Double-Helix Stair

A cherry spiral built with divine inspiration, a little steam and a lot of clamps

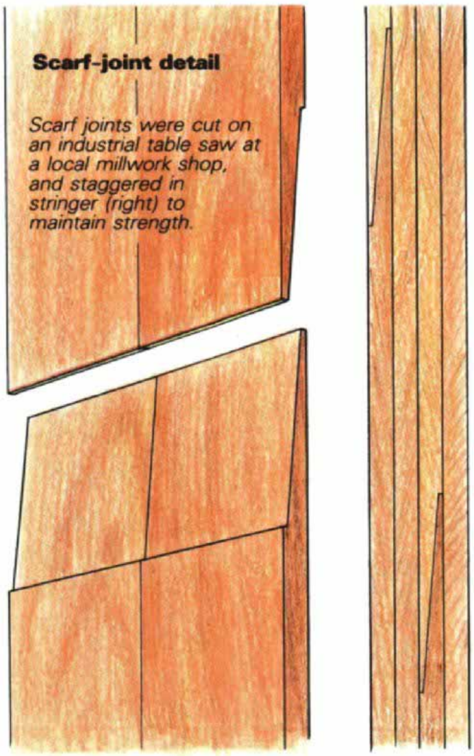
by Robin Ferguson

The house is majestic, sitting on a bend of Castle Creek, 8,000 ft. up in the heart of the Colorado Rockies. And a castle it seems, with its medieval lines and three towers. The central, and highest, tower was designed for solitude, meditation and glimpsing the sunset. When the clients looked at the architect's model of the house, they liked the tower. It was just what they wanted, but with the tower centered over the living room, they wondered how they'd get up there. In response, Steven Conger and Michael Martins, who had designed the house, conceived a sculptural, double-helix stair (photo right).

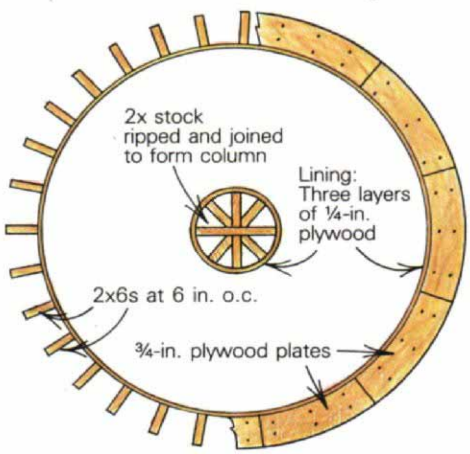
The design and construction of the stair was a group effort that evolved over many months. On hearing the architects' concept for the stair, construction foreman Ivar Eidsmo said he'd seen one just like what they had in mind. He was referring to the Miraculous Staircase in the Loretto Chapel in Santa Fe, N. Mex. (photo below). It was built about 1878 by an itinerant carpenter who appeared out of nowhere, apparently in re-

Alan Becker

Unlike conventional spiral stairs that are supported by a central post, the cherry staircase at right stands on two helical stringers. It rises over 16 ft. to an observation tower above the living room. The design of this double-helix stair was Inspired by the Miraculous Staircase (above), which leads to the choir loft of the Loretto Chapel in Santa Fe, N. Mex.



Plan view of column and cage



sponse to prayers to St. Joseph, carpenter of Galilee. The anonymous carpenter worked four months and disappeared as mysteriously as he had arrived, without finishing the railing and without payment for his work.

Eidsmo went down to Santa Fe and photographed the Miraculous Staircase. Although the stair we built is very different structurally and is shorter, narrower and much less ambitious, the Miraculous Staircase did serve as inspiration.

Rising over 16 ft. around a 2½-ft. radius and revolving 1½ turns along the way, our stair was a major undertaking. It was begun by Chuck Miller, one of the carpenters working on the house. I came along later, after the layout had been done and the forms built. Initially my job was to speed up production, but when Miller had to leave the project, I took responsibility for its completion.

Specifications—During the design stage, an engineering firm, Nicol and Giltner, was hired to do structural specifications for the stair. To match the interior woodwork, the staircase is made of cherry. So the engineers based their calculations on the strength of that wood.

They determined that the stringers should be 2 in. thick, composed of eight layers: four ¼-in. plies in the middle, two 5/16-in. crossband plies with their grain running perpendicular to the others, and two 3/16-in. face veneers.

Because of the wedge-shaped treads, the inside stringer needed to be 7 in. wide, while the outer one had to be 14 in. wide. At the top and bottom of each stringer, a ¼-in. steel plate had to be sandwiched across the full width and securely lag-bolted to the landing and floor system. To hide these plates and cover the various structural laminations, we had to glue 1-in. thick caps, made with eight layers of solid cherry, to the upper and lower edges of the stringers.

In addition, the engineering firm also specified the 2-in. thickness of the treads and their installation details. The treads are held in place by five ½-in. dia. lag bolts 6 in. long—two through the inside stringer and three through the outside one. The heads of the bolts are concealed beneath the final ply.

Since the stringers are so long (the outside one is nearly 28 ft.), each ply is composed of sections, 6 ft. to 8 ft. long, glued up to form one full-length piece. For maximum strength, the adjoining ends of each ply were scarf-jointed (drawing, top left) on a huge industrial table saw at a local millwork shop.

Column and cage—Building the laminating forms was the first big hurdle in the construction process. Rather than build the stair in a woodshop and then transport and install it, we set up the laminating forms right in the stairwell. The stringers were laminated in place, and the forms were then stripped away from them.

We built an inner column of solid 2x fir, and an outer cage encircling it (drawing, middle left). These we wrapped with plywood along the path of the stringers. The cage consisted of vertical 2x6s on 6-in. centers. We used ¾-in. plywood to make the curved plates by bandsawing segments to form a 5-ft. dia. circle.

The column was made with seven pieces of 2x stock stood on end and cut to radiate out from a central axis, like spokes on a wheel, to create a star-shaped cross section with a 12-in. diameter. Three layers of ¼-in. AC plywood were used for the lining, and this is where our wood-bending difficulties began.

Straight curves are relatively easy to bend, but compound or twisting curves put a much greater stress on the wood, so we had to use steam. Eventually we built three different steamboxes, each one longer than the last. These were simple plywood boxes (6 in. by 14 in.) with a perforated copper pipe running through them, and fed by a 2½-gal. kettle (photo below left). Steaming made the plies supple enough, but once out of the box, the thin wood cooled so fast that we had only seconds to get the piece bent in the form. With the help of several people, we held it there and screwed it to the form with plenty of drywall screws.

As each full-length layer was completed, careful truing had to be done before the next could be added. We checked the curves with templates cut to the appropriate radius (which changed with each layer). Any high spots caused by the steaming or by slight imperfections in the column or the 2x6 cage were removed with a lot of grinding and hand sanding. This was a tedious process, and given the length of the forms and the cramped 2-ft. space between column and cage where we were working, we came to appreciate the term "cage."

Clamping setup—The engineering firm we consulted had specified resorcinol as the best glue for our project. Commonly used in plywood and gluelam beams, resorcinol requires extreme clamping pressure (175 psi) to bond properly. To satisfy this requirement, we used vertical 2x6s on edge, forming a continuous row of cauls or battens along the length of the outside stringer. We ran ⅜-in. threaded rods through the ends of the cauls and into steel plates that had been tapped and lagged securely to the form (drawing, facing page, top right). Now we

The twisting curves in this stair are so severe that even the thin laminations had to be steamed before they were pliable enough to bend around the forms.

Photo: Germaine Dietch

could apply plenty of pressure and distribute that pressure uniformly.

Before starting on the stringers, we laminated a pressure board from four layers of ¼-in. plywood to place over the stringer during the gluing operation to protect it and further distribute the clamping force of the cauls.

Before we could begin laminating stringers, we built another steambox, this one 30 ft. long, to accommodate the veneers. Once we got started, we soon learned that oversteaming did no good. After about 20 minutes, the cherry veneers were as pliable as they were going to get. Extra time only made the wood swell—a potential disaster when it shrank later.

As with the plywood, the cherry plies cooled rapidly, and getting the pieces from the box to the form in time was hard. Four people would run the plies into the house and feed them up to four others positioned around the form. Cherry isn't the best wood for bending, but there could be no dry runs—glue was rolled on to the previous lamination, the ply run in and clamped.

Resorcinol sets in about two hours—so the directions say—but here in the Rockies, the humidity is very low. Getting the ply in place, pressure boards on and all 90-odd clamps tightened before the glue set was frantic work.

On the inside stringer, we couldn't use the same clamping technique because the radius was too tight and the rise too steep. Instead of full-length plies, we laid up sections and clamped them with metal straps and a Signode model DO-3A banding machine (Signode Corp., 3610 W. Lake Ave., Glenview, Ill. 60025), like those used in lumberyards to bind stacks of plywood. Using about 30 bands around the column for a 5-ft. length, we achieved tremendous pressure. This method worked very well. As with the form itself, each full-length layer was carefully trued before the next was applied.

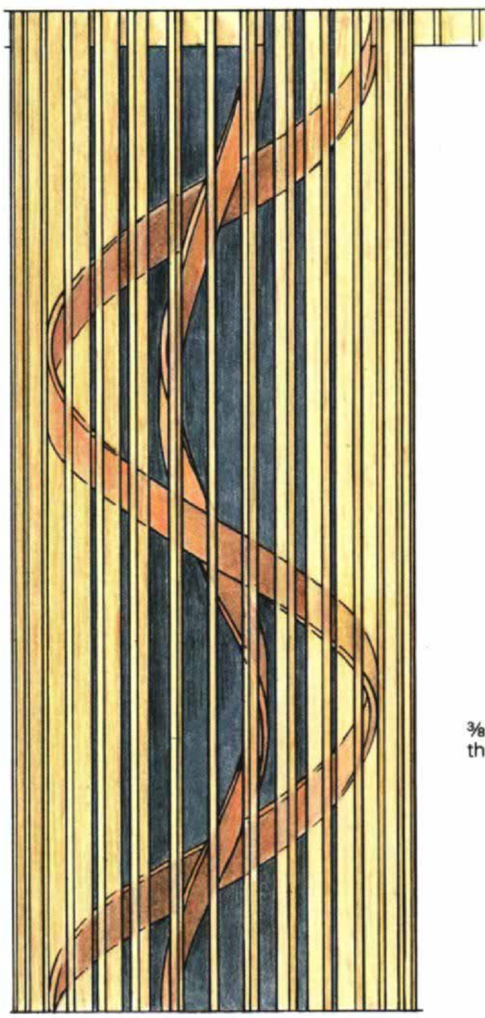
Adding the caps—We could laminate only six of the eight layers around the form. So after laminating as many as we could, our next step was to square the upper and lower edges of the stringers and glue on the caps. For this we used a 1½-in. straight-flute bit in a router. To keep the bit from wobbling on the curved surface, we had to sculpt wooden bases for the router, both convex and concave, to match the stringer's shape.

We attached a flexible guide strip along the face of the stringer for the router to ride against. As with most of the work on this stair, there was no convenient way to arrange a trial run. So the routing itself was a very intense process; we were keenly aware that an errant cut couldn't be easily hidden or fixed.

To apply the cap strips, we had to rethink our clamping methods, for pressure was now required in two directions: against the form and onto the stringer. We drilled 3-in. thick cherry blocks and threaded bolts through them. With the blocks screwed to the form, the bolts could be run down to exert pressure on the cap (drawing, bottom right). Even though we were using machine-thread bolts, the wooden threads they cut in the hardwood blocks were plenty strong enough for our purpose.

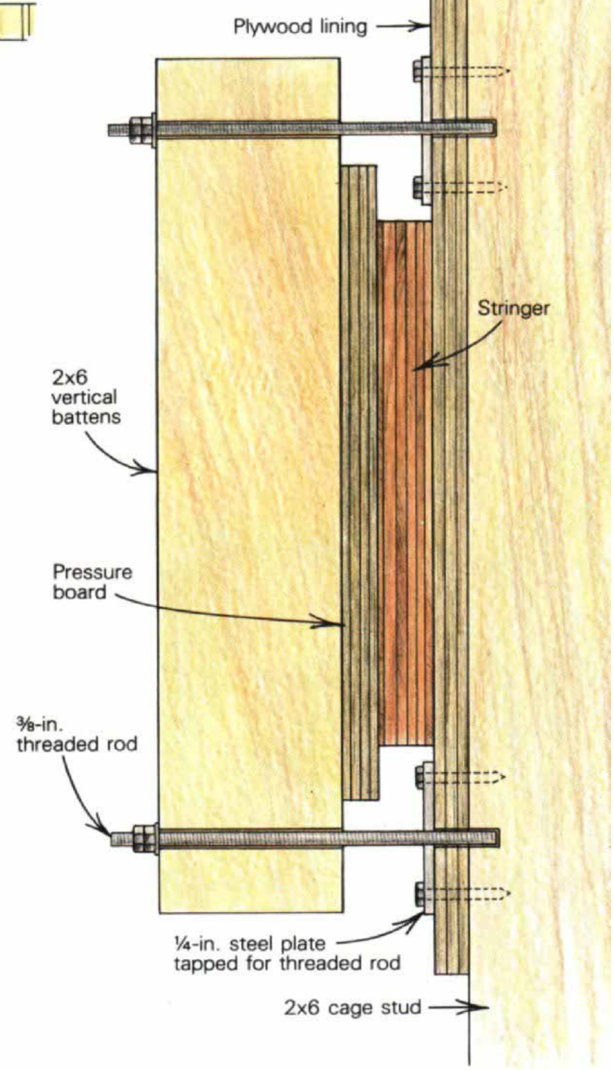
For holding the cap strips against the form,

Conceptual view of stringer glue-up

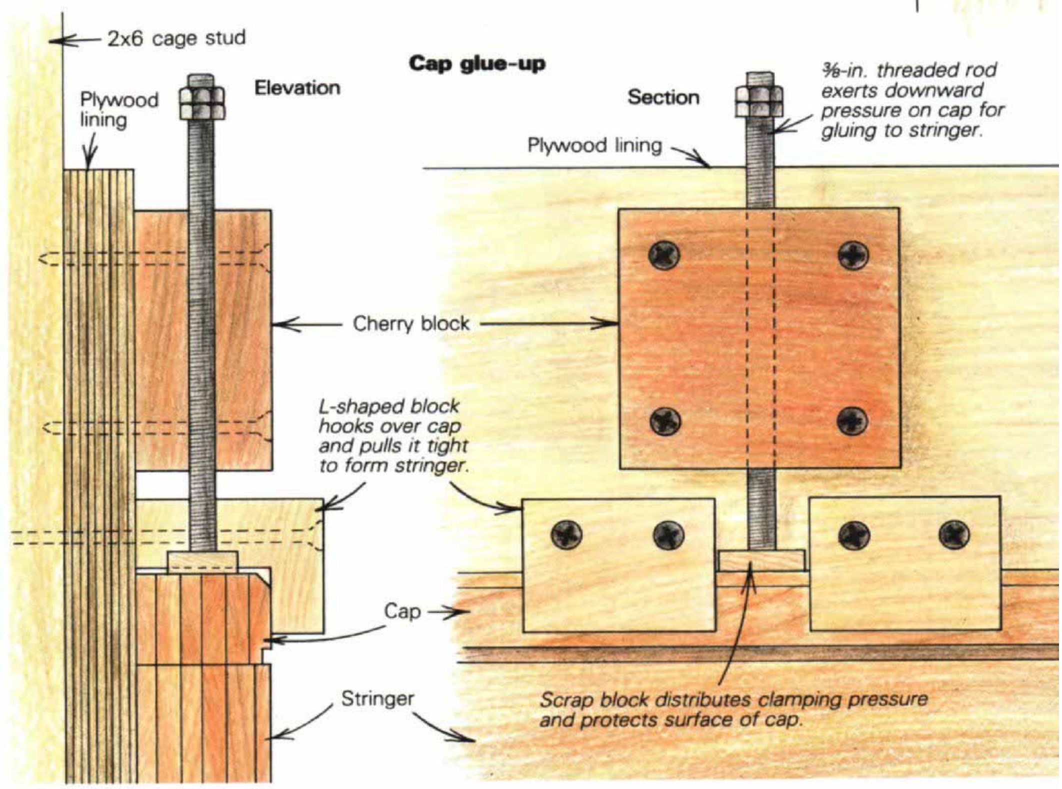


Plywood lining not shown.

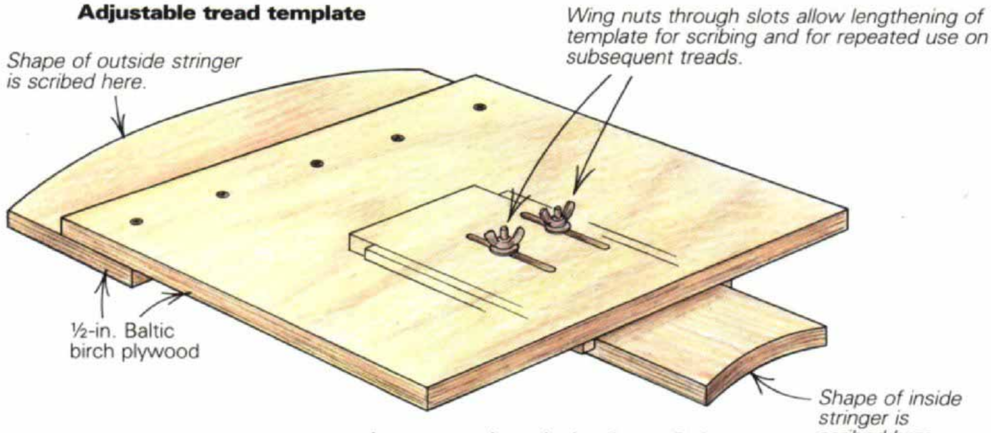
Clamping system

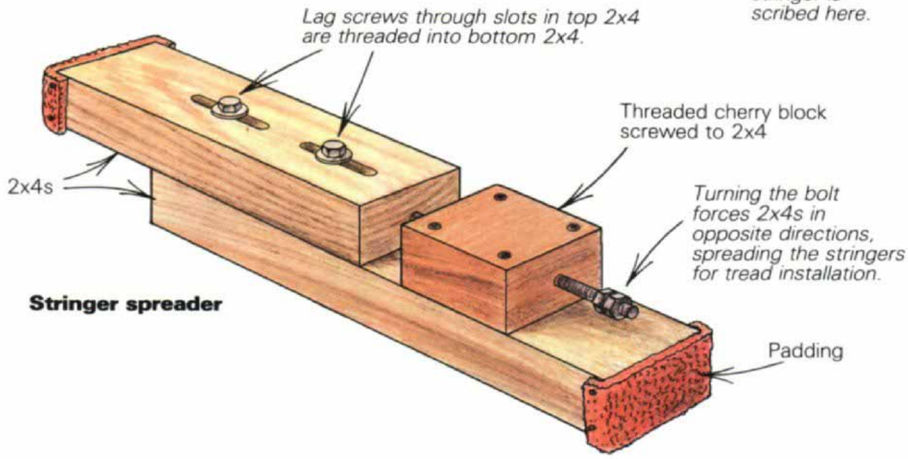


Cap glue-up

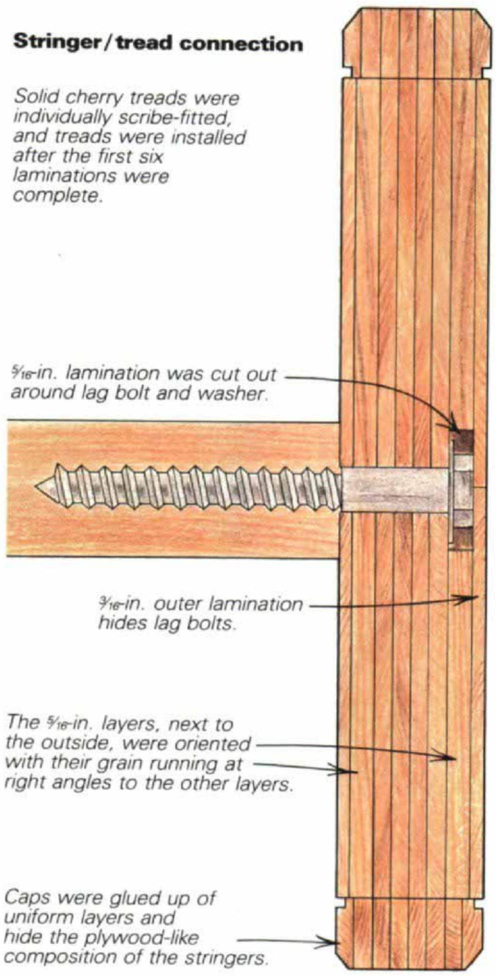


Drawings: Chuck Lockhart





Truck-tire inner tubes, cut up and laced into long bands, were used to clamp the final layer of cherry in place while the epoxy set.



we cut 2-in. wide L-shaped blocks that hooked over the edge of the cap. We spaced them every 4 in. and pulled them tight to the form with drywall screws. Once the cap strips were secure, we no longer needed the forms and set about to dismantle them. All the drywall screws did their best to keep the column and cage intact, and it seemed for a time that the stringers would be destroyed with the forms.

Treads—The main purpose of all the careful truing was so that one tread pattern could be used for the whole stair. But so much for careful planning. With the forms stripped away, the stringers took a set of their own, and while the differences were minute, a single tread pattern was now out of the question. We were obliged to cut 21 individual treads, each having to fit perfectly between the convex and concave surfaces of the stringers.

In order to make individual patterns for each of the treads, I built an adjustable template of ½-in. Baltic birch plywood (drawing, top left). I made it in two pieces, held together with bolts and wing nuts in oblong slots, and cut each end to the appropriate radius. It could then be extended to make contact with both stringers. After scribing the exact curve, I belt-sanded down to my line. 1 repeated the process (each time opening the jig slightly) until I had a perfect fit. The template was then used to make a pattern of ⅛-in. tempered hardboard. We glued each pattern to a tread blank, bandsawed to within 1/16 in., and trimmed it flush with a 2-in. bearing-over router bit.

The treads were such a tight fit that they couldn't be installed without marring the faces of the stringers. We had to make another device to spread the stringers slightly so we could get them into place (drawing, middle left). For this I used two pieces of 2x4, held together with lag bolts run through slots, and just tight enough to hold the two together yet allow movement. With one of the blocks of cherry from the cap glue-up (tapped for a bolt) mounted on one of the 2x4s, and the bolt against the end of the other, the two could be forced apart by turning the boh.

Having installed all 21 treads, we were able to use the stair. It was quite a sensation, after so many months, finally being able to climb the thing. Even so, some of the most challenging work still lay ahead.

Epoxy to the rescue—Applying the last two plies required still other methods of clamping. Since we had dismantled the forms, our old system was no longer available to us. Satisfying the high pressure requirements for resorcinol would have dictated major retooling.

I knew about epoxies but had never used them for anything but plastic laminates. But for the final plies they proved a great problem solver. Instead of resorcinol, we used epoxy that had an open time of six hours, with a full cure in seven days. Rather than clamp each 5/16-in. layer, we stapled it in place, since contact was all the epoxy needed for a strong bond. Before clamping, we cut holes in the wood around the lag bolts, and after the epoxy had set, ground the heads flush. These holes in turn were filled with

Photo: Michael Owsley

auto-body filler and sanded smooth. It was time at last for the face veneer of cherry.

We couldn't use staples on the last veneer so our clamping system changed again. To hold the veneer tight to the stringer during glue-up, we used a series of 2x2 vertical cauls, snugged against the veneer with 30 truck-tire inner tubes. After cutting them into rings and lacing them into bands, we wove the tubing between the treads and around the opposite stringer (photo facing page). This worked amazingly well.

Railing and connections—The handrails had been glued up before the forms were dismantled, but they needed their upper and lower surfaces squared before they could be installed. Trying to work the outside rail required a great deal of patience. At nearly 28 ft. long, 1½ turns and a 5-ft. diameter (photo top right), just getting it clamped was like wrestling a giant snake. Once it was clamped, we could work only a short portion before the twist had us working upside-down and we were forced to reposition it.

We hand-planed the surfaces of the rail, trying to follow the twist with each stroke. It was impossible to avoid some tearout because, with all the plies, there was always grain running in opposite directions. But we cleaned this up with sharp cabinet scrapers.

Once shaped, the rails were clamped temporarily in place. Because of slight variations in the distance between stringer and rail, the square balusters had to be fit individually. They are doweled into both the handrail and stringer.

One unusual feature of this stair is that it has two handrails. A regular spiral stair built with a center post has only an outside handrail. Our stair also has a rail that hovers just above the inside stringer, so you can hold on with both hands as you go up or down. Two rails make the stair more comfortable and secure to use.

Foam patterns—The final phase, and for me the most enjoyable, was designing and carving the many rail connections. At the suggestion of Michael Owsley, who aided greatly in the completion of this stair, we glued up pieces of polystyrene foam into big chunks. We wanted to experiment with these before making the transitional rail connections in cherry.

After permanently installing all the long sections of rail, we glued the polystyrene chunks in place between the rails with five-minute epoxy and a piece of paper sandwiched between the foam and wood. (The paper allowed us to break apart the glue joints later.) These were then shaped with various saws and rasps to form the final models (photo bottom right).

Passing inspection—The Uniform Building Code says that a staircase shall not rise more than 12 ft. vertically between landings. Our staircase rises over 16 ft., but we were granted an official variance by the building department. Since this is a low-use stair that leads only to an observation tower and is not for egress, the inspector felt the variance was justified. □

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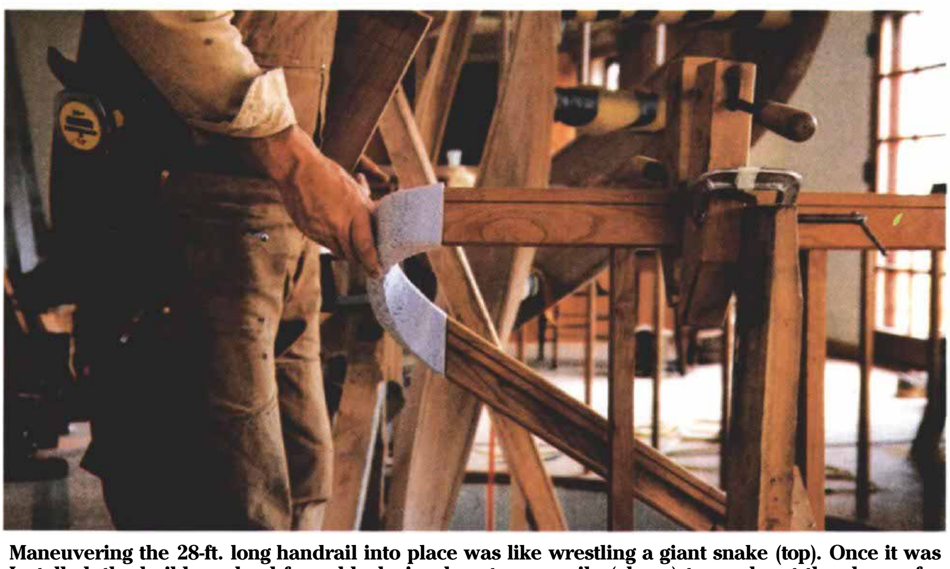

Maneuvering the 28-ft. long handrail into place was like wrestling a giant snake (top). Once it was Installed, the builders glued foam blocks in place temporarily (above) to work out the shapes for the transitional sections of handrail.

Top photo: Germaine Dietch; Bottom photo: Robin Ferguson