TIMBER FRAMING

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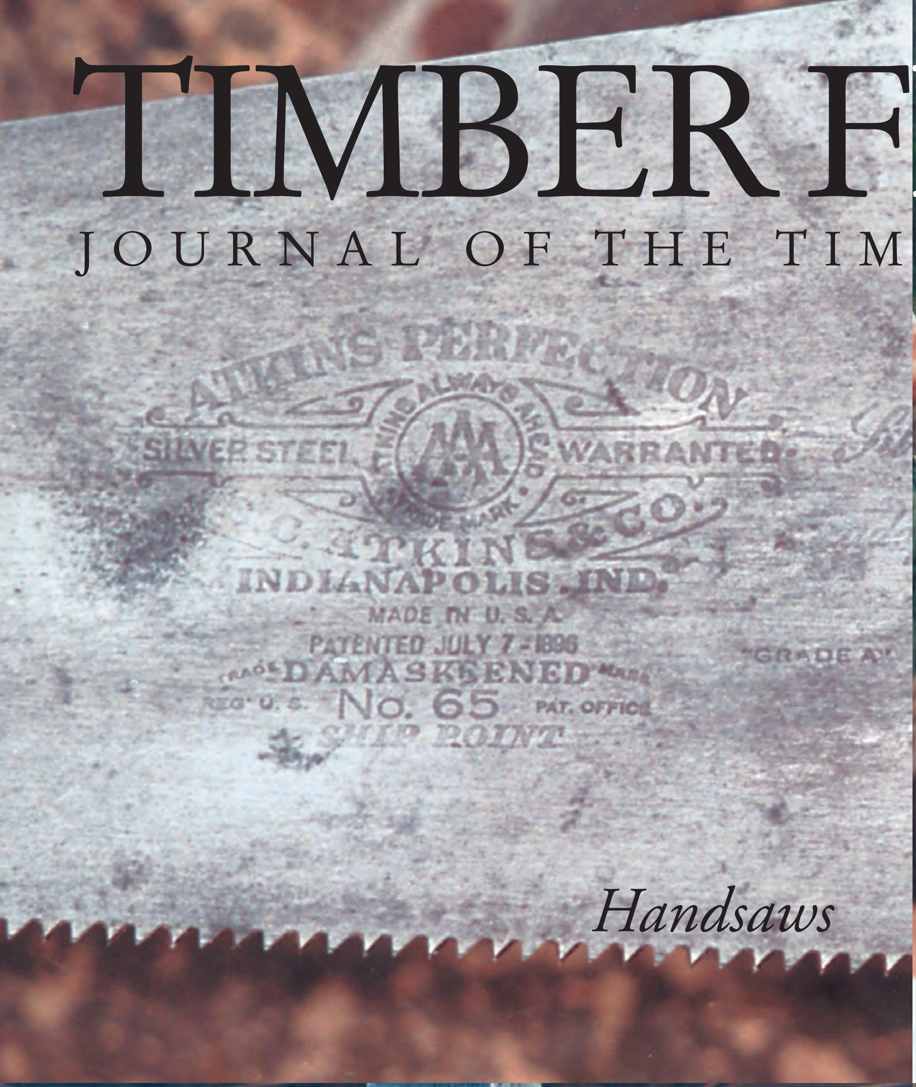
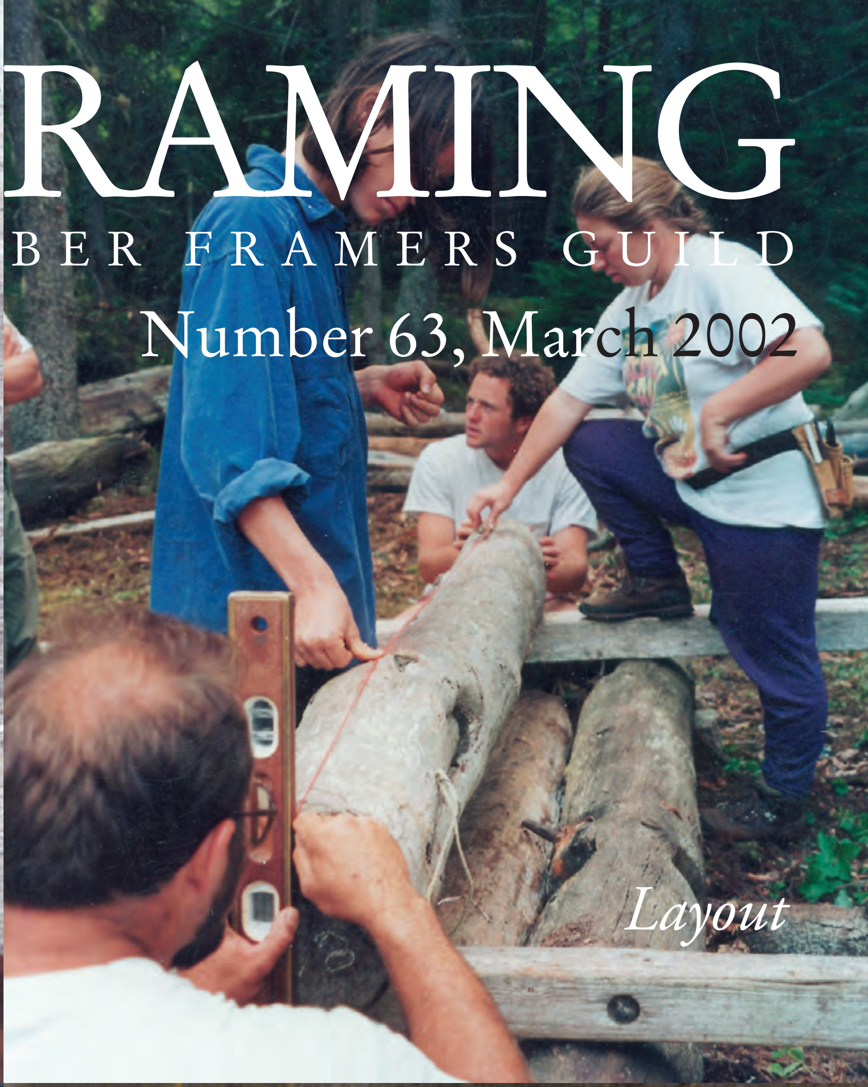


Handsaws



Layout

Sutter's Mill

Lateral Load Testing

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On the cover, clockwise from top left: etching on plate of Atkins No. 65 handsaw, ca. 1935, photo by Doug Eaton; striking centerline on log to be laid out, Greene Island, Maine, photo by Will Beemer; tenon relish failure during timber frame testing at the University of Wyoming, photo by Rob Erikson; naïve timber framing at Sutter's Mill replica, Coloma, California, photo by Paul Oatman.

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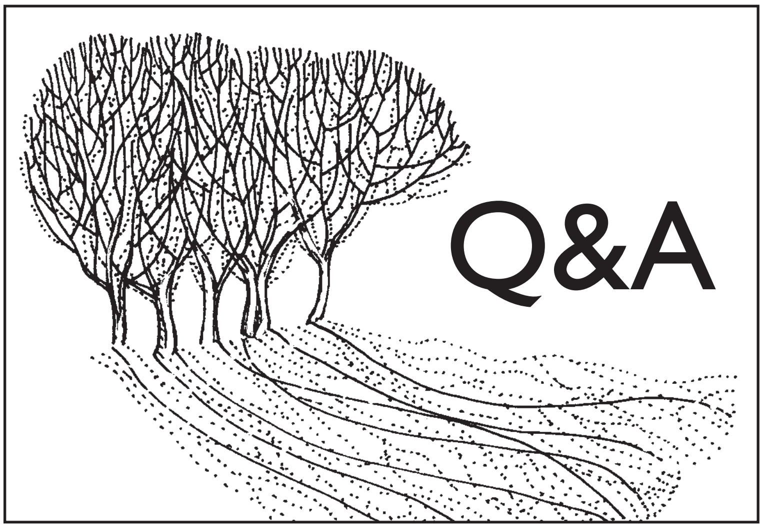


Lateral Stiffness, An Exchange

Terry Weatherby, of Jackson, California, writes:
I have been doing timber frame structural engineering design for 10-15 years and have run into a problem I have never encountered before. A building official says that we cannot use a timber frame as a lateral-load-resisting structural system because it is not defined in the 1997 Uniform Building Code, Table 16-N. The official, employed by the plan-checking service for El Dorado County Building Department, says I can use the timber frame system as long as I provide plywood shear walls or an otherwise designed system. I'm just curious if you have run into that anywhere before. Any ideas on how to argue against this wacko interpretation?

Dick Schmidt, professor of Civil and Architectural Engineering at the University of Wyoming, replies:
At the risk of being regarded as a wacko, I suggested in TF 41 (September 1996) just such an interpretation of the UBC. See the last paragraph of that essay. Anyway, I agree with that interpretation. That is not to say a timber frame is not safe in California. However, I have wondered myself how timber frames are getting approved in seismically active regions without some form of engineered lateral load system. If you are using structural insulated panels to enclose your frame, I believe they can be installed in a manner to provide the needed lateral load capacity. If you are using some other enclosure system, then you will need interior shear walls, rather than light partitions, to do the job. Based on our testing (see "Laterally Loaded Timber Frames," TF 62), a timber frame by itself does not have enough STIFFNESS to resist any serious lateral loads (high wind or earthquake). There has to be more structure in order to provide enough stiffness so that nonstructural components (doors, windows, drywall, etc.) are not destroyed by the racking response.

I believe that strength is not a problem. However, pegged mortise and tenon joinery is not sufficiently rigid to prevent unacceptable lateral displacements. Your panel supplier should be able to provide some guidance about the strength and stiffness developed using their panels and recommended fasteners.

We are in Seismic Zone 3, which generates similar lateral loads to 70 MPH, Exposure C, Wind. In design, we typically look at both cases in a static sense to generate a shear force, and design to resist that force. When looking at ultimate loads, I agree that seismic may be more difficult based on the initial jolt and overstress taken by the frame, but it seems to me that typical timber frames will have similar responses as, for example, steel eccentric-braced frames. The beams and columns will help absorb energy. At least that's how I've rationalized using these frames in the past.

The drift allowance in your article seems somewhat more conservative than the UBC. The UBC says to limit drift to 1/200 the height yet you limited side-sway to 1/400. Is that from ASCE 7-98 or another source? By the way, we use 1/150 for concrete tilt-up wall panels. Most failures listed in the article were in the oak pegs. In past issues of the journal, it has been suggested that since the shear capacity of the joint is limited by the dowel bearing capacity of the mortise and the tenon, the same shear value might be assumed for the peg as for a steel bolt of the same diameter. Is that a valid assumption?

Again, I want to emphasize that strength is not a problem. Stiffness is. The wood peg does not hold the wood members in tight bearing contact. Even the compression brace must cause peg deformation before there can be any wood-on-wood bearing to stiffen up the frame. Use of a steel pin in place of a wood peg could help significantly. The steel pin stays straighter, so there is more uniform distribution of bearing stresses between the pin and the wood. Hence there is less drift thanks to reduced pin bending, as well as less local deformation around the pin. This effect is likely limited to relatively low density framing timber, such as Eastern white pine. The long-term report that I wrote with Garth Scholl (available from the TFG web site, members-only section) describes our work in that regard. We didn't do an exhaustive study, but the results were significant enough to draw some obvious conclusions. We have not extrapolated that work to frame behavior with steel pins.

You might be on to something. It shouldn't be hard to determine the increase in joint stiffness due to use of steel pins instead of pegs, and then to use that to factor up frame stiffness. That might give you a frame of adequate stiffness. Our H/400 drift limit might be a bit conservative, but it was selected just for demonstration purposes. As you know, there are not many firm limits on drift set by the building codes. Those in the UBC (H/200) are for seismic loading, which is based on strength design criteria. We are assuming that working stress design is followed, for which lateral loads are not factored. The differences between the two (L/400 for service loads vs. L/200 for factored loads) are not likely all that large.

I received your fax. I think that your analysis makes sense and that, with a 1-in. steel bolt, you can probably achieve a stiffness that is close to the value that a conventional structural analysis model with pinned joints would give you. In this case, the steel bolt is not particularly effective. I suspect that the strength of your joint is governed by dowel bearing on the tenon. You can get basically the same strength (but not the same stiffness) from a wood peg. So use of a steel bolt might help you with your stiffness problem. Also, you might have some problem getting the required end distance on the tenon (7 diameters). It is amazing how inefficient timber frames are as structural systems. Perhaps their beauty makes up for it!

I've often wondered about that 7-dia. end distance requirement for the tenons. Based on your testing and the higher value of direct bearing (compression) of the brace, it would seem that the compression brace actually takes most of the force—assuming the member is "tight," of course. How tight should we assume the timber frame to be? The tightness of the frame would seem to be a result of the quality of workmanship by the carpenter who builds it. The better the timber framer, the tighter the frame, and the higher lateral forces the frame can resist. It would seem that some kind of steel wedges pounded into the dowels (for expansion) would also stiffen up the connections.

Another item is how much lateral movement should be allowed. As you said earlier, the H/200 is a seismic requirement. If the exterior walls are really flexible (wood, not plaster), frames could probably resist higher loads by allowing more deflection. This may be reasonable justification to allow timber framing in the voluminous number of barns built. In the UBC, agricultural buildings are allowed to be designed for lower wind loads than other buildings. Your testing apparatus allowed a deflection of plus or minus 3 in. If the deflection allowed were increased to plus or minus 6 to 8 in., how much additional force would be allowed? This might be enough to resist the "overstrength" factors required in UBC seismic design.

I think that the failure mode of the frame needs to be in the bending of the beam element—the strong column-weak beam system used in steel eccentric-braced frame systems. If the tension component of the braces is assumed to be zero (because of edge distance concerns), then the compression element can be jacked up to pretty high loads (allowing deflection, of course), and the failure would be in the bending of the column or beam. The key is to make sure it is in the beam (potential partial collapse) and not the column (potential total collapse).

Well, back to my problem. On Monday, the plan-checker said they had decided they would not allow the timber frame [with steel pins] as the primary lateral load-resisting system. The residential building consists of two boxes, one (two story: bedrooms, living room, and kitchen) larger than the other (living room over partial basement garage). At the interface between the two boxes, a timber frame stands in the end wall of each, one frame smaller than the other. The exterior wall of the larger element extends 5 ft. 6 in. farther than the smaller element but has a 2 ft. 3-in. window in the middle. This leaves space for a shear element of about 19½ in. each side of the window. We are considering using an 18-in.-wide Simpson Strong-Wall each side of the window, assuming I can get them to resist the required lateral loads. The rest of the building can be sheathed in ⅜-in. ply (or OSB, of course) and pretty much comply with conventional construction provisions.

Paul Oatman, the contractor, called Jack Sobon earlier today and told him our story. Jack was flabbergasted that one engineer would actually contradict another. Welcome to California plan-checking, I guess.

We pushed a two-story, two-bay frame (see the article elsewhere in this issue) to about 8 in. of deflection. The prying action of the compression knee brace ALMOST caused the beam to be forced up and out of the housing in the post. This frame was assembled with splines in the beam-to-post joints, rather than integral tenons on the beam ends. Ultimately the frame "failed" by cross-grain tension at the base of the post where an inadequate detail attached the frame to our test fixture.

As you know, the members are so damned big that there is little likelihood of failure in them, unless a really bad joinery detail results in removal of too much wood. My personal feeling is that if you can provide the stiffness, these structures are adequate for short-duration lateral load. I try to avoid designing pegged mortise and tenon joints to carry long-duration tension (I agree 100 percent on that point with Jack Sobon).

I don't think that you can lay the stiffness issue entirely on the shoulders of the builder. Unless you are working with salvaged material, shrinkage will have a major effect on the tightness of the joint. I don't believe that it is possible, even with wedges, to develop tight bearing of wood-to-wood connection. The joints will always rely initially on the pegs as load is applied. Then as load increases, wood surfaces can come into contact to provide more stiffness. It sounds as if you have enough conventional wood-frame building to just let the timber frame go along for the ride.

Q&A, a new feature in TF, welcomes questions on all timber framing subjects.

Sutter's Mill, Some History

When James Marshall, a carpenter from Lambertville, New Jersey, discovered gold in the tailrace of the sawmill he was building in northern California in 1848, the repercussions shook the world. This roughly built timber-framed mill may have received more attention than any other structure in the state. Historians, in their pursuit of the exact day and time of the discovery of gold, have studied volumes of diaries, and archaeologists have unearthed timbers and flooring of the lower frame to inscribe into California history the exact location of the sawmill in what is now the town of Coloma. A replica of the sawmill, constructed in the sixties to last a hundred years, is falling apart thirty-odd years later.

The story begins with Swiss immigrant John Sutter, whose empire was expanding and who needed plenty of lumber. He had a whipsawn supply from land he acquired on the Russian coast, but it was costly to ship the lumber to Yerba Buena, now known as San Francisco, and then up the Sacramento River to New Helvetia, now Sacramento. He also had some sawpits about 40 miles from Sutter's Fort in the Sierra foothills near what is today the town of Sutter Creek. He had a lot of handwork to do and not enough hands to meet his needs; waterpower became his focus. To this end he sent out exploratory parties, and made a final decision in the selection of the site, and a partner, on August 27, 1847. In his New Helvetia Diary, he wrote, "Made a contract and entered into partnership with Marshall for a sawmill to be built on the Amer: fork."[1] Sutter would supply labor, equipment, supplies and cash. Marshall would build the mill and run it, and they would split the profits.

Marshall soon left for the mill site, followed by wagonloads of provisions, ten laborers (five of them Indians, five Mormons) and 20 sheep to provide the crew with fresh meat.[2] After a number of trips to Sutter's Fort for supplies, Marshall also was able to round out his workforce, in the persons of more Mormons. Two of them, Henry William Bigler and Azariah Smith, kept diaries. The following entry is from Bigler's diary.

> Monday the twenty-seventh of September. . . a man dressed in buckskin came to our quarters while we were at dinner, informing us that Captain Sutter wanted four men from our crowd to go . . . up the American fork into the mountains about 30 miles, to work and help build a sawmill. This man, whom we were to accompany, was James W. Marshall, an entire stranger to us, but proved to be a gentleman nevertheless. He told us he had been up in the mountains with a few hands only a short time; but as some of them were going to leave soon he wished to get a few more. We learned that he and Sutter were in co-partnership in building the sawmill. So late that afternoon myself and three others set out with Mr. Marshall, accompanied by a Charles Bennett late from Oregon.
>
> We arrived on the twenty-ninth. . . . The country around the mill site looked wild and lonesome. Surrounded by high mountains on the south side of the river, the mountains were densely covered with pine, balsam, pinion pine, redwood [probably cedar], white oak, and low down the live oak, while on the north side there was not much timber; the mountains were more abrupt and rocky, covered in places with patches of chamisal and greasewood. . . . The work now to be done was to get out the mill timbers, dig out a mill site, put in a dam, and cut a tail race 40 or 50 rods long. . . .
>
> Everything was now going on nicely, Bennett and Scott working on the bench, Stevens hewing timbers, Brown and Barger either chopping, scoring, or chopping down timber. Sometimes the two latter whipsawed, and sometimes it was Brown and an Indian that sawed together. . . . [The latter] seemed to be very fond and anxious to learn, and when we told him we were making a mill that would saw by itself, he did not believe it. Said it was a damned lie, such a thing in his estimation could not be done. Wimmer had charge of some Indians cutting the race a little deeper. I was drilling into some boulders near where the water wheel was to be, while Marshall superintended the whole affair.[3]

Photos Paul Oatman

Photograph of copy of 1853 daguerreotype hanging at the California State Library at Sacramento, showing Sutter's Mill in a state of dilapidation. Boarding and cloth hanging in farther bay suggest its use as a rough habitation. The man standing in the tailrace, now deeply silted up, has been uncertainly identified as James Marshall.

Azariah Smith's diary gives further particulars:

> Sunday Nov the 14th — The past week I made pins for the mill.
> Sunday Nov the 21st — The week past I have been to work by the day boreing, and martaceing timber.
> Sunday Nov the 28th — The week has passed off pretty busy, and the mill goes ahead a good job; we have part of the dam in, and the bents, and plates of the lower story raised.
> Sunday Dec the 19th — The week past I with two others pin[n]ed the pla[nks] on the forebay.[4]

Scholars have fixed January 24, 1848, as the fateful day of the discovery of gold. Bigler's entry that day reads, "This day some kind of mettle was found in the tail race that . . . looks like goald." The next morning after breakfast, Bigler reports,

> Brown to his sawing, Stevens to hewing, I to my drilling, every man at his own job. Marshall came up carrying his old white hat in his arm looking wonderfully pleased and good natured. . . . As he came up he said, "Boys, by G-d. I believe I have found a gold mine."[5]

But the work on the mill resumed. On Sundays the men would pick for gold with their pocket knives. Bigler's entry for February 22 reads,

> When we arose that morning we found the ground white with snow that fell during the night. The upper frame of the sawmill, or top story if you please, was to have been raised that day. Marshall came in about the time we were at breakfast and said, "Boys it is going to be pretty slippery today and rather bad about putting up the frame."

It seems everyone agreed and then ran off for a day (or more) of gold hunting. Neither Smith nor Bigler gives the day of the raising, and they differ by one day on the actual inauguration of the sawmill. Bigler's account mentions the skeptical Indian It's-A-Damned Lie:

> On Saturday the 11th of March, Mr. Marshall started the sawmill. It was a curiosity to the Indians, and the very Indian who said it was a lie, that no such outfit could be made, was completely beat. He lay on his belly where he could have a fair view from the bank, but near the saw, and lay there for two hours watching it. He was taken with it and said it was "wano" [bueno] and wanted to be a sawyer right off. . . . The next day was Sunday. The saw ran all day and cut very well, and for aught I know, it was the first sawmill built in California. There was not quite fall enough yet in the tailrace, and the week was mostly spent in completing the race.[6]

Smith's account puts the inauguration of the mill on the next day:

> Sunday March the 12th — The past two weeks as usual, I have been to work on the mill; and last Sunday I picked up two dollars and a half, below this place about two miles. Today we started the mill, and sawed up one log and are pinning it to the forebay. The mill runs very well, but the back water hinders some, and the tailrace will have to be dug deeper.
> Sunday March the 19th — Last week we ran the mill some and it cuts well, making beautiful plank.[7]

The mill had a very short life. It operated only a couple of weeks, during spring high waters in 1848, and then lack of laborers forced it to close until March of 1849. Spring rains closed it again until June. By this time Sutter had sold his interest, and Marshall had some new partners, Alden Bayley and John Winters. The mill did a good business from 1849 to 1850. But other mills started operating in the area, and mismanagement drove the mill into the ground. By 1853 the millrace was buried in the river bed and Marshall was in debt. A daguerreotype made that year shows Marshall standing in the tailrace.[8] This one picture, along with Marshall's drawings of the building, are the only original sources we have for the size and framing of the sawmill, which was stripped of its wood for other uses. The most interesting use was by a Coloma carpenter, John McGonnigal, who gained possession of the oak headblocks and turned them into canes for souvenirs.

An early call for preservation was made by the editor of the Coloma *Empire County Argus* on May 13, 1854:

> It would be well to preserve some vestige of the past—a relic to open the pages of our early history: and what more fitting emblem could be preserved than Sutter's Mill. It is, at the present time an object of curiosity and will become more so. Frequent pilgrimages are made to the place on purpose to visit the old Mill. . . . As time progresses, this spot will become more attractive and consequently numerous visitors will congregate here, to examine the place where gold was first discovered and take a look at the old Mill. Who would dispute its claim to being classic ground? [9]

Though unheeded, the editor's prophecy became truth.

In 1965, a replica of Sutter's Mill was begun in Coloma for the State of California as part of the James Marshall Gold Discovery Park.

INTEREST in Sutter's Mill revived about 1920. The State of California sought to mark the exact location of the historic mill. During the particularly dry year of 1924, a Coloma resident had noticed the foundation of the old mill sticking just above the water. Satisfied after investigating that this was the foundation of Sutter's Mill, San Francisco's Society of California Pioneers that year directed a marker of river rocks to be set in concrete at the mill site. While excavating for the marker, workmen found a hewn 10x10 about 12 ft. long, thought to be from the lower frame, and a 5-in. whipsaw about 6 ft. long.[10] With the approach of California's Gold Centennial in 1948, interest in the mill awakened again. The state acquired the site with nine acres in 1942.

In a 1947 publication of the California Historical Society to mark the centennial of the gold discovery, Dr. R. F. Heizer, then assistant professor of Anthropology at the University of California, shed an astronomical amount of light on the exact size and construction of Sutter's Mill.[11] Through careful excavation, Dr. Heizer was able to document the timbers, the flooring and other artifacts. His permanent records comprise two journals, a set of field notes, a large number of photographs and 300 ft. of 16mm movie film. Heizer wrote a large interpretive section, but it's difficult to comprehend because of his confusion of builder's terms. For example, a post may be called an upright, but not an upright joist. Heizer also confuses sleepers with stringers and girders with plates, and at times gives the same timbers different names. Nonetheless, his drawings and measurements are persuasive.

Drawings of early sawmills confirm that John Marshall was familiar with mill construction (for example, sleepers seem to be the normal base). Marshall built separate upper and lower wood frames for his two-story structure, though some mills of the period had a stone or brick first story, or continuous posts to the top plate. Marshall's design may have arisen from a lack of sufficient manpower to handle a 30-ft.-high wall, and, in any case, the building was intended for a cut-and-run operation, rather than to last indefinitely. However, the structural logic is evident, with the lower story particularly well braced in the direction of timber movement through the mill, and the upper story, merely a roof over the operation, lightly braced.

The drawing by Adan E. Treganza, included in Heizer's report, illustrates the mill frame. Marshall specified a plan 60 ft. long by 20 ft. wide, and Heizer confirmed these measurements from a number of sleepers excavated along with a ground sill. The base of the mill comprised five sleepers roughly 30 ft. long set on 15-ft. centers. Variable notches about 5 in. deep and 20 ft. apart received the 60-ft. ground sills. The notches varied probably to achieve level, and one had a shim in it. (Was it Bigler, Smith or someone else who miscut?) The 11x12 ground sills had 2½ by 6-in. mortises for the posts, set in from the ends to provide relish.

In the lower fame, 18-ft. 12x12 posts carried dropped 12x12 tie beams with central through-tenons, double pinned. Buttresses ran from near the ends of the sleepers to about 8 ft. high on the outsides of the posts; 2-in. pins alone fixed the butt joints at each end. The 4x6 head braces from the posts to the dropped tie beams were fixed with single pins across standard housed mortise and tenon brace joints. Full-length X-bracing (lapped at the crossings and apparently mortised in) provided extra stiffness to the working bays. Floor joists for the upper level appear to have been 8x8s somewhere around 2 to 3 ft. on center.

Whether the streak sills (the long timbers intermediate between groundsills and top plates) and top plates were full length is unknown, as the majority of timbers recovered are from the lower frame. Head braces in the upper level appear to have been on an unusual 30-degree angle, again with standard mortise and tenon brace joints. The roof frame comprised a common rafter system of 4x4s about 4 ft. on center, with nailers spaced about 3 ft. apart and roof boards running from plate to peak nailed to the purlins. The main frame was virgin sugar pine. The flooring was 1-in. sugar pine 14 in. wide and pinned down by our boy Azariah Smith.

These flooring pins were fox-wedged in the sleepers. The end of a pin was cut off square, then kerfed and the thin end of a wedge inserted. When the pin was driven, the wedge, arriving at the bottom of the hole, would be forced deep into the kerf and thus spread the side-grain of the pin tightly against the bore. Dr. Heizer supposed from this evidence that all the pins in the frame must have been square ended, but, chances are, they were pointed for a drawbore. Many of the beams he found are now enclosed in a climate-controlled, glass-walled building at Marshall Gold Discovery Park in Coloma.

In 1965 a replica of the mill was built. I understand that this was during the Dark Ages of timber framing, but the crew who constructed this frame went beyond the pale. With all the experts watching, they ignored the daguerreotype as a primary source of information as well as Adan Treganza's excellent drawing representing Dr. Heizer's findings. The builders left no relish at the ends of the plates, resulting in open mortises that left the posts to twist as they pleased. They single-pinned the dropped tie beam tenons, significantly weakening the connection. They face-pinned the braces (housed but not mortised) and cut unique and alarming scarf joints in the girts and plates.

Glen Shepherd, one of the carpenters, described how the braces were installed: "The knee braces were put in place by using a 5-ton hydraulic jack. We placed it in the center of the cross-members using a 4x4 from the ground level up to the cross-member. We then jacked up the cross-member into a 3-in. crown. While the timber was in this position we slipped in the new braces."[12] The State of California has plans to try again, sometime in the next three to ten years. This time, up-to-date skills could be employed, perhaps under the wise aegis of the Guild, to replicate the valuable timbers—the gold—that Dr. Heizer discovered. —Paul Oatman

Paul Oatman (209-295-5100) is a contractor and timber framer in Pioneer, California.

Notes

[1] Cited in Theressa Gay, *James W. Marshall, The Discoverer of California Gold* (Georgetown, California: The Talisman Press, 1967), 132.

[2] Ibid, 133-134.

[3] Cited in Erwin G. Gudde, *Bigler's Chronicle of the West* (Berkeley: University of California Press, 1962). Several versions exist of *Diary of a Mormon*, of which Gudde believed that the MS at the Bancroft Library (Berkeley) was the most nearly complete.

[4] Cited in David L. Bigler, *The Gold Discovery Journal of Azariah Smith* (Logan: Utah State University Press, 1996), 106-107. Most early works on timber framing refer to timber fastenings as pins. The term "peg" is reserved for furniture. The expression "pin it down" might have its origin in the pinning of planking to framing.

[5] Gudde, 87-89.

[6] Ibid, 104.

[7] David L. Bigler, 111.

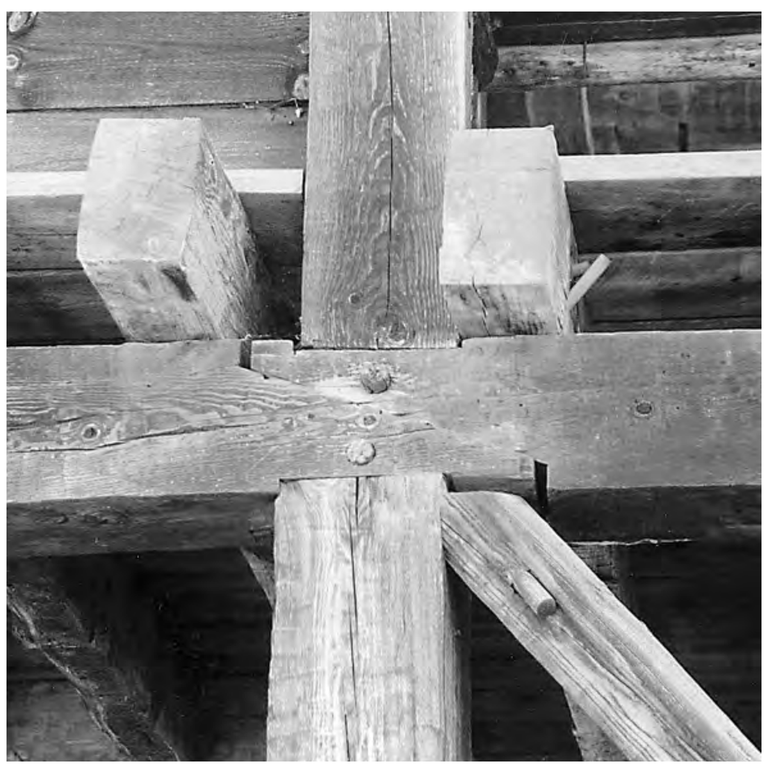
[8] The picture hangs in the California State Library, Sacramento.

[9] Cited in Gay, 293.

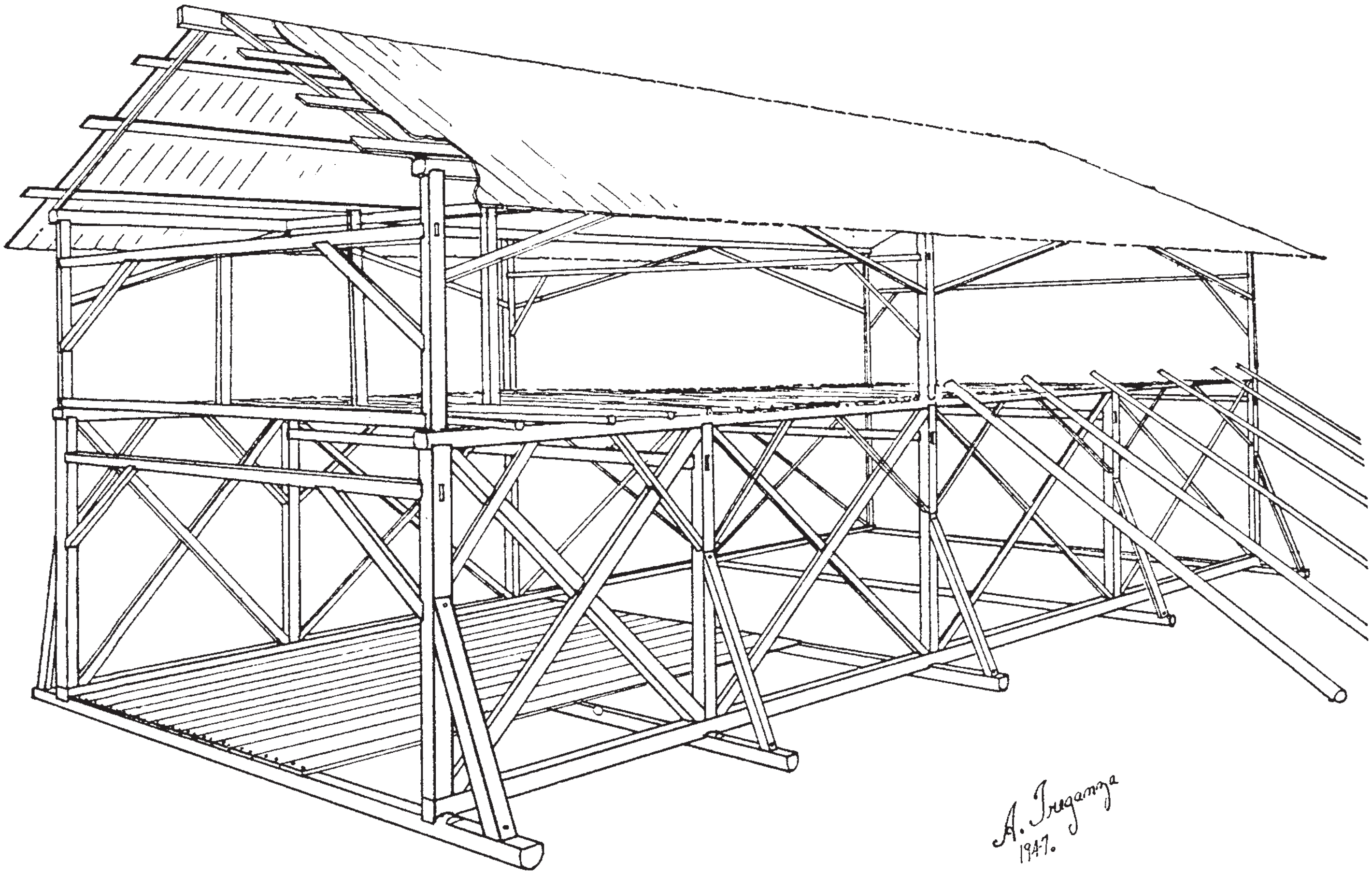
[10] Philip Baldwin Bekeart, "Location and Site of Sutter's Sawmill," *Society Of California Pioneers Quarterly* I, No. 3 (September 1924), 17-30. The timbers are on display at the Marshall Gold Discovery Park in Coloma.

[11] "California Gold Discovery Centennial Papers," *California Historical Quarterly,* Vol. XXVI, No. 2, 1947.

[12] Collection of original notes and photographs on the Sutter's Mill reconstruction, kept in the Marshall Gold Discovery Park Library.



Scarf joint at the midpoint of the streak sill on the 1965 replica.



Above, Adan Treganza's drawing developed from R. F. Heizer's archaeological findings at the mill site and the 1853 daguerreotype evidence. Overall dimensions of the mill were 20 x 60 x 37 ft. 6 in. high.

Below, elevation of the 1965 replica, built with the drawing in mind but with incomplete attention to detail and good framing practice. But the 30,000 bd. ft. of timber were pressure-treated for durability.

LATERALLY LOADED TIMBER FRAMES

II. Two-Story Frame Behavior

This article is second in a series to discuss the results of research conducted at the University of Wyoming on the behavior of sheathed and unsheathed timber frames subjected to an applied lateral load. Primary funding for this research was provided by the US Department of Agriculture National Research Initiative Competitive Grants Program, with additional support from the Timber Frame Business Council, the Timber Framers Guild and individual timber framing companies who contributed the test frames. Subsequent articles will present behavior of laterally loaded sheathed frames, behavior of laterally loaded structural insulated panel-to-timber connections and modeling of unsheathed and sheathed frames.

DESCRIPTION OF EXPERIMENTAL FRAMES. Four separate two-story, two-bay (2S2B) frames, each 24 ft. wide by 16 ft. high, were subjected to lateral load as shown in Fig. 1. Timber species included Douglas fir, Eastern white pine, Port Orford cedar and white oak; all frames were surface-planed and shipped unseasoned from their respective manufacturers. Nominal dimensions of the timbers were typically 6x10 for beams, 8x8 for posts and 4x6 for braces. The only significant exceptions were 7x10 posts in the white oak frame. Because of the extended period of the testing schedule, significant drying and consequential shrinkage occurred in the timbers. The average moisture content at the time of testing ranged from 6 percent for the white oak frame to 9 percent for the Douglas fir frame.

Brace dimension *kb* (Fig. 2) was 36 in. for the Eastern white pine and white oak frames, 30 in. for the Douglas fir and Port Orford cedar frames. Brace end and edge distances each varied from 1½ in. to 2½ in., and tenon thickness was either 1½ or 2 in. All frames had one peg at each brace joint except the white oak frame, which had two. All frames had full-height continuous posts, with splines connecting the lower beams across the interior post. The Douglas fir and white oak frames also had splines at the connections between the upper beams and the interior post, while the Eastern white pine and Port Orford cedar frames had continuous top beams. The Eastern white pine frame had tongue and fork joints (open mortises) at the outer post tops. All other connections of all frames were typical blind mortise and tenon joints. All joints were fastened by 1-in. oak pegs, with two exceptions: the Eastern white pine frames had ¾-in. pegs at the brace joints, and the white oak frame used 1¼-in. pegs across the splined connections.

Photos Rob Erikson

FIGURE 1. EXPERIMENTAL APPARATUS IN THE LAB. 2S2B FRAME SUBJECTED TO LATERAL LOAD. THE LOAD-SPREADING MECHANISM IS ATTACHED TO THE UPPER PART OF THE NEAREST POST.

Load and Displacement. As shown in Fig. 2, two horizontal point loads P/2 were applied at the elevation of each beam by an MTS hydraulic actuator system with a load capacity of 55 kips and available displacement of 3½ in. in each direction (7 in. total). The actuator force was transferred to the upper and lower beams via a load-splitting mechanism, thereby ensuring an equal distribution of the load. Consequently the displacements at the top and mid-height beams were not necessarily equal, but rather functions of the frame stiffness at the respective height. The applied force was measured with a load cell at the actuator, and displacements Δ_{top} and Δ_{mid} were measured with string potentiometers at the upper and lower beam levels. Displacement was imposed in both directions; the westerly direction as shown in Fig. 2 was defined as the "push" stroke, the easterly direction as the "pull" stroke.

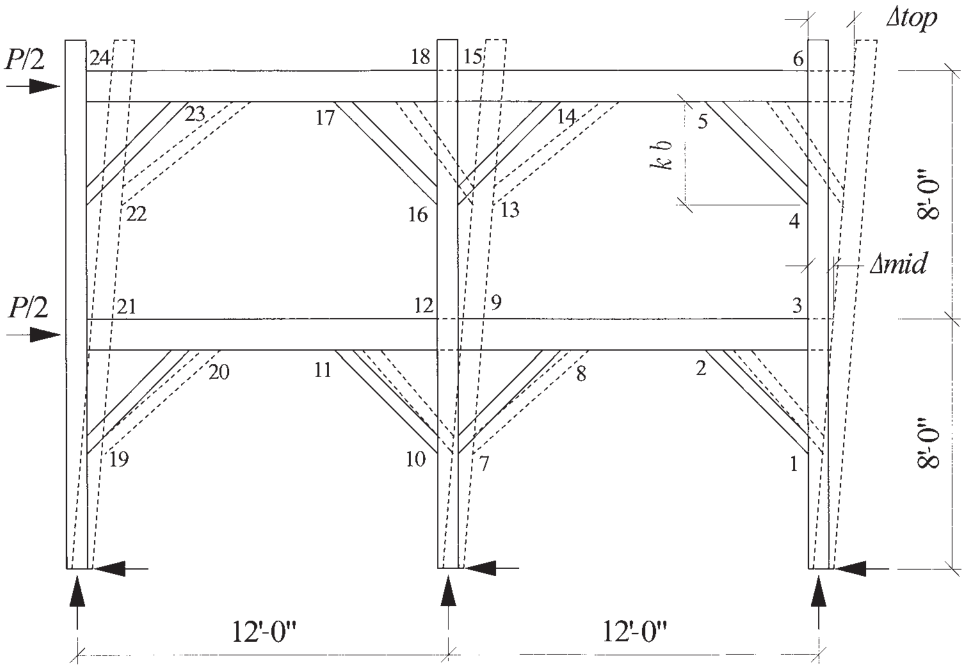


FIGURE 2. DIMENSIONS, LOAD, REACTIONS, DISPLACEMENT AND JOINT NUMBERS. (NORTH ELEVATION.)

FIGURE 3. WHITE PINE POST FAILURE AT TEST FIXTURE (REACTION CONNECTION).

Applied load magnitude was arbitrary. We assumed a total design wind pressure of 16 lbs. per sq. ft. and a loaded area of 192 sq. ft. (a wall 16x12), with the resulting pressure applied in line with our test frame. This value would vary with the assumed wind pressure and the actual size of the structure, and is provided only as a means to compare an applied test load to an anticipated design load.

OVERVIEW OF TEST RESULTS. The following paragraphs provide a description of the load cycles for each of the four frames. Brief descriptions of observed joint damage and failure are also included in the following sections (see Fig. 2 for joint numbering). Failure of individual frame joints was observed in many forms, as described in Part I of this series in TF 62. Tenon relish and peg failures were illustrated in that article.

Douglas Fir: The Douglas fir frame was load-cycled 115 times. Disassembly of the frame after the last load cycle revealed a relish failure at brace joint 20. Peg flexural failures occurred at brace joints 1, 4 and 22, all at outer posts.

Eastern White Pine: The white pine frame was cycled 19 times. Following cycling at service-level loads, the frame was loaded to failure. Sufficient displacement to cause failure was achieved by pushing the frame to the maximum available ram stroke, then blocking the frame in place to relieve actuator load and resetting the load fixture. The load reached a maximum of 6150 pounds at a corresponding top beam lateral displacement of 7.9 in. As the frame was pushed to maximum load, several joints failed, but the frame continued to carry increasing load until a cross-grain tensile failure occurred at the west post reaction connection (Fig. 3). Although a load-limiting failure occurred at the test fixture, ultimate failure of the frame was imminent as the beam at joint 12 had been pried out of its housing, and the spline also had suffered significant wedging damage (Fig. 3A). Inspection of the joints upon disassembly revealed relish failures at brace joints 2, 8, 13, 16, 19 and 23. There was a cross-grain tension failure of the tenon in the top beam at joint 6. Peg flexure failures occurred at brace joints 2, 4, 10 and 20 and at beam joint 21. The failure of the peg at joint 21 occurred in the vicinity of a small knot in the peg.

Port Orford Cedar: The cedar frame was cycled 611 times. Initially the frame was cycled slowly five times, oscillated 600 times at a period of one second and a ram displacement of 1 in. in each direction and, finally, cycled slowly six more times. Brace tenon relish failures occurred at joints 2, 8 and 19. The only peg failure occurred at brace joint 10. This peg sustained a flexural failure in sloped grain aggravated by a small knot.

White Oak: The white oak frame was cycled 9 times. As with the Eastern white pine frame, additional ram stroke was obtained by successive loading and resetting of the load fixture. In this manner, the frame was subjected to a maximum top displacement of 8½ in. in the push direction at a total load of 15,700 pounds. At this point, ultimate frame failure occurred, as defined by significantly reduced load with increasing displacement. There were many localized joint failures, but the major cause of reduced load capacity was a cross-grain tensile failure through the peg holes of the mortised member (post) at joint 6. Tenon relish failures occurred at brace joints 2, 8,

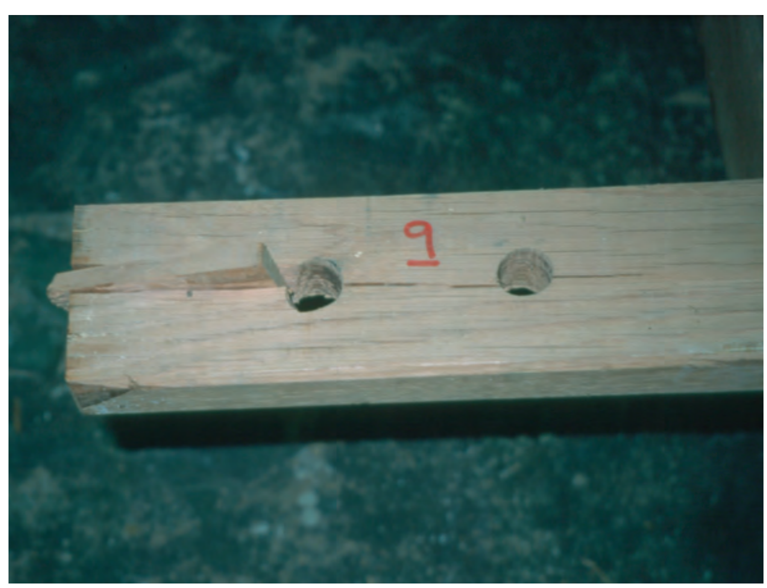


FIGURE 3A. WEDGING DAMAGE TO OAK SPLINE (WHITE PINE FRAME).

FIGURE 3B. COMPLETE DESTRUCTION OF BRACE TENON AND DAMAGE TO MORTISE AT JOINT 20 (OAK FRAME).

13, 14, 19 and 22. Splitting of the tenon occurred at brace joints 1, 2 and 4. The tenon at brace joint 20 was destroyed with the tenon severed in tension across both peg holes (Fig. 3B). Both splined joints at the interior post had relish failures through both peg holes at one end, and the peg in the spline at joint 12 also sustained a flexural failure. Flexural failures were evident in at least one peg at brace joints 1, 4, 5, 11, 13 and 22 and at beam joint 3. Combined shear and flexural failures were seen in pegs at brace joints 2 and 4 and beam joints 3 and 6. Note that most of the failures were near the west side of the frame, which appeared to resist a larger portion of the load when the frame was subjected to the maximum displacement to the west.

Service Level Load Results. Table 1 provides frame stiffness results for the first viable load cycle of significant lateral load, and the typical load-displacement plot of the Port Orford cedar frame is shown in Fig. 4. The white oak frame, with an average stiffness of 3060 lbs. per in., had more than twice the stiffness of any other frame. The higher stiffness of the white oak frame was primarily due to the higher stiffness of oak joints and the additional peg at all brace connections. Contrary to indications of the one-story, one-bay frame test results described in Part I of this series, the 2S2B results revealed no free displacement in the absence of gravity load.

Removal of Brace Pegs: The effects of removing brace pegs from the white oak frame are shown in Table 2 and Fig. 5. In this frame, each brace joint had two pegs. One of the pegs was removed for cycle 5 and both were removed for cycle 6. With one peg removed, the frame still had greater stiffness than any of the other frames.

Cyclic Effects: Two frames were examined for the effects of multiple load cycles. Fig. 6 compares the load-displacement response of load cycle 114 to cycle 2 for the Douglas fir frame. The average frame stiffness was reduced to 670 lbs. per in. from 900, but there was no evidence of free displacement. Subjecting the Port Orford cedar frame to 600 cycles did not significantly affect global stiffness, but the effects of cycling created a free displacement of 0.3 in. This was the only observed incidence of significant free displacement in a 2S2B frame subjected to service level lateral loading.

Maximum Load. Maximum applied loads and corresponding top-level displacements for all frames are listed in Table 3. The Douglas fir and Port Orford cedar frames resisted the maximum available actuator displacement of 3½ in. without incurring failure, and the Eastern white pine frame incurred a failure at its attachment to the test fixture, at an imposed top displacement of 7.9 in. In other words, all three of these frames were able to resist increasing lateral load to the point of maximum displacement. The load-displacement curve for these frames was slightly pinched, indicating the presence of some free displacement, but this was likely due to joint damage incurred in previous tests. The white oak frame was the only 2S2B frame displaced sufficiently to reach an ultimate load within the frame itself rather than at the support fixture. The maximum load cycle of the white oak frame is presented in Fig. 7.

Summary. In order to normalize the comparison of frame performance, the average stiffness and lateral drift at design load for each frame are listed in Table 4. The lateral drift was computed by dividing the design load of 3070 pounds by the average frame stiffness. The calculated drift values are comparable to the actual deflections observed during the maximum load cycles. These relatively high lateral displacements at design load indicate that unsheathed braced timber frames may not have adequate stiffness to resist typical wind loads without the addition of a supplemental lateral load-carrying system. At this point you may be wondering when one would encounter an unsheathed frame that experiences the full design wind load that we have proposed. After all, a frame would not be subjected to full wind load unless there were an enclosing envelope.

Consider the following scenario. A rectangular building is fully sheathed on three sides, but the

Frame	Cycle	Push Stroke Max. Load (lb)	Push Stroke Max. Disp. (in)	Push Stroke Stiffness at Max. Load (lb/in)	Pull Stroke Max. Load (lb)	Pull Stroke Max. Disp. (in)	Pull Stroke Stiffness at Max. Load (lb/in)	Average Stiffness at Max. Load (lb/in)
Douglas Fir	2	983	1.01	790	1147	1.02	1010	900
Eastern White Pine	3	1990	1.54	1450	2050	1.53	1130	1290
Port Orford Cedar	4	1515	1.13	1240	1524	1.2	1160	1200
White Oak	1	3050	1.02	3270	3360	1.02	2860	3060

TABLE 1. SUMMARY OF SERVICE LEVEL PERFORMANCE.

Cycle	Condition	Push Stroke Max. Load (lb)	Push Stroke Stiffness at Max. Load (lb/in)	Pull Stroke Max. Load (lb)	Pull Stroke Stiffness at Max. Load (lb/in)	Average Stiffness at Max. Load (lb/in)	Change in Stiffness
1	Fully pegged	3050	3270	3360	2860	3060	0%
5	One peg removed	2190	2450	2470	2700	2570	16%
6	Both pegs removed	698	760	623	530	640	79%

TABLE 2. REMOVAL OF BRACE PEGS, WHITE OAK FRAME.

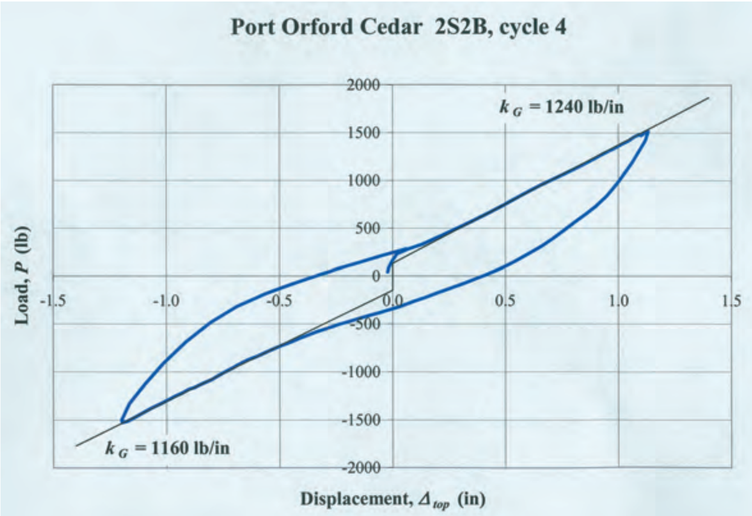


FIGURE 4. TYPICAL SERVICE LEVEL LOAD VS. DISPLACEMENT CURVE.

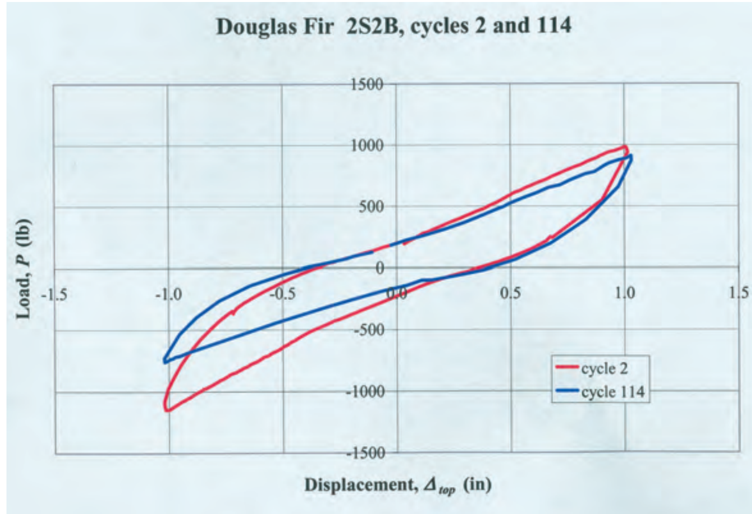


FIGURE 6. EFFECT OF MULTIPLE LOAD CYCLES.

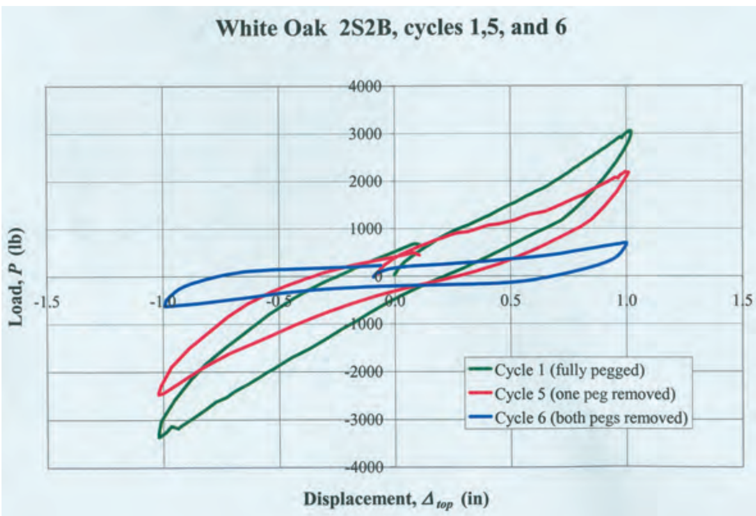


FIGURE 5. EFFECT OF REMOVING BRACE PEGS.

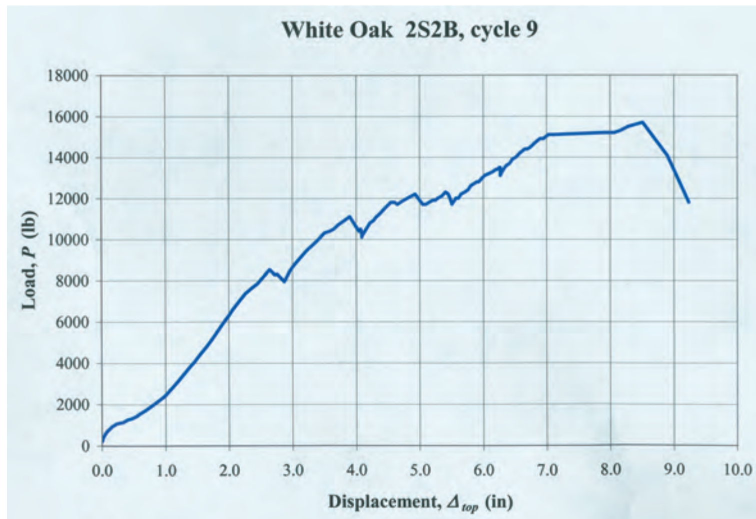


FIGURE 7. MAXIMUM LOAD CYCLE.

fourth wall (let's say the south wall) is mostly enclosed with windows, without the benefit of a significant amount of structural sheathing. With full wind acting on the east and west walls, the lateral load must be carried by the north wall, the south window wall, and possibly an unsheathed interior wall. Unless all the load is transferred via a horizontal diaphragm to the north wall, a portion of the wind will be resisted by unsheathed frames. The results of our research indicate that unless an alternate path is developed, or the frame is stiffened through other construction methods (metal plates, for example), an unsheathed wood-pegged timber frame may experience unacceptable deformations due to lateral drift.

However, a favorable characteristic of these frames was that, as shown in Table 4, all frames were able to resist loads greater than the assumed design load. Recall that the imposed displacement of the Douglas fir and Port Orford frames was limited to the available actuator stroke of 3½ inches; the failure load is assumed to be much greater than the maximum applied load in these cases. This assumption is supported by the results of the white oak and Eastern white pine maximum load cycles. The oak frame failed only after being subjected to displacement and load far beyond expected service conditions, and the pine frame failed at the connection to the test fixture. Therefore, these frames had sufficient strength to resist a lateral load comparable to typical wind-induced loads.

—ROB ERIKSON and DICK SCHMIDT

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		Push Stroke		Pull Stroke	
Frame	Cycle	Max. Load (lb)	Max. Disp. (in)	Max. Load (lb)	Max. Disp. (in)
Douglas Fir	115	3608	4.23	3176	2.88
Eastern White Pine	19	6150	7.92	-	-
Port Orford Cedar	609	3881	3.48	4150	3.31
White Oak	9	15,700	8.51	-	-

TABLE 3. SUMMARY OF MAXIMUM LOAD CYCLES.

Frame	Average Frame Stiffness (lb/in)	Calculated Lateral Drift at Design Load (in)	Maximum Applied Load (lb)
Douglas Fir	900	3.4	3608
Eastern White Pine	1290	2.4	6150
Port Orford Cedar	1200	2.6	3881
White Oak	3060	1.0	15,700

TABLE 4. 2S2B FRAME STIFFNESS, LATERAL DRIFT AND MAXIMUM LOAD.

TIMBER FRAMING FOR BEGINNERS

III. Introduction to Layout

LAYOUT is the method used for locating and marking each joint in the frame. In a perfect world (which we try to attain with a four-sided planer), all timber dimensions would be consistent from piece to piece. However, we often use materials that vary from nominal dimensions and may be out of square. They may be unseasoned and change shape over time. Over the centuries, techniques have been developed to work through these irregularities during layout and to produce tight, good-looking joinery.

Four distinct layout approaches are found in common use today: Mill Rule, Mapping, Scribe Rule and Square Rule. By "rule" I mean here a measuring system or group of techniques, not a hard and fast set of laws. The first two may not be recognized as traditional layout systems, but they warrant explanation since they are often used, especially in determining lengths of pieces.

Layout can be divided into two distinct steps: determining the lengths of the pieces and the locations of the joinery along them, and then drawing out each joint at its proper location. Both the techniques and the tools differ for each of these steps.

Becoming fluent with any layout technique (and you may use a variety or all of them within a single project) requires an understanding of the concept of *reference* planes and surfaces. These are for the most part the surfaces of the frame that will be covered by a sheathing material, and thus should be flat. The outsides of exterior walls and the tops of floor joists and rafters are normally keyed as reference planes, and most timbers in the frame will have one face in a reference plane. Centerlines may also indicate reference planes, most often in scribe work. Interior posts and beams don't have a surface on the exterior of the building, so a convention must be adopted. Traditionally this might be a compass point (North, for instance), or the side of the member facing the nearest exterior bent, or the side facing the center aisle.

The best indicator of the reference planes of the frame can be found on the construction drawings. Here you will see (assuming they were drawn by a competent designer who understands framing) that dimensions are given from reference plane to reference plane. In floor-framing plans, you will find dimensions from outside of building to outside of building, and also to one side (or perhaps the centerline) of joists, headers and summer beams (Fig. 1) . If the dimension is to one side, that indicates the reference face of that timber. Each timber has *two* reference surfaces or intersecting planes, adjacent and at right angles to each other.

In sections (taken from the interior) or elevations (taken from the exterior) showing side views of the frame, you will find dimensions from the top of the first floor framing to the top of the second floor framing, as well as to the top of the plates, purlins and ridge and perhaps to the bottom of door and window headers. All the dimensions indicate where these faces must end up in the finished structure. Reference surfaces need not be dimensioned on every timber, only those necessary for doors and windows and other millwork to fit and for the building to fit on the foundation. If a dimension isn't given, it's up to the framer to use some consistent (often arbitrary) method for designating reference faces, but each timber still needs two before commencing layout.

Recognizing the reference planes in the building, you can then determine the lengths of timbers required to produce an assembly that will have its reference faces on those planes. Let's look at a particular example and see how the four different techniques mentioned above can be used to determine lengths, and make more apparent some of the advantages and disadvantages of each method.

Drawings Will Beemer except where noted

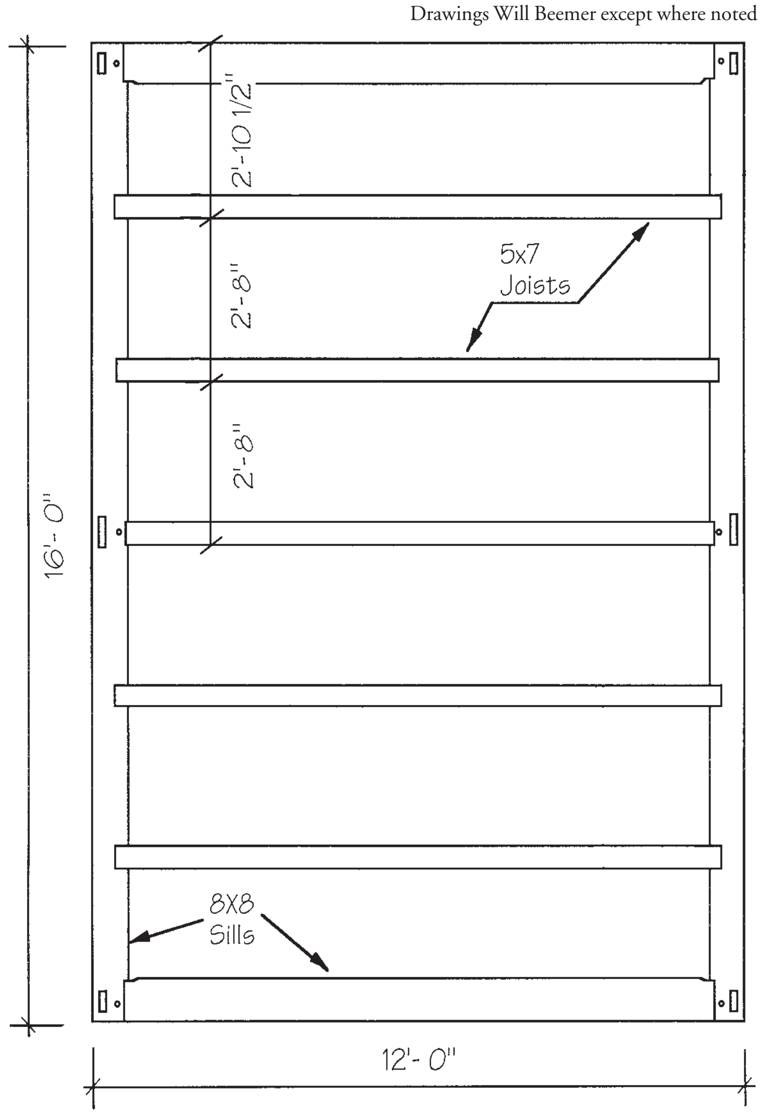


Fig. 1. Representative floor framing scheme.

In the floor plan shown in Fig. 1 (facing page), we have a 12-ft. by 16-ft. floor system comprising sills and joists. The dimensions are given to the exterior faces of the sills. Since we know that the top of the floor system is another reference plane, we immediately see that the tops and exterior faces of the sills will be the adjacent reference surfaces when it comes time to mark them out. The sills are shown at 8 in. by 8 in. as their nominal (in name only) dimensions, but we know their actual dimensions could vary by as much as ½ in. either way if delivered directly from the sawmill, or even more if hewn or tapered. Nominal dimensions are usually recognized by the absence of inch marks after the numbers; if the inch marks are shown, I expect these numbers to be actual dimensions.

Since the longer, 16-ft. sills overlap the 12-ft. ones, 16 ft. is their final length. Assuming a mortise and tenon joint, we can see that the short sill will have the tenon and the long one will have the mortise. As a systematic approach, I would recommend laying out all the joinery on a timber before cutting the ends to length. You never know when you might need to relocate the joinery a few inches because of a timber defect.

SO, how long will the short sills be? We'll take each of our four layout methods and see how to come up with a different answer depending on which we use.

Mill Rule is a term coined by Rudy Christian a few years ago to describe layout techniques for four-sided timbers planed to a consistent section. In this system, all the 8x8s in our frame would have been previously planed to, say, 7½ by 7½ in. Thus, without even selecting or looking at the sill timbers, we can calculate the length of the short one. Assuming a simple mortise and tenon with no housing and the shoulder of the short sill abutting the inside face of the long one, the shoulder-to-shoulder length of the short sill would be, in inches, 144 – 7½ – 7½, or 129. Tenon length will be added to this, but not until we're actually marking the timber. The shoulder-to-shoulder length is the critical dimension, and if it's wrong the building will not be the correct size. So I follow the mantra, *avoid adding and subtracting numbers whenever possible* (that's where mistakes can happen), and I don't even routinely figure the overall length of tenoned members. (That might be necessary if the roughsawn timbers lack the customary length allowances that loggers observe.)

We have quickly calculated the shoulder length for the short sill, and both short sills will be the same length since they're joining identically sized timbers. Here is one significant advantage of Mill Rule (shared with Square Rule): like timbers are interchangeable. Another advantage is that you don't have to find the mating timber and measure it because you know it's been planed square to a set dimension. The disadvantage is that you have to pay for the sizing, and perhaps additional shipping costs. If you intend to plane the timbers anyway for appearance, the 10 percent extra cost in purchasing planed timber would seem a bargain. But you should still know the following layout methods and how to deal with the occasional irregularities that are bound to occur in your timbers, even four-sided timbers.

The next three methods all account for variations in timber dimensions and can thus be used with roughsawn timbers. *Mapping* puts the two reference faces of the timber (which you should make square to one another if they are not already so) normally to the top and outside, and then any variation in size at a mortise location is factored into the theoretical shoulder-to-shoulder length of the tenoned piece intended for that location. In our example, let's say the north end of the east sill, the one to be mortised, measured 8¼ in. wide, and the north end of the corresponding west sill measured 7⅝ in. wide. Our short sill would then have a shoulder-to-shoulder length of 144 – 8¼ – 7⅝, or 128⅛ in. If the south ends of the long sills were 8 in and 7½ in., respectively, then the shoulder-to-shoulder length of the short south sill would be 144 – 8 – 7½, or 128½ in.

Mapping can get very detailed since many pieces have to be mapped to two faces, and then you have to keep track of which piece goes where. If the joinery face you're mapping to is out of square, you may have even more information to transfer between the pieces. Like pieces are not interchangeable since the lengths vary depending on their location. You have to find the mating piece and measure it before you begin layout. In a sense it's like scribing in your mind, transferring irregularities from one piece to another by calculation. Mapping is too cumbersome to use on a frame-wide basis but could be handy if you make a mistake and need to map a single piece to fit.

Scribe Rule can be used equally conveniently with regular or irregular, even vastly irregular, timber and logs: bowed, twisted, severely out-of-square or wany (natural-edged). This layout system for timber framing evolved before literacy and numeracy were commonplace, and it persists where large, straight timber has rarely been available for ordinary domestic construction. For scribe rule marking, timbers are literally laid out one above another in the positions they will have with respect to one another in the assembled frame.

Will Beemer

Marc Guilhemjouan demonstrates the use of the plumb bob to transfer joinery lines from timber to timber.

Joint lines are transferred by hand and eye, using plumb bobs suspended on lines (above) and dividers or other scribing devices. This layout method requires a lot of handling and space as pieces are repeatedly moved around, assembled and taken apart. Assemblies must be carefully leveled since plumb and level are the system's universal reference constants. Although you may use reference surfaces if the timber is reasonably straight and square, centerlines are just as often used, and necessary on round pieces. In the last case, the dimensions on the plans should read to the center of a piece, or you must calculate the offset from the reference plane to the centerline.

If we were scribing our floor frame example, we would set the two long sills 12 ft. apart (outside dimension) and parallel to each other, level them both across and lengthwise, and then set the uncut short sill across them, sitting exactly over its final position. The short sill would also be leveled up. Using a plumb bob (or any of a number of other devices that measure plumb), we would then project the inside surfaces of the long sills up onto the short ones and mark for shoulders. This operation establishes the shoulder-to-shoulder length, without using any numbers, no matter how irregular in shape or surface the long sills might be.

But if the sills are irregular, especially if they are without any straight edges, how would we set them parallel and how would we set them square to one another? To do so, some external reference system must be provided to establish square in the horizontal plane. The 3-4-5 right triangle, which follows, in convenient whole numbers, the Pythagorean rule that the sum of the squares of the sides is equal to the square of the hypotenuse, is probably the most familiar such construct in building.

In the French scribe tradition, we would draw (with chalk lines) a four-unit by three-unit rectangle on the floor, to represent the outside dimensions of the building. To get the drawing square, we would make sure the diagonal measurements from corner to corner equaled five units exactly. In our case, the chalked rectangle would be 16 ft. by 12 ft., the diagonal 20 ft., and we would set up the four sills over the drawing, moving them around until the four outside intersections where the timbers were to cross fell plumb over the corners of the drawing. Note that it's possible to draw many geometric figures and angles using a chalk line and trammel points, the latter as giant dividers to swing arcs and to step off distances.

If we did not have a layout floor, we would mark points 16 ft. apart on the outside arrises of the long sills, and set the sills so that the points were 12 ft. across from each other *and* 20 ft. apart diagonally. Then we would set the uncut short sills on top, making sure their outside faces were plumb over the end points on the long sills.

Scribing requires the most skill of all the layout systems, but it can also produce the best fits. The joinery seems to flow from one piece to the next. The lines on the timbers are not interrupted by unsightly gains. Although setup is time consuming, it can be done efficiently by experienced people. Like pieces such as braces, joists and rafters are obviously not interchangeable as in Square Rule or Mill Rule, but because you can actually see the joint develop as it is laid out, and simple tools are used, with direct measure, Scribe Rule seems to have been well suited to the highly skilled, illiterate carpenters of yore, who had good eyes but no tape measures.

THE *Square Rule* was developed in North America, apparently near the turn of the 19th century (the earliest dated example is 1803). Timber framers could now get roughly squared timber relatively easily. The trees here were large and could be milled or hewn down to a nearly consistent section along the length without concern for wasting too much of the tree, and surfaces were true and straight enough to serve as references.

The Square Rule layout system adopts the principle that within every irregular timber lies a smaller, perfect timber that is square, straight and of uniform section. The perfect timber within can share the two reference faces of the larger timber, and the joinery intersections to be laid out on the opposite faces can be reduced or sized to the inner surfaces of the perfect timber. The sizes of the various perfect timbers for a frame are determined by the actual (measured) minimum dimensions of the rough timbers. Since the sizing reductions, also called *gains*, are laid out at uniform distances from reference faces, they may vary in depth according to how much larger any actual given timber might be than its perfect timber within. In some cases the perfect timber within does not share any faces with the rough timber outside, but instead shares centerlines or other reference planes from which the gains are laid out.

Note that a sizing reduction is often concealed in a structural housing, a substantial shoulder at least ¾ in. deep found at the lower end of a mortise and intended to support a significantly loaded beam whose tenon alone would not serve. If the tenoned piece is much smaller in section than the mortised piece, for instance in the case of a brace entering a post or beam, or a beam entering a post broader than itself, then both of the sized faces can go into a gain closed on three sides, called a *stopped housing*. In contrast, a *through housing* crosses the entire width of the mortised timber (Fig. 3).

Now, let's say that in framing my floor system I look through the stack of timbers and find that the sawyer has sawn all the 8-in. material to nominal size or greater, with maybe one or two pieces ¼ in. or ½ in. under nominal at the ends. I could then safely say that my 8x8 sills have perfect 7½-in. x 7½-in. timbers within. Determining the shoulder-to-shoulder length for the tenoned pieces is then easy: the short sills will be 144 – 7½ – 7½, or 129 in., to fit between the sized long sills. I must also make the tenoned pieces 7½ in. wide where they will fit into the mortised pieces.

As shown schematically in Fig. 2 below, the person laying out the long sills will mark a housing with its surface, or table, at 7½ in.

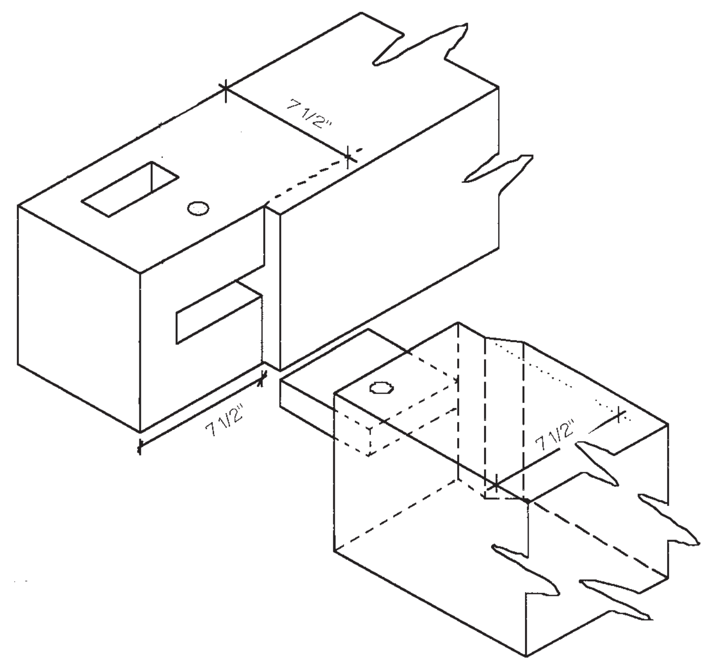


Fig. 2. Sill corner joint with sizing reductions.

from the reference face (the outside), and its length 7½ in. as measured along the grain from the end of the sill. The person producing the short sill will mark to reduce the width of the timber to 7½ in. for a short distance back from the shoulder (usually ½ in.) to clear any unreduced width in the long sill. Both workers can be confident their timbers will fit together and produce the correct overall dimensions for the assembly.

If the mating timbers have the same nominal section, the reduction only needs to occur on one of the joinery faces of the tenoned piece. The other face will be only approximately flush, but this is just an appearance issue and doesn't affect the fit of the joint.

In the case of our sill corner joint, we have a complication. The tops of the sills and joists must be flush for the flooring, and the undersides of the sills sit on the foundation. Since both can't be references, we decide that the floor plane rules and that, if need be, we will shim the undersides of the sills to bear evenly on the foundation.

Photos Will Beemer

Square rule means a gain or a housing at every joint, including at the tops of the posts. Below, ingenuity is sometimes required in transferring location points.

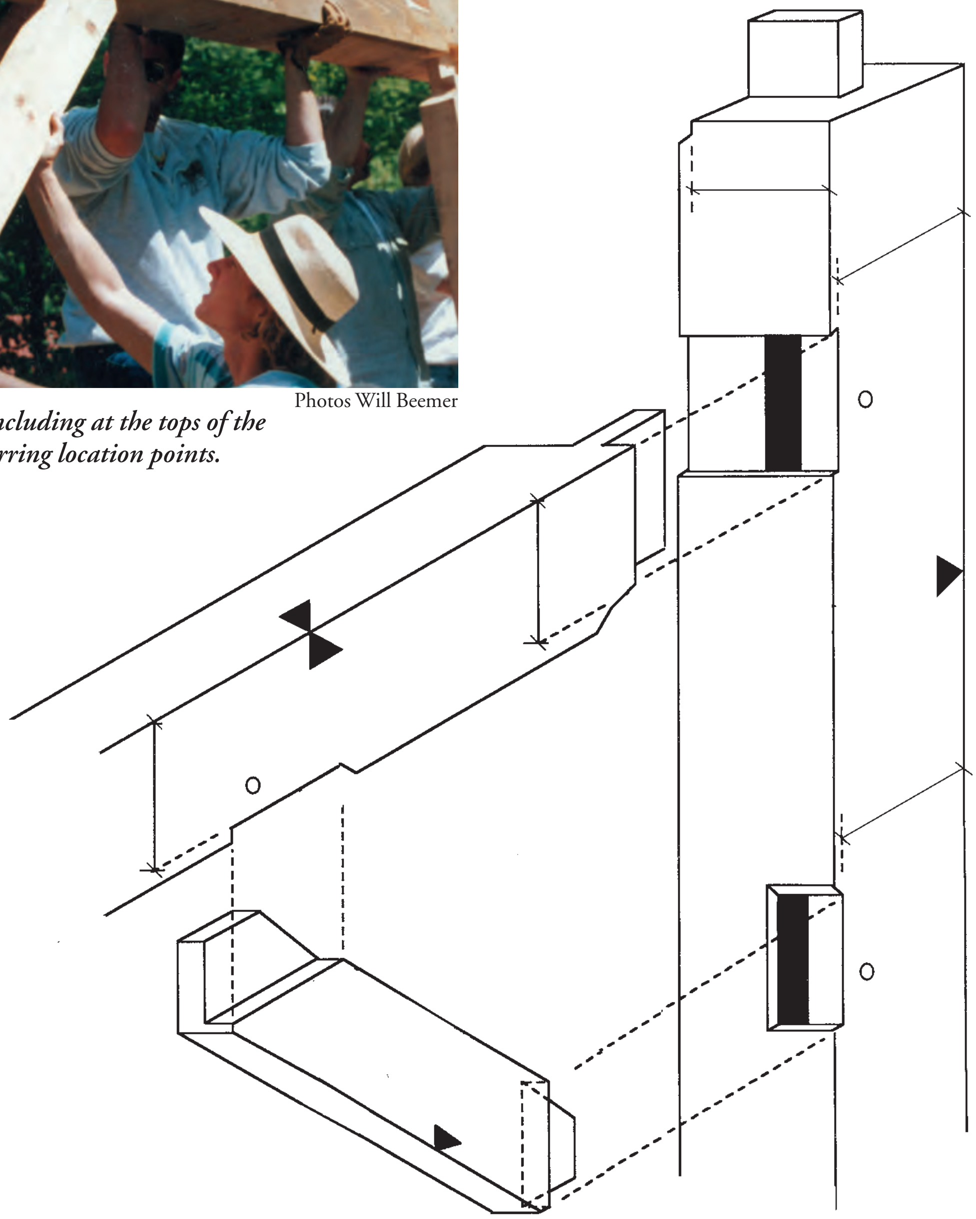
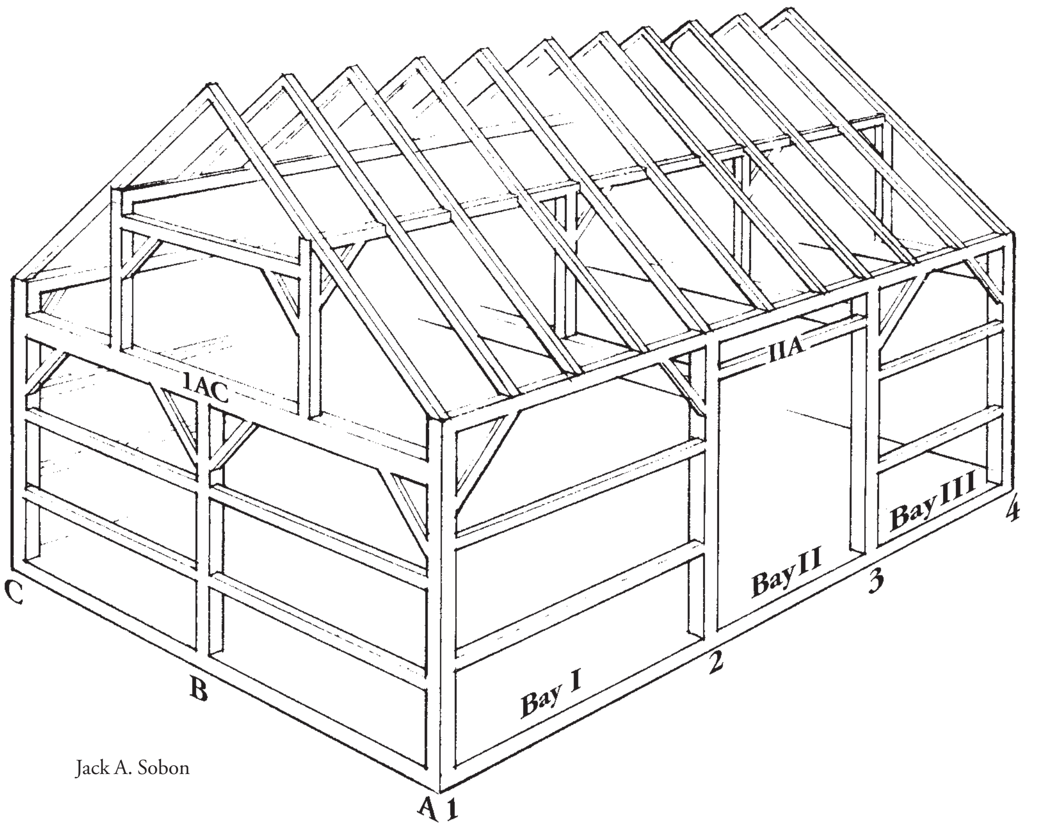


Fig. 3. Representative assembly showing essential reductions at joinery faces. Beam is supported by through housing on post; brace enters stopped housings.

A distinguishing characteristic of traditional Square Rule layout is that shared reference surfaces on timbers are flush to one another, so that even interior braces would be flush to one side of their posts, not centered. Square Rule exploits the interchangeability of like pieces—joinery can be laid out on one timber without looking at the mating piece. (Perhaps it hasn't even been sawn yet.) I am pretty comfortable with the accuracy of the sawyers I use and stipulate when I make an order that I want no timbers more than ¼ in. under nominal; over is okay. The disadvantage of Square Rule is that all joinery, at least on joinery faces, must be housed to the smaller perfect timber, and this is extra work, both in creating the housing and in reducing the tenoned piece.

The well-versed timber framer will realize that plumb, level, square and straight are the final objectives for the frame, a holy grail of universal constants we can always use as references for layout if the timber doesn't provide them. Often, different tools and layout systems can be used in combination to achieve the desired goal. For example, say you wish to lay out a curving brace using the Square Rule, but you have no straight edge to lay your framing square on, or no surface to strike a chalk line on. You could run a string or straightedge from end to end, with the brace curving in and out between, and use that registration line to hold your square against. You could also use squares in combination with levels and other squares to get a point transferred around a timber that has already been leveled.

EVEN before shoulder-to-shoulder lengths are determined from a frame drawing, you should figure out a labeling system to identify each timber. This label or code will help you visualize the timber in the frame as you work on it, and it will also assist mightily on raising day as the crew is looking for the next piece to bring up on the deck. Many timbers look alike but have subtle dif-



Jack A. Sobon

Fig. 4. Labeling scheme for small barn frame. Wall and bent coordinates give most locations. Bay numbers help group secondary timbers.

ferences in dimension or number of joints. A label indicates clearly and concisely the location and orientation of the timber in the frame and it should be easily understandable by everyone on site.

Perhaps the frame designers have already labeled the drawings in such a way that you can use their designations. Typically, labeling is based on the floor plan, with bents, bays and posts being numbered (or lettered) from one side or end of the building to the other. Joists, girts, plates and ties are then labeled according to their bent or bay, and their ends can be marked with the code of the piece they are to join. Interchangeable braces, joists and rafters may not even need labels unless there are various groups to identify in the stack.

You may want to number the bents 1, 2, 3, etc. and use Roman numerals I, II, III, etc. for the bays, both starting from one gable end. The lines of posts (which can also be seen as walls bounding the aisles of the building) can be lettered A, B, C, etc. In Fig. 4 , Bent 1 has three posts to be labeled 1A, 1B, 1C. The tie beam at the near gable end connects Walls A and C in Bent 1, so is logically coded 1AC, and each end of the timber would be marked with its appropriate letter. The header over the doorway in Bay II lies in the A wall, and could be labeled IIA. In another system, it could equally well be labeled A 2-3. In all systems, it's frequently helpful to have the ends of the piece marked additionally for the mating pieces, to prevent reversal or inversion of apparently symmetrical members.

On old timber frames you might find numbers incised with different-size chisels to indicate on which side of the building the timber belongs. For example, numbers cut with a 1½-in. chisel could indicate the west side of the building, 2-in. marks the east side. European carpenters often use "flags" or other symbols attached to the numbers to show different locations such as floor levels. No matter what system you use, try to be consistent and avoid duplication; this becomes harder the larger and more complex the frame. You will usually label a timber on an unseen face and perhaps on the ends, using a cutting tool such as a chisel or race knife, or a reasonably durable marker such as a timber crayon or "permanent" felt-tip marker.

ONCE you've determined the label for your timber and its shoulder-to-shoulder length, you can get your piece out on the sawhorses and begin layout of the joinery. Here we have space only to discuss general layout tips and the sequence for working with typical material from the sawmill. Specifics on the Scribe Rule or Square Rule systems can best be learned through practical experience or already published material (see the bibliography).

Choose the desired piece from the timber inventory, keeping in mind its eventual position in the frame and its consequent structural and appearance requirements. A bowed or twisted piece is not right for the exterior of the building where it would cause the sheathing to bulge, but it could work on an interior bent where there will be no sheathing or flooring attached to it. I use the term "bow" to mean any curve along the length of a timber, usually resulting from sawing or seasoning. (In a horizontally spanning member, if the bow is up, it's properly called "crown," if down it's called "sag" and if to one side it's called "crook.") A piece with a large knot midway might not be structurally ideal for a joist but could be used where a partition wall is to be framed under it. Stained faces can be oriented to be hidden; good-looking faces can be exposed (the best-looking faces are often not reference faces); the heart side of a timber can be expected generally to check more than the bark side. Many things should be considered as you determine the orientation of the timber, but remember another mantra I use: nothing is random. Which face is up, which end goes where, these do make a difference, and if you find yourself saying "It doesn't matter," think again. But be wary not to get bogged down in analysis paralysis.

The first thing to do with the timber on the horses is to identify the bowed surfaces (if any). On horizontal members, the bow should usually be up (crowned) to resist loading; for posts in a plane, the bows should all go the same way and should be avoided entirely on exterior and major posts. Save your straight material for these locations, or plane off the bow. More crown is acceptable on longer horizontal members, especially if loading will take some of it out. Crown of less than ¼ in. over 12 ft. I usually ignore, or I plane it off if it's on a critical reference face. If the crown is severe but doesn't need to be removed because nothing will be attached to that surface, an option is to snap a straight chalk line on both sides along the length to use to register a square when marking for shoulders. You may find one face crowned but the opposite face straight because of reactions of the timber while it was being sawn; in this case, make the straight face your reference face.

With the bow up on your sawhorses you may have already identified one of your reference faces (top of floor or roof, outside of exterior posts, etc.). Next check for *twist* (also called *wind*, indicating rotation) in the timber. Set framing squares across the timber, about a foot in from each end, with the tongues (the narrower, 16-in. part) hanging down. Sight across the squares from one end of the timber. Any variation of ⅛ in. or more will be readily apparent. If the twist is significant, then you must plane down one end or both until the squares are in parallel, then snap chalk lines a set distance down from the newly made surfaces to establish a reference plane. These lines can be snapped as far down from the theoretical face as the offset of the mortises and tenons of the piece, usually 1½ or 2 in.

Will Beemer

Two framing squares will make evident any twist in the length of a timber. In square rule layout, twist should be corrected at the joinery faces before the joints are cut.

While using chalk lines for reference is more work than using well milled timber, it is standard operating procedure on hewn material and for many framers who want to insure accuracy on doubtful pieces. Variations in a timber along its length can throw off a square when laying out a joint; registering your square to a line assures that you're squaring off a straight plane. The timber I get is usually sawn well enough that snapping lines is only necessary on a few pieces in each job, and I just pay attention on the others to see that my square isn't thrown off by a knot or some other local variation.

After crown and wind are checked, find an adjacent face of the timber that is square to the upper face; again, if there is none you will have to square a face up by planing and then snap chalk lines to establish a reference plane down the length of the timber. Once you have established the two reference faces, you should then mark them. I use a stick or cake of chalk at this stage of layout, labeling the timber on a face to be hidden, marking each end with the number of the timber it will join, and indicating the arris (the meeting line shared by both reference faces) by marking a V on each face pointing to the arris.

Once the reference faces are identified, and the two ends of the timber assigned to their proper locations, you should be able to visualize the timber in the frame. This ability to imagine your "castle in the air" is critical, and if you don't understand what the timber should look like in the finished frame while the timber is still on the sawhorses, mistakes are much more likely to occur.

Now you can lay your tape measure along the arris and mark the shoulders and the other control points that locate all the joinery along the length of the timber. Take the opportunity before marking to slide the tape back and forth, to avoid as much as possible knots or other obstructions to joinery (assuming you have the extra length to do so). Each joint will have one control point, usually a centerline or an end line, indicated by the dimensions on the drawing; after locating those, I put the tape measure away and use squares to lay out the individual joints.

Once your two reference faces are chosen, it's imperative that all joinery along those faces be parallel or perpendicular to them. Gains and housings serve this purpose, and using the framing square in "combination" with a combination square will help you transfer dimensions around the timber and onto the joinery faces. Just keep in mind that you can't use a square (or a mortising machine, for that matter) on a joinery face if it's not square to a reference face. This limitation becomes important when you're checking a mortise, housing or tenon from a joinery face. If you've snapped chalk lines to establish reference planes because a timber was excessively crowned or twisted, your framing square will be placed on these lines to transfer lines around, rather than on the actual edge of the timber.

Unless you're going to plane the timbers before raising, be very careful marking on what will be visible surfaces in the finished frame. The only solid lines I draw with a pencil (never a pen) are lines that will be cut; I'll transfer other lines around the timber with either tick marks or lightly dashed lines that can be erased easily. Reference surfaces that won't later be hidden should be planed clean before beginning the layout, being careful to keep them square (or taking the opportunity to make them square). Surfaces that will be covered later don't need to be planed, and joinery faces between the housings or sizing reductions can be planed later without affecting assembled dimensions.

Joinery design follows an understanding of the nature of wood and engineering principles. It is a large subject unto itself. But many joints, such as corresponding mortises and tenons, are typically laid out at some set distance from the reference face (or centerline), and these distances often correspond to the width of the framing square blade (2 in.) or tongue (1½ in.). The tenons or mortises themselves can also be laid out using the square as a template. I normally use 1½-in. tenons for hardwood or softwood less than 8 in. wide, and 2 in. for larger softwood tenons. Once the control points are located along the length of the timber with a tape measure, the rest of the joinery can often be laid out with just a framing square.

If you find an old photograph, or even a new one, of the happy raising crew perched on the frame, look for the person with the framing square. That framer was probably the one in charge of layout. I think it's a tradition we should keep alive. —Will Beemer

Will Beemer (will@tfguild.org) administers the Guild's workshop program and has directed the Heartwood School for many years. *The references below will provide more detail on the various layout methods. Workshops in both Scribe Rule and Square Rule are offered by the Guild, and some timber framing companies include hands-on layout instruction in their public workshops. Previous articles in this series have covered The Toolkit (TF 61) and Timber Frame Design (TF62). The series will resume in the December 2002 issue.*

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Handsaw Primer

THE handsaw is a proud tool with a history that goes back at least 4,000 years in the annals of human technology. More recently, but still long ago, Shakespeare's Hamlet declared: "I am but mad north-north-west: when the wind is southerly I know a hawk from a handsaw."

Scholars have argued over the meaning of Hamlet's puzzling lines to Rosencrantz and Guildenstern in Act II, Scene 2. It may be that "hawk" was Elizabethan slang for mattock—a grubbing tool—and so the contrast is reasonable, but this view fails to explain the allusion to compass points and the wind. Alternatively, it may be that "handsaw" is an intentional corruption by Shakespeare of "hernshaw," a medieval term for the heron (hawks were used to hunt herons in Elizabethan England), and that Hamlet used it deliberately to confuse and thwart Rosencrantz and Guildenstern in their snooping on behalf of King Claudius. In this interpretation, the hawk represents Claudius and the hernshaw Hamlet's murdered father. Regardless of its interpretation, if the word "handsaw" is original to the text, Shakespeare had in mind a forerunner of our closed-handled Western handsaw.

In his comprehensive discussion of tools in TF 61 ("Timber Framing for Beginners: The Tool Kit"), respected teacher Will Beemer gave short shrift to the Western handsaw as a tool for cutting timber frame joinery. And yet, a properly tuned Western handsaw can be useful in timber framing and general carpentry. It can also be a pleasure to behold and to use.

Photos Doug Eaton

Atkins No. 68, author's favorite, with "Perfection" handle, ca. 1915.

The D-95 with Disstonite (bakelite) handle—comfortable, though.

Some years ago I became fascinated by antique American hand tools. I purchased planes by Stanley and framing chisels by Buck Brothers and T. H. Witherby (to replace my shorter Japanese chisels). I bought a broad axe and an adze. I searched antique shops, garage sales, white elephant sales, flea markets and used-tool dealers. My interest in American handsaws was piqued by the purchase of an E. C. Atkins No. 65 ship point saw, circa 1935. After hammering out a small kink in the blade, cleaning it (which revealed the interesting etching) and having it sharpened at Standard Saw Works here in Oakland (a shop that appears not to have changed since its founding in 1919), I had a fully restored, very usable and attractive tool. This 8-point crosscut saw makes short work of a 2x4, in about a dozen stokes. Restoring its utility was satisfying. As a result, I bought several more saws. Another Atkins model, a 6-pt. No. 68, became my favorite framing saw.

The handsaw evolved as the main cutting tool in the American carpenter's tool box with the advent of light framing in the mid-19th century. Carpenters before that time used an array of craftsman-made bow saws and frame saws of varying types as well as pistol grip, or open-handled, handsaws. Eric Sloane in his *Museum of Early American Tools* estimates that the American version of closed-handle saws first appeared in the 1760s. But it was 70 years later in the midst of the American Industrial Revolution that the handsaw as we know it was first mass-produced. It fulfilled the needs of the vast army of carpenters who built tens of millions of light-framed houses in the 19th century and the first half of the 20th century. Although the early days of industrial saw manufacture are not well documented, we know that in 1832 Simonds Manufacturing Company began making a line of hand tools in Fitchburg, Massachusetts, that probably included handsaws. A British immigrant, Henry Disston, began in 1840 to manufacture saws and other steel tools in Philadelphia. And in 1857, E. C. Atkins and Co. in Indianapolis joined the tool-making competition. Hundreds of other small saw makers were also in business, but most failed or were bought out by the larger manufacturers.

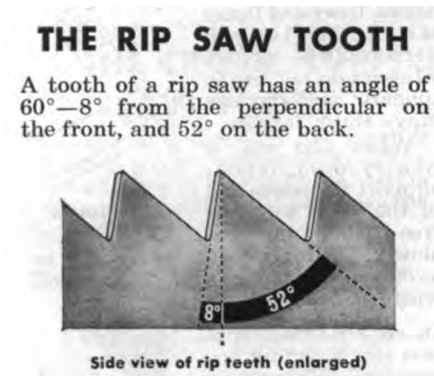
While other manufacturers such as Geo. Bishop, C. E. Jennings, Richardson Bros, Harvey W. Peace and Pacific Saw, and British manufacturers such as Spear and Jackson, sold handsaws in the US, the majority from 1865 to 1950 were produced by Simonds, Disston or Atkins. Their predominance lasted well into the 20th century. While each maker produced a premium line of saws sold under the company name, many of the saws one finds now with medallions reading "Warranted Superior," or with obscure names such as "Brown's Hardware" etched into the blade, were in fact manufactured by one of the Big Three. Simonds produced a line of handsaws celebrating famous Indian chiefs and tribes, with names such as Pontiac, King Philip, Shenandoah, Hiawatha, Osceola, Sioux, Algonquin and Iroquois. Disston produced handsaws etched to order under such labels as Brown's Hardware (above), Black Diamond, Phila. Saw Co., Blue Jacket, Challenge, The Imp and Enterprise. Atkins produced an entire secondary line of handsaws under the Sheffield Saw Works label and would also etch blades to customer specifications.

The introduction of portable electric circular saws in the 1920s foreshadowed the eventual collapse of handsaw manufacturing. The labor problems Disston and Atkins experienced in the '30s also contributed. A decade later, the widespread adoption of circular and other electric saws after World War II all but finished off the industry. In order to attract buyers during this period of decline, manufacturers offered gimmicky handsaws that were as much style as substance. The art deco two-tone bakelite handles Disston introduced in the '30s with their D-95, and the streamlined aluminum and walnut handle of the D-100 of the early '60s (which calls to mind the big-finned automobiles of the period), were the gasps of a dying industry. Handsaws were being produced (and still are), but workmen weren't wearing them out regularly through constant use and abuse on the job. Consequently, the market gradually collapsed, and production was significantly reduced. Saws declined in quality as the makers began to concentrate on do-it-yourselfers who didn't want to invest in a circular saw just to make a few cuts around the house. I recall using handsaws only occasionally in my stick-framing days of the '70s, although we did cut the parts for all the walls of one house with hand saws because the boss had neglected to get temporary power on the job site. We used handsaws primarily for three tasks: occasional square or notched cuts in flat finish work, finishing circular saw cuts in larger timbers and making single cuts in cases when setting up the electrical cords would have wasted time.

The saws produced in the 19th century were good, but the pinnacle of manufacturing excellence was probably reached in the first two decades of the 20th century, when the manufacturers had numerous models available in several handle styles, blade lengths and steel types, to suit the needs of a variety of customers.

Disston offered four apparently different grades of steel in their premium-grade handsaws: Extra Refined London Spring, Refined London Spring, Refined Crucible Steel and Crucible Steel. Their Extra Refined London Spring steel saws were considerably more expensive, almost half again more than the crucible steel models. The highly regarded Disston No. 12 of Extra Refined London Spring steel cost $29.00 per dozen in the 26-in. size in the Disston 1918 catalogue, while the No. 7, the workhorse of the Disston line since the beginning of the company's history and made of mere Crucible Steel, cost $20.00 per dozen. It's also true that the No. 7 had an unadorned beech handle while the No. 12 had a wheat-stalk design carved into an applewood handle.

It turns out, however, that the grades of saw steel used by Disston appear to have been mere marketing contrivance, unless it can be proved that the company knew things about steel that escape the eye of modern science. Metallurgical tests arranged by Eric von Sneidern (at dissstonianinstitute.com) found little difference among four different models of saw, each representing a differently named grade of steel and a different era of manufacture ranging from the 1890s to the 1950s. "Chemically," he reported, "they are all the same: medium carbon steel with little, if any, intentional alloy." Tests for hardness yielded similar results, with all four saws scoring in the low 50s on the Rockwell scale. (An 1860s backsaw was also tested, but scored somewhat lower on both tests.)



Disston's Saw, Tool & File Manual (ex lib. Pete Taran)

It's a good possibility that the same result would be found for Atkins saws (Silver Steel, Special Steel, Fine Crucible Steel and Cast Steel) and Simonds saws (Warranted Special Crucible Steel, Warranted Crucible Steel and, on their Indian labels, Spring Steel). Nor would I be surprised to learn that a test comparing the proprietary steels of one maker to the others' yielded a similar result.

Steel, however, is not the only element of a good handsaw. Grinding the blank on a complex taper such that the sawplate is thickest at the cutting edge and just forward of the handle, thinnest at the top of the tip, would add to the cost. So would fitting a handle of rosewood and carving that handle and, perhaps, so would dandifying the etching. But most of the high-grade handsaws, those with the manufacturer's logo etching and saw-nut medallion, are taper ground even though they differed significantly in original price. I suspect the highest end saws were overpriced to provide people of means and the need to acquire "the Finest on Earth" (Atkins describing their No. 400) or "the latest and finest Handsaw ever made" (Disston describing their D115) an opportunity to spend their money. There's an advantage in this for today's carpenter or casual user. Because the difference between best-quality and lesser quality saws of high-grade is probably marginal, a lot of good, old handsaws are available and affordable on the used-tool market.

The antique market offers collector-grade and user-grade handsaws. The collector-grade saw is of high value because of pristine condition, scarcity or historical significance. A user-grade saw shows repeated use or its age but is still fully restorable as a useful tool. (There is a third category, valueless to collectors and useless as a tool, the rusted or pitted saw one finds on the walls of saloons, restaurants and shops to lend an air of antiquity.)

SOME definitions of terms and attributes are in order. In the catalogues of the era, rip saws have blades between 26 and 32 in. long with teeth cut between 3 and 7 points per inch. Panel saws are filed for crosscutting (occasionally for ripping), with blades 24 in. or shorter. A handsaw is a crosscut saw with a 26-in. blade, although 28-in. and even 30-in. blades were produced. They usually have between 5 and 12 points per inch. Although the term "handsaw" may have originally referred only to the 26-in. crosscut saw, it has today become a generic term used to describe any of the three saw-types: rip, panel or crosscut.

The difference in crosscut saw teeth and ripsaw teeth is the difference between a scissors blade and chisel blade. Crosscut teeth are pointed at their tips, for severing, while rip teeth present an arris at their tips, for chopping. Both are beveled and set alternately to the left and right for the length of the saw, projecting slightly from the saw plate. While the teeth of both types form a gullet angle of 60 degrees (to accommodate triangular sharpening files), the rake angle or cutting slope of a rip saw is approximately 8 degrees from plumb, while it's roughly 15 degrees from plumb on a crosscut saw. Saw teeth are usually specified and measured in points per inch. (The number is stamped on the blade just beneath the handle, on the etching-medallion side of the blade.) Some sellers today describe saws in terms of teeth per inch, which confuses matters. Any given saw will have one fewer tooth per inch than points per inch.

Saw makers offered a wide variety of specialized saws—ice, cabinet, dovetail, back, miter, keyhole, pruning, flooring—and for plumbers, patternmakers, joiners, stair builders, etc. They also made several kinds of one-man crosscut saws for cutting timber. One that might be of interest to timber framers is the docking saw, a 4- or 4½-point 30- to 36-in. crosscut saw, used for a variety of tasks, but primarily to cut off 3- and 4-in. decking planks on docks. It's fast cutting and, when properly sharpened, will quickly square off the end of a large timber. Unfortunately, the docking saw usually comes with a malleable iron or aluminum handle attached to the blade with two rivets. Once the handle loosens from age or use, it can't be tightened conveniently. One exception is the Disston No. 196 docking saw with the D-shaped beech handle customarily found only on the larger one-man timber saws. Unfortunately, this saw is much less commonly found than its metal-handled counterpart. (See both saws overleaf.)

When purchasing an antique handsaw for use, there are several things to look for. The handle can have chips, dents or scratches, but it should fit tightly and the saw screws and nuts should not be stripped or bent. An etching on the blade that identifies the saw is a

At top, anonymous (Atkins?) metal-handled docking saw. Above, rare "full-breasted" Disston No. 196, with beech handle. Both saws are aggressive enough for timber framing.

plus. *The Handsaw Catalogue Collection* (Astragal Press, Mendham, N.J., 1994), a compilation of the catalogues of Simonds, Disston, Atkins and Spear and Jackson from the period 1910-1919, can help with identification. Ideally, the toothed edge and the back of the saw should be straight. A slight, fair waver is acceptable, but pronounced bends and kinks are not. Missing teeth do not disqualify a saw but should affect its price. At my saw shop, it costs $12 to have a saw retoothed, set and sharpened. A standard treatment (without retoothing) of jointing, setting and filing is also $12.

Rust is problematic and needs to be looked at carefully. A light coating of rust is acceptable, but a saw with heavily crusted flaking rust is not, and may be deeply pitted. Only a small amount of pitting, an inch or more from the teeth, is acceptable on the blade. Some staining is almost inevitable.

Old handsaws come in two general shapes: the full size, the only type you could buy in the 19th century, and the ship point (or ship pattern) that began to appear around the turn of the 20th century as a lightweight alternative to the full-size. Both shapes were available in skewback and straight back patterns. In 1928, Disston began to

E.C. Atkins No. 53 ship point finish saw, 1930s.

make the majority of their handsaws in the ship point form but changed the term in the catalogues to "lightweight." The width of a new, full-size saw blade was usually 2¾ to 3 in. at the tip. Saws with a nib—a kind of gunsight protrusion on the back of the saw near the tip—were a little narrower. Lightweight ship points were sold at about 1½ to 1¾ inches wide at the tip. Most of this width should remain on any used saw to be acquired. Sometimes full-sized saws have been sharpened so many times they resemble the ship point saws. Such saws can be good users but should be tested. Saws of either original type found with a pointed tip from too many sharpenings should be avoided.

Which to buy, full-sized or lightweight? Why, both, of course! Each comes in handy. I like the full-size saw for cutting timbers and 2x lumber, and I like the ship point for finish work.

AN important change in 19th-century handsaw design, the skewback saw pattern, which saved steel and weight, was an 1873 invention of Henry Disston, who one morning reportedly told Albert Thitterworth, his superintendent of many years: "There's more blade there than is required. It's too wide. That width isn't necessary, and it only adds to a man's labor to push and pull a wide saw. Just cut off a section of the back . . . curve it."

Atkins takes the credit for inventing true taper grinding, which probably eased a man's labor as much as the use of a skewback, for it kept a saw from binding even if set very lightly. As Atkins put the matter in its literature: "The kerf cut by the teeth is wide enough to permit the balance of the blade to drop easily into the cut without an excessive set and with no possibility of bending and buckling. . . . There is a distinction between Atkins Taper Grinding and the so-called thinback saws of other makes, which are simply ground an even thickness along the tooth edge and dubbed off thinner at the back. Atkins Silver Steel saws are gradually tapered throughout the blade from the thickest to the thinnest point. This is another exclusive Atkins feature and is found only in Atkins saws."

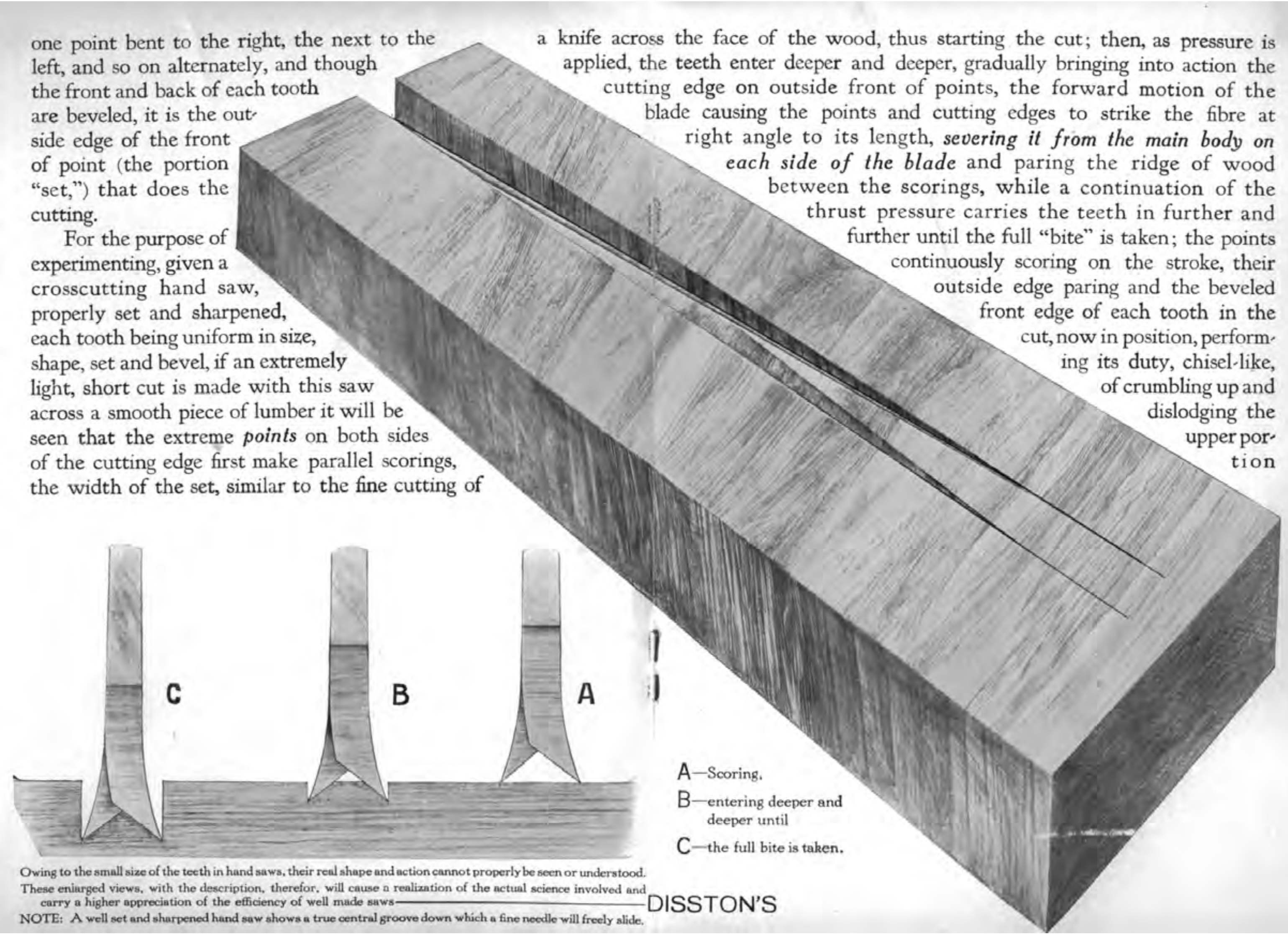
A third major change, more evolutionary in nature, was in the design of handles. There are roughly three types of closed handles on antique handsaws: the old English-style handle, the five-nut handle popularized by Disston with the introduction of the D-8 in the 1870s and, for want of a better word, the modern handle.

The English style is found on Disston's No. 7 and No. 12 as well as on certain models made by Atkins and Simonds. The World War I-era catalogues from all three manufacturers show a strong inclination toward the five-nut, D-8-style handle in various model numbers. Disston's D-115, D-120, D-17 and D-100 all mimic the original D-8 design. Simonds' Nos. 4, 8, 8½ and 9 are similarly designed. Atkins used fewer of that shape because they had already introduced the first modern-style handle, the "Perfection," which they were convinced was superior to anything that had preceded it.

The important difference among the three designs lies in the angle of the handle hole in relation to the blade. Using a protractor, I measured the old-style handles at between 70 and 75 degrees, the D-8 style at about 65 degrees and the modern style at between 55 and 60 degrees. (These are approximations but adequately describe the differences.) The handle holes also vary in shape and size, with the holes becoming larger as the handles became more modern.

The Disston D-8 was introduced in 1874. Because of the innovative new 5-nut handle design and the skewback blade, soon after its introduction it became the most popular saw sold, and influenced design at the other manufacturers, who quickly began to imitate the more ergonomic style. During its long history, more D-8s were made and sold than any other model. The D-8 looks like a saw *should* look.

But I have large hands and so prefer the modern-style handles first introduced by Atkins and later copied by Disston in their D-20, D-21, D-22 and D-23 saws. Generally speaking, the English-style handles are definitely too small and feel slightly awkward to use. The D-8 style is just a touch tight but with a better "hang" in relation to the blade. The modern style usually fits my hand best and has the best hang of all. ("Hang" is one of those mysterious terms the old saw makers used to describe the balance, feel and angle of the handle in relation to the saw blade.) Of course, anyone who wants to use these saws should try all three handles and choose what fits.



one point bent to the right, the next to the left, and so on alternately, and though the front and back of each tooth are beveled, it is the outside edge of the front of point (the portion "set,") that does the cutting.

For the purpose of experimenting, given a crosscutting hand saw, properly set and sharpened, each tooth being uniform in size, shape, set and bevel, if an extremely light, short cut is made with this saw across a smooth piece of lumber it will be seen that the extreme ***points*** on both sides of the cutting edge first make parallel scorings, the width of the set, similar to the fine cutting of a knife across the face of the wood, thus starting the cut; then, as pressure is applied, the teeth enter deeper and deeper, gradually bringing into action the cutting edge on outside front of points, the forward motion of the blade causing the points and cutting edges to strike the fibre at right angle to its length, ***severing it from the main body on each side of the blade*** and paring the ridge of wood between the scorings, while a continuation of the thrust pressure carries the teeth in further and further until the full "bite" is taken; the points continuously scoring on the stroke, their outside edge paring and the beveled front edge of each tooth in the cut, now in position, performing its duty, chisel-like, of crumbling up and dislodging the upper portion

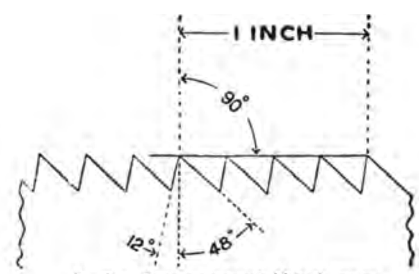
Owing to the small size of the teeth in hand saws, their real shape and action cannot properly be seen or understood. These enlarged views, with the description, therefor, will cause a realization of the actual science involved and carry a higher appreciation of the efficiency of well made saws——DISSTON'S

NOTE: A well set and sharpened hand saw shows a true central groove down which a fine needle will freely slide.

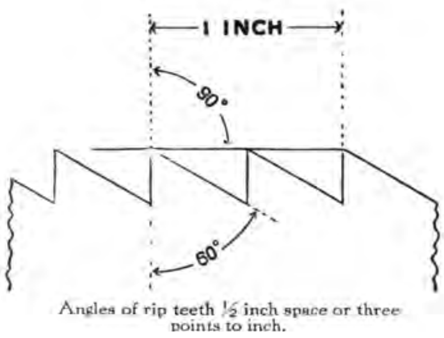
Illustrations from the library of Pete Taran at vintagesaws.com

Illustrations from F. M. Bassler, "Why a Saw Cuts," a manual written for Henry Disston and Sons, published in 1916. In the spread reproduced above, the footnote reads, "A well set and sharpened handsaw shows a true central groove down which a fine needle will freely slide."

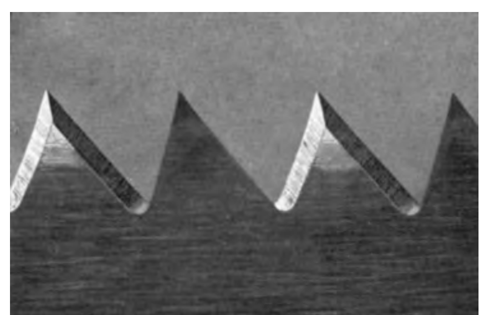
Below left, illustration showing the distinct chisel action of rip teeth. Below center, elevations of teeth as they are cut into the edge of the sawplate before the teeth are set and bevel filed. Below right, halftones showing sharpening bevels.

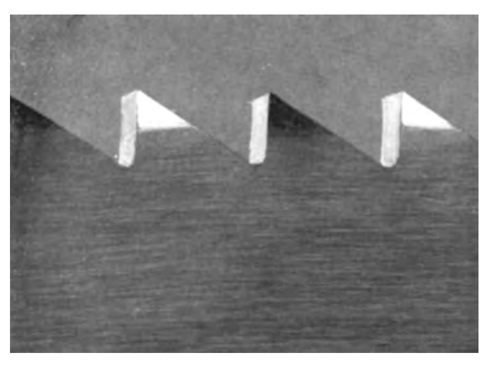


Angles of crosscut teeth ¼ inch space or five points to inch.



Angles of rip teeth ½ inch space or three points to inch.





To restore an old handsaw the low-tech way, carefully remove the blade from the handle. (If the handle is old-style with flush slotted ring nuts, you might want to skip removing the handle to avoid damaging the hardware.) Spray the blade with a solvent and allow it to penetrate. Then scrape carefully with a single-edge razor blade in a holder, if the rust is particularly thick, or go right to sanding lightly with 600 grit wet-dry sandpaper if not. Make sure you sand with the "grain" of the metal, parallel to the line of the teeth, and lighten the pressure around the etching (if it's still visible) to preserve it. Do not use a coarser grit of sandpaper than 600. Some saw experts advise that sandpaper should not be used at all, but that the restorer should instead use penetrating oil baths and wrap the blades in towels for hours, scrape with razor blades and repeat the process several times. Stains are usually too deep to be removable.

When re-assembling the saw, be careful not to force the brass threads of the screws through the holes in the blade, for the steel edges will strip them. It's best not to tighten any nuts until all the screws have been threaded through the holes in the blade. This allows you to maneuver the handle to best advantage while inserting the rest of the screws.

Sharpening saws is an acquired skill and time-consuming to boot. (For those who wish to learn, since living teachers are rare now, vintagesaws.com offers detailed instructions on the subject.) Sharpening consists of three phases: *jointing, setting and filing*. In *jointing*, a flat file is drawn across the top of the teeth to give them equal height before setting and filing. This assures that all the teeth are doing equal work. The best-cutting saws are "breasted," or filed to a gentle convex curve in the length, approximately the height of a saw tooth as you sight down the cutting edge. *Setting* bends the teeth alternatively left and right away from the center of the blade, in order to prevent the saw plate binding in the kerf. After setting, the saw becomes slightly thicker at the teeth than elsewhere. (A taper ground saw needs significantly less set than a flat ground saw, since much of the desired clearance has already been established by the grind.) A light set is best for smooth and accurate cutting, except in green wood, where a heavier set may be needed to clear damp and sticky sawdust. *Filing* with a triangular file sharpens each tooth at the proper angle and produces the clean points on a crosscut saw or the clean edges on a rip saw.

Since most of the saws I buy are dull, unevenly jointed and badly set at purchase, I usually send them out for the full treatment. When they begin to dull after that, I'll take a file occasionally and sharpen them until they need to be jointed or set again. A properly sized triangular file (the back of the file package will tell you the correct size based on the point size of your saw) and a saw-vice of some kind are all that you need for this limited work.

If you start using handsaws with any regularity, you might want to make some shorter sawhorses (or shorten an existing pair) to give you the best angle for sawing. I've found that waist-high or hip-high sawhorses are too tall. Mid-thigh seems to work best for me. It allows me to lean into the work and comfortably secure the work with my knee or hand if necessary when sawing smaller boards or timbers. Another trick to make sawing easier is to screw a stop of some kind to your horses or worktable. This makes the job of your off-hand easier and prevents the piece from sliding away from you. When sawing, don't grip the handle too tightly. It only tires out the hand and prevents feeling the cut. Let the saw do the work.

Why handsaws? Circular saws are fast, powerful and useful, but they are not exactly an ergonomic joy to use. They are loud and heavy and they spew dust. I'm getting to the point in life where efficiency and speed are less important than enjoying the work and saving my lungs and eardrums. After the age of 50, we tend to spend time plotting the postponement of our inevitable decline. I can take pleasure in doing something strenuous at a leisurely pace and, by doing so, postpone my descent into geezerhood.

To protect a sharp handsaw, make a guard of softwood by slotting a ¾-in.-deep groove the length of a 1x3. Thread two rawhide strings through holes drilled in the bottom of the guard to tie it on.

Disston D-7, ca. 1895, 5½-pt. ripsaw with quartered beech handle, an old and beautiful pattern, but often too small for all four fingers.

Lakeside Saw & Tool (Montgomery Ward) L-8, retoothed from 5½-pt. rip to 7-pt. crosscut. The thumbhole in the applewood handle, originally for two-handed ripping, remains useful for heavy crosscutting.

Simonds No. 8, ca. 1905, 5-pt. skewback rip, comfortably long at 28 in. A response to the market power of the Disston D-8 and very similar, although without the customary thumbhole for the opposite hand .

A tuned handsaw is more enjoyable to use than a circular saw and more respecting of the respiratory tract and the ears. But the word *tuned* needs to be emphasized. Handsaws could have little appeal if the saws young carpenters recovered from their fathers' basements were dull. For when a saw is dull, it doesn't cut wood so much as frustrate the sawyer. —Doug Eaton

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INTERIOR view, upper story of the new base lodge at the Dartmouth Skiway in Lyme Center, N.H., winner of a 2002 New Hampshire AIA Excellence in Architectural Design Award. Built primarily of Eastern white pine, the timber frame of the lodge covers a 7750 sq. ft. area, enclosing 136,000 cu. ft. with over 600 timbers tallying some 40,000 bd. ft. At its midpoint, the 180-ft. hall takes a 45-degree turn, wrapping around a 12-ft.-dia. skylit octagonal stair tower. The two black appendages apparently part of the sprinkler system are loudspeakers. The timber frame was designed by Ed Levin (Dartmouth '69) of Paradigm Builders, Hanover, N.H., and built by Vermont Timber Frames, Inc., of Cambridge, N.Y. Project architect was Stuart White of Banwell Architects, Lebanon, N.H.