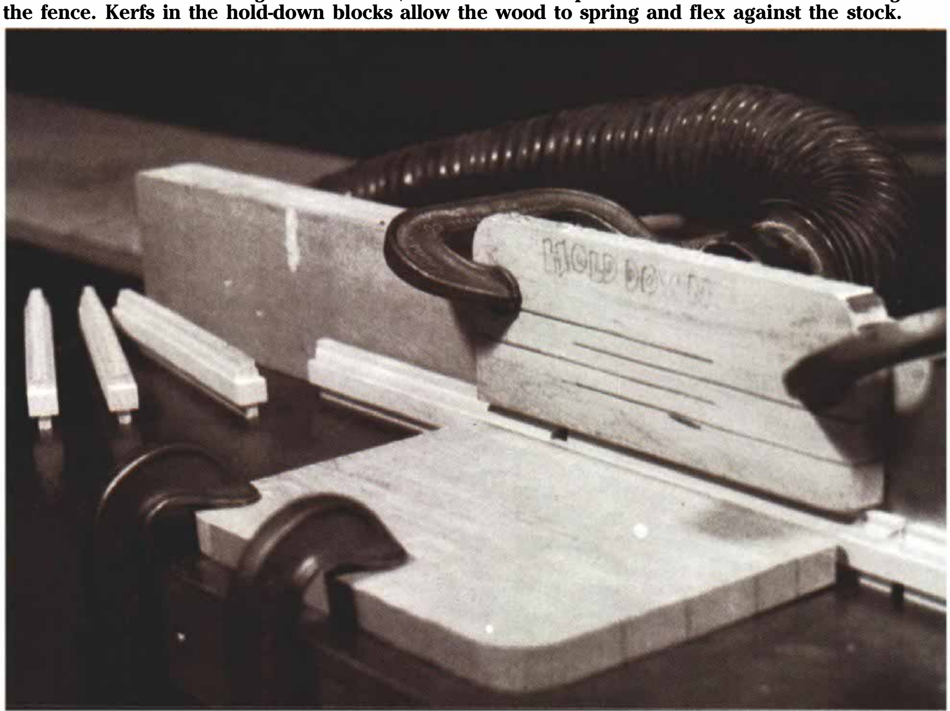
Cutting tenons on rails and muntins—For plain-rail sash there are two tenon lengths—the long through-tenons on the rails and on the stile ends of the horizontal muntins, and the short tenons on the vertical muntins and on horizontal muntins where they are joined to the vertical muntins. It could be that your sash will have a third tenon length for vertical muntins that are joined into the rails, and a fourth tenon length if your stiles are to be tenoned into meeting rails with weather stops. Before setting up to cut tenons, the stock for the rails, stiles and muntins must be surfaced to final thickness and crosscut to finished length. But the stock for the rails and muntins should not at this point be ripped to final width, especially the muntin stock. It's easier and safer to cut the tenons and do the coping on wide boards; it saves time and avoids tearout as well. Remember to mill up some spare pieces for trial fitting, and to be substituted if you ruin good ones. And it's a good idea at

Tenoning with a router. **With the router mounted on the underside of his saw's extension wing, Leeke removes the correct amount of wood to produce the cheek of a tenon. The stock is fed into the bit with a push gauge; it squares the workpiece to the cutter and keeps the wood from splintering out on the back side of the cut. A shop-vacuum hose pulls chips through a hole in the fence.**



Ripping muntins to width **from stock that has already been tenoned and coped saves time and minimizes splintering and tearout from cross-grain cutting. Because the horizontal muntins are thin and short, a pair of push sticks has to be used.**

Rabbeting and molding **muntin edges requires the use of two hold-downs. The one attached to the fence holds the stock against the table, and the one clamped to the table holds the work against the fence. Kerfs in the hold-down blocks allow the wood to spring and flex against the stock.**



this point to set up the hollow-chisel mortiser in your drill press because you'll need to cut some mortises in scrap to test-fit the tenons.

Most tenons are slightly offset from the center of the stock, but because all the framing members are the same thickness, you can set the router bit to cut the tenon cheek on the inside faces of all the pieces, then reset the bit to cut the cheeks on the outside faces. Mark out the dimensions of the two lengths of tenons on a pair of test pieces, and set the bit at the precise height for cutting the face side. This requires careful measuring, for which I use a vernier height gauge.

Calculating tenon length is complicated by the need to cope the tenon shoulder, which in effect lengthens the tenon. This added length equals the depth of the molding profile, and has to be deducted from the length of the tenon. Say your stile width is 1¾ in. and your molding-profile depth is 3⁄16 in.; your through-tenon length before coping will be 1 9⁄16 in., so you'll set the fence 1 9⁄16 in. from the farthest point of the bit's cutting arc.

Once the bit is set at the proper height to cut the cheek on the inside-face side of the pieces and the fence is set to cut the longer tenons, you can begin cutting. It's best to make each cut in several passes, even if you're using a large (½-in. or ⅝-in.) carbide-tipped straight bit. You'll get better results without putting an unreasonable demand on the router's motor. Make certain when you make the final pass that the end of the stock is pressed firmly against the fence and at the same time held snugly against your push gauge. Holding the stock this way ensures that the tenon will be the correct length and that the shoulder will be perfectly square.

After the first series of cuts on the rails and on the stile ends of the muntins, you need to set up to make the first cuts on the muntins for the short tenons. To keep from moving the fence and having to set it up again when you cut the cheeks on the outside face of the rails, you can thickness a scrap piece and clamp it to the fence to shim it out from the bit's cutting arc to make a tenon of the correct length.

Once you've made the cuts on the inside face of the muntin stock, you're ready to complete the tenoning by cutting the wood away on the outside face. Leave the shim clamped in place, and reset the router bit to the proper height above the table to make the next cuts. Careful measuring here is critical because your tenons won't fit if the bit is set at the wrong height. So make a cut on one of your spare pieces and trial-fit it in the test mortise. Once you get the bit set correctly, run all your muntin stock through. Then unclamp the spacer from the fence and make the cuts on the outside face of your rail stock and the muntin stock that gets long tenons.

Coping the shoulders—Coping with a router means you have to pattern-grind a matched pair of bits—a concave bit to cut the molding on the inside edges of sash members, and a convex bit to cut the cope on the tenon shoulders (photo above right). The positive and negative shapes of the pair must be perfectly complementary or your joint won't close properly, and will have gaps. The sidebar at right explains how to grind stock high-speed steel bits to get a matched set.

Now you're in a dilemma because you need a molded, rabbeted and mortised stile to test-fit the pieces you've tenoned and are getting ready to cope. The best choice here is to rip a stile to finished width, set up the router to mold the inner edges and rabbet the outer ones according to a full-size drawing of the stile in section. But you're having to perform an operation out of its logical sequence, and that can seem a waste of time. You'll also need a couple of muntin pieces; so rip a couple to width and mold and rabbet them at the same time you do the same to the stile. Whatever you do, don't throw your sample pieces away once you've gone to the trouble to make them. If you ever need them again, you'll save several tedious hours of trial-and-error setup if you have these samples to refer to.

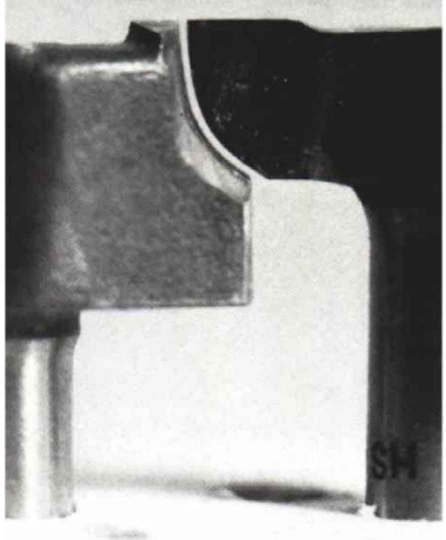
Now that you've got a stile prototype and a couple of muntin samples, chuck the coping bit in the router and set the height so that the top of the cutter just lightly touches the bottom edge of the tenon (stock held inside face down on the table), as shown in the upper drawing on the facing page. Next set the fence to cope the shoulders of the muntins with short tenons. Be conservative when you set up. Make a pass into the cutter, and trial-fit the piece. If the fit is bad, adjust the fence cautiously and try again. Keep making minute adjustments until you get it right. You'll get some tearout on the exit side of the cut because the edge has been molded, but this won't matter for the test piece. Now cope all the shoulders for the short tenons of the muntin stock. Next reset the fence to cope the shoulders of the long tenons.

At this point you should rip the muntins to width (middle photo, facing page). To keep from having to clean up the sawn surface with a plane, I use a sharp planer blade in my bench saw. Because the muntins are thin, I use a pair of push sticks to feed the stock into the blade. Also at this time you should rip the rails and stiles to final width.

Mortising stiles and muntins—I use a ½-in. hollow-chisel mortiser that I keep sharp for this job. You can buy one of these attachments for your drill press at most woodworking-machinery dealers. Be sure to buy a little conical grinding stone that keeps the chisel sharp. A dull chisel will tear the wood on the walls of the mortise and cause nasty splitting out on the back side of the stock. Even a sharp chisel will do some tearing out if you don't back up the cut with a maple block. I use an aluminum plate that's cut out to the precise ½-in. square dimensions of my hollow chisel. The edges of the square hole give positive support to the wood as the chisel exits, and prevent splintering altogether.

To get precise results, each mortise should be laid out with care. It's best if you use a mortising gauge and striking knife, but a sharp

Pattern-grinding router bits



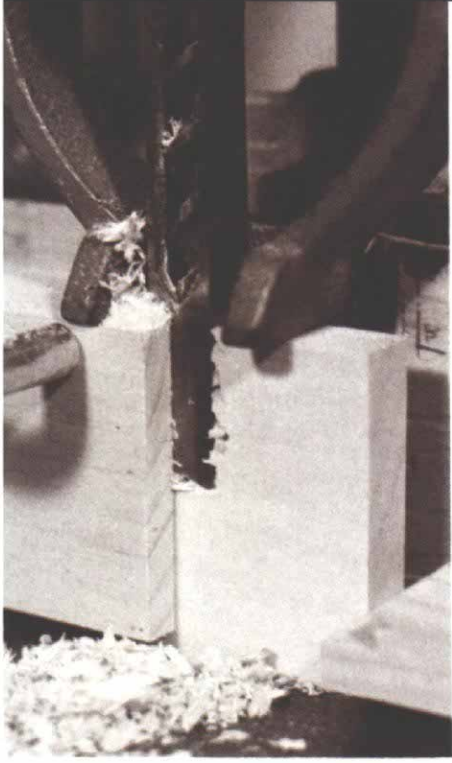
You have to be able to grind your own router-bit profiles if you want to reproduce moldings or make new ones of your own design. For one set of window sash that I was making, I needed a matched pair—a quarter-round bead and a cope. To make such a a pair, I begin by buying "blanks"—common high-speed steel bits, large enough to yield the finished shape I need. For these sash I used a rabbeting bit for the molding cutter and a rounding-over bit for the coping cutter.

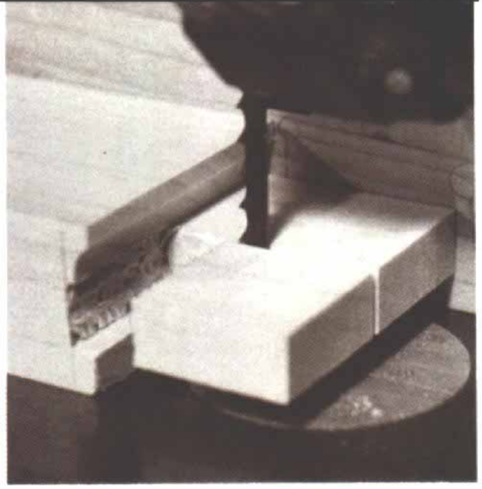
To lay out the shape for the cutting edge, I first coat the back face (opposite the beveled face) of each bit with machinist's blue marking dye, and then scratch the profile that I want on the surface, Dye makes the pattern easy to see when grinding. If I am reproducing a molding, I lay a thin cross-sectional piece of the molding on the back face of the bit and scratch around it.

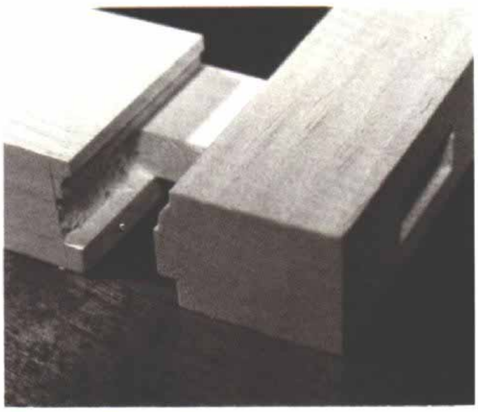
Holding the bit in a hand vise, I grind away the unwanted steel on my bench grinder. As I near the mark I make certain to match or slightly undercut the original bevel. All of this grinding is freehand, steadied a bit by using the grinder's tool rest. For tight inside curves, I use a small, thin grindstone mounted on the work arbor of my lathe. I am careful to remove the same amount of steel from both flutes so the balance of the cutter is maintained,:

After I've ground right up to the mark, I refine the shape by hand with medium and fine India slipstones, sharpening the edge in the process. Then I touch up the edge with hard Arkansas slipstones. Finally I mount the cutter in the router to test the shape it will make on a scrap of wood. If the resulting shape is not correct, I grind a little more, resharpen and test again.

To make a coping cutter match another bit, I use the bit itself as a pattern for the layout When the grinding on the coping cutter is approaching the final shape, I slip both cutters into a simple jig that holds the shanks parallel. The jig is just two ¼-in. holes drilled in a block of hardwood with a drill press. I turn the bits so their cutting edges are next to each other. Holding the assembly up to the light, I can easily see where more steel must be removed to make the edges coincide. *-J.L.*







Franking is an operation that removes stock above the tenon to let the shoulder of the rail conform to the profile of the stile. This is easily done with a hollow-chisel mortiser (above). After franking, the waste portion of the tenon is sawn off on the bandsaw (above right). Then the joint can be assembled (right).

Assembly is straightforward. Daub the mortise walls with glue, and tap the frame members together. Then drive in the wedges for the through tenons, and snug up the frame with two bar clamps. The frame shown here is slip-joined because it will be a fixed upper unit and not subjected to the stresses that sliding sash are.

#4 pencil and a try square will do. I clamp an end stop to the drill-press table to ensure that mortises at tops and bottoms of stiles are all the same distance from the ends of the stock.

Molding and rabbeting—The next machining processes mold the inner edges of the frame members on their inside face and rabbet the inner edges on the outside face. First I install the molding bit in the router, adjust its height and set the fence. Having done this already on the test pieces, I use one of them to help with the setup. Then I mold the stiles and rails, after which I clamp hold-downs on the fence and the saw table (bottom photo, p. 74), to run the thin, narrow muntins. Molding done, I cut the rabbets, using the same straight bit that cut the tenons. Again, I clamp hold-downs to the fence and table.

Franking—When you lay out the through mortise-and-tenon joints for the rails and stiles, you'll need to leave at least an inch or more of wood between the end of the mortise and the ends of the stile, or the wood can split out. Therefore, the tenon needs to be an inch or so narrower than the rail is wide. When you cut the tenons with the router, you get a tenon the full width of the rail, so you must cut part of it away to get a tenon the right width and to get the newly exposed shoulder to fit the sectional profile of the stile. Molding and rabbeting the stile produces a proud land (flat ridge) that runs the length of the member, and the new tenon shoulder has to be relieved to accommodate this long, flat ridge.

Relieving the upper shoulder of the tenon in this way is called franking, which I do with the hollow-chisel mortiser (photo top left). What's required is mortising back behind the tenon's shoulder to the width that the land is proud and to a depth that stops at the line of the top of the finished tenon. Then all you do is saw away the waste (photo top right).

Assembly—I really enjoy this part of sashmaking, when all the work finally pays off. Traditionally, joints were put together with thick paint between the parts I suspect the sashmakers in those days expected the paint to seal moisture out of the joint rather than act as glue to hold it together, but they didn't rely much on the adhesive strength of either paint or glue. They pegged the tenon through the inside face of the stile and wedged it top and bottom from the open end of the mortise.

Most weatherproof glues seem to work well, except for formaldehyde-resorcinol, which can bleed through to the surface after the sash is painted. When all the parts of a sash are fitted together, I snug up the joints with a bar clamp, and wedge the through tenons.

After wedging I check the sash for squareness and then peg the joints. Pegging is especially important for the joints of the meeting rail on the lower sash, because they are subject to a lot of stress during use. If pegs pass through to the outside of the sash, they could let water get into the joint. My pegs stop just short of the outside surface. □

Installing sash

When you're deciding what to do with sash that are in poor shape, you should consider the window as a whole. Examine the frames for deterioration. Windows on the south side of a house are subject to repeated wetting and drying. This can cause large checks or cracks in sills and stiles, so that these members need to be replaced. The north side of the house will be damper because it is in the shade, and you're likely to find rot in the joints of the sill and the jamb stiles.

Jambs and casing—If the sill or jambs need replacing, I usually take the whole window frame out of the wall. I begin by carefully removing the exterior casing and moldings (as shown on the cover of this magazine). This exposes the space between the jamb stiles and the structural framing (trimmer studs, header and rough sill), which gives me room to cut the nails that hold the frame in place. I use a reciprocating saw or hacksaw blade for this. There also may be nails that hold the interior casing to the frame that will have to be cut.

Once the frame is loose, it can be pulled out at the top and removed from the wall. I try to use heartwood for replacement parts of the jamb and casing because it is more rot-resistant than sapwood. In any case, the parts should be treated with a water-repellent preservative before assembly and reinstallation. Reusing old casing and molding that are still in good shape helps blend the new work in with the rest of the house. If the old jambs are still good, I scrape and sand their inside surfaces so they are flat and smooth for the sash to slide against.

Fitting the sash—To install double-hung sash with the upper sash fixed in place and the lower sash sliding up and open, you first trim the stiles to fit, then glaze and finally install the sash in the jambs.

Start sizing the top sash by planing the edges of the stiles so the sash will fit into the frame without binding. This should be a free-fit, but not so loose it will rattle side-to-side. Put the sash in place and slide it up to the frame header. If the top rail of the sash doesn't fit uniformly flush along the header, it should be scribed to the header with dividers and trimmed to fit. Then fit in the two outer stops, which are strips of wood that lay flat against the jamb stiles and hold the upper sash in place. If the top rail of the bottom sash and the bottom rail of the top sash are made to overlap and form a weather stop, your jambs must be fitted with parting strips. These are strips of wood that are let into grooves, one in each inner face of the jamb, that run the length of the jamb stile and serve to separate the two sash so they don't slide against one another. Fit the parting strips into the grooves in the stiles so they are held in place by compression only. Don't glue or nail them in place.

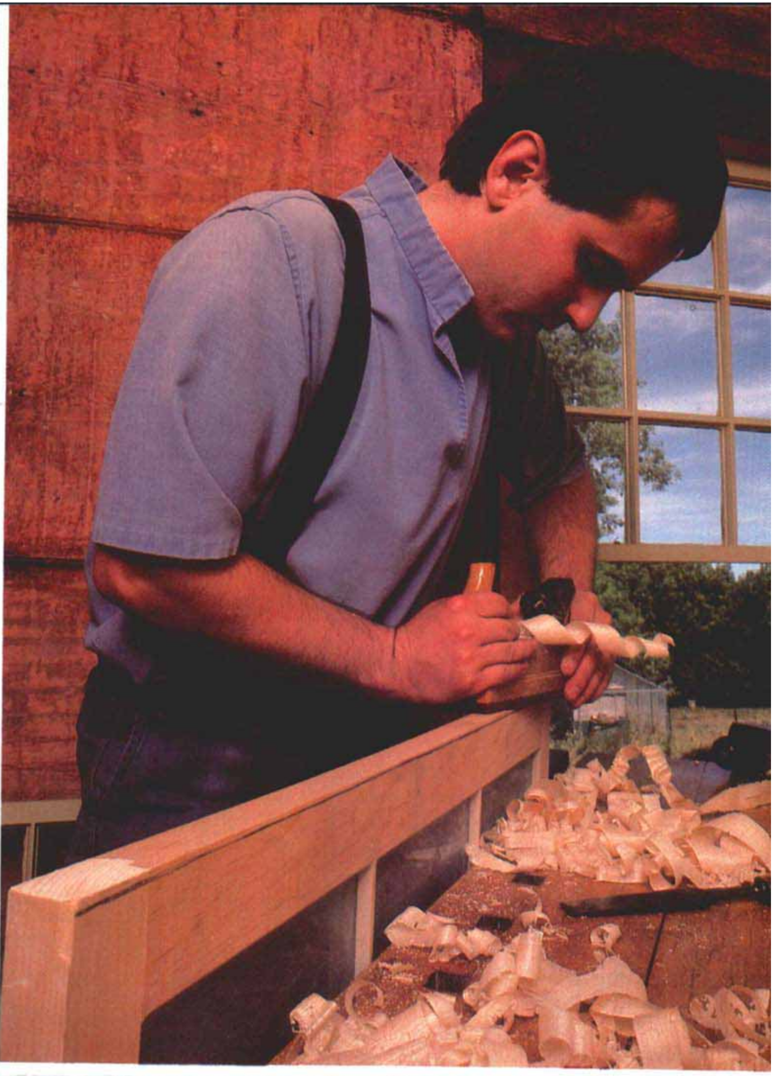
Next trim the lower sash to fit by planing its side edges until it runs smoothly up and down in the frame. Set the sash in place with the bottom rail resting on the sill. Then scribe the bottom rail to the sill with dividers set to the distance between the top surfaces of the meeting rails. Plane off the bottom rail to the scribed line (photo above right), forming a bevel that matches the slope of the sill. The weather stops should fit tightly together when the bottom rail of the lower sash is against the sill. If too much is planed off the bottom of the lower sash, this fit is lost. So take some care when trimming for this fit.

When the sash are sized to fit, they should be treated with a water-repellent preservative and primed for painting. Do not prime the side edges of the sash. They should be left bare to slide against the stiles.

Glazing, painting and finishing—I usually take sash to the glass shop to be glazed. The glass should be bedded in a thin layer of glazing compound and set in place with glazing points. When complete, the glazing compound should have a neat beveled appearance and not show from the inside.

The sash should have two top coats of paint. I prefer oil-base paints. Run the paint just slightly onto the glass, thereby sealing the glazing from rainwater. Do not paint the edges of the sash that will slide against the frame. When the paint is dry, wash the glass.

To install the window in its jamb, set the top sash in place and slip the parting strips into their slots. Trim any beads of paint that may have dried on the side edges of the lower sash, and test to see if it still slides freely in the frame. When you are satisfied with the way the sash fits, then secure it in place with the beaded or molded inner stop, taking care to use thin brads so as not to split the wood. These stops should be carefully positioned so the sash is free to move but not so loose that it will rattle in the wind. —*J. L.*



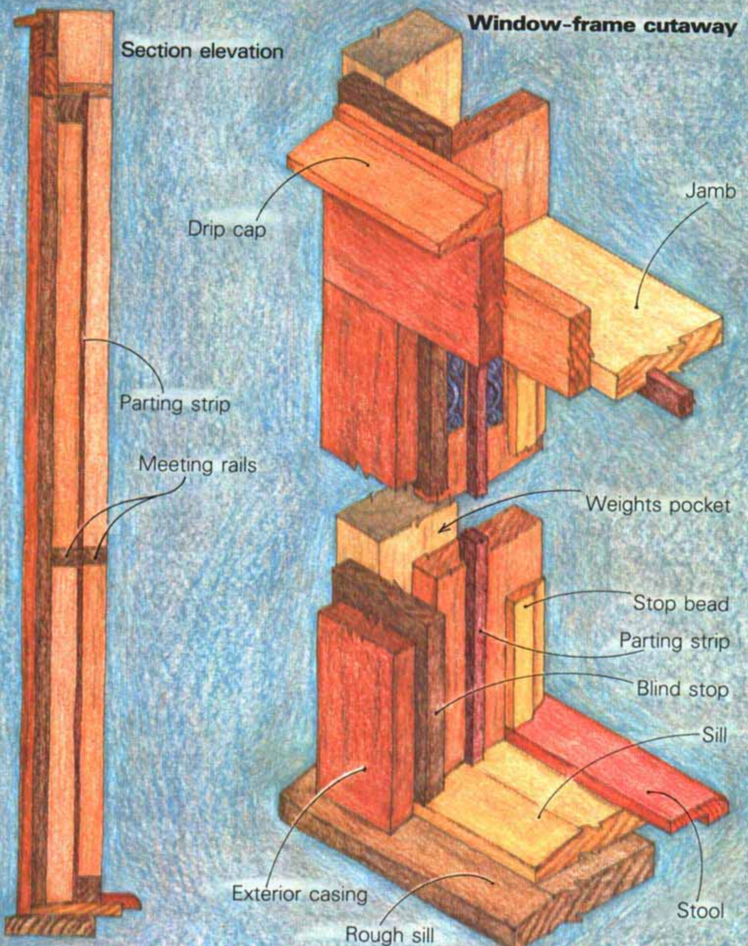


Photo this page: Andrew Edgar