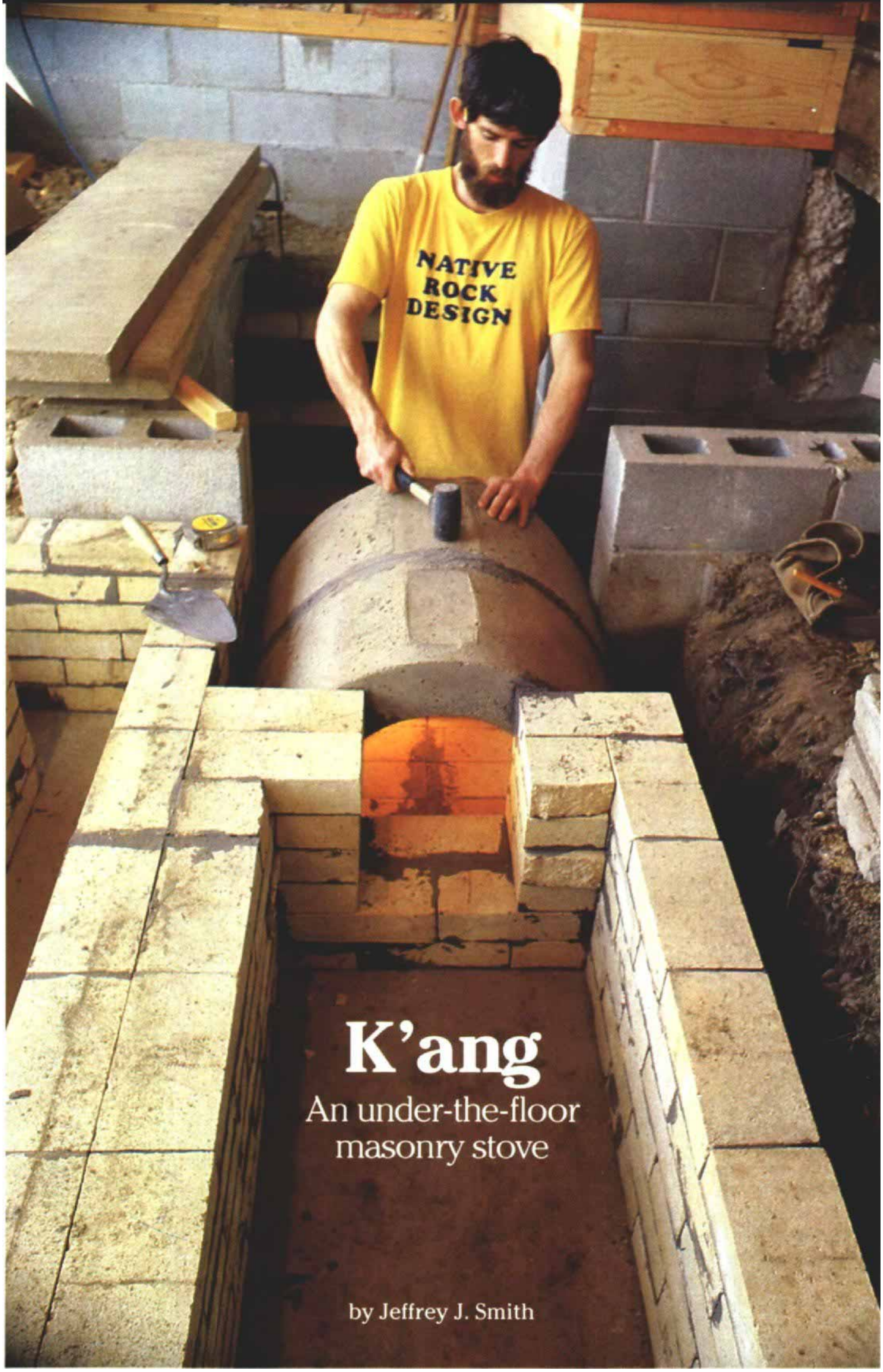


K'ang

An under-the-floor masonry stove

by Jeffrey J. Smith

Karl Marcus, a stonemason in Missoula, Mont., was experienced in building Russian fireplaces, and he wanted to include one of these masonry stoves in his passive-solar addition, a south-facing greenhouse/office. But Marcus didn't want to sacrifice any of the floor space (170 sq. ft.), which was at a premium in his older home. The solution was to build a masonry stove beneath the addition's floor.

Marcus's idea wasn't a new one but rather an adaptation of an ancient, multi-cultural tradition. In *The Book of Masonry Stoves* ($14.95 from Brick House Publishing Co., Inc., 3 Main St., Andover, Mass. 01810), David Lyle writes that the ancient Roman hypocaust and the Chinese k'ang, both subfloor heating systems, were used 2,000 years ago. An Afghan version, called the tawakhaneh, may have been around for as long as 4,000 years.

The k'ang firebox is small, 3.1 cu. ft., and designed to burn sticks rather than logs. But it must withstand temperatures of 1,100°F to 1,800°F. The firebox arches were cast in custom forms using refractory concrete.

Marcus built his k'ang to wring every last Btu from his firewood. The stove does this by burning wood at high temperatures and by storing the tremendous heat that it generates. Marcus's k'ang won't need to burn a constant fire, either. He believes that an hour-long burn twice a day

Drawing: Chuck Lockhart

will be enough to heat the addition and contribute substantially to heating his entire house. There are 225,000 Btus in 30 lb. of firewood. If the k'ang is 90% efficient, it will generate and hold 202,500 Btus morning and night (see the sidebar on p. 33).

I had seen Marcus's work, and was intrigued by some other masonry stoves he'd built. I was especially impressed with the massive, under-the-floor stove in the conference center of the building where I worked. The heat it produced was very comfortable. So last spring, when Marcus mentioned that he had started to build his under-the-floor stove, I asked if I could watch the construction and write about the process.

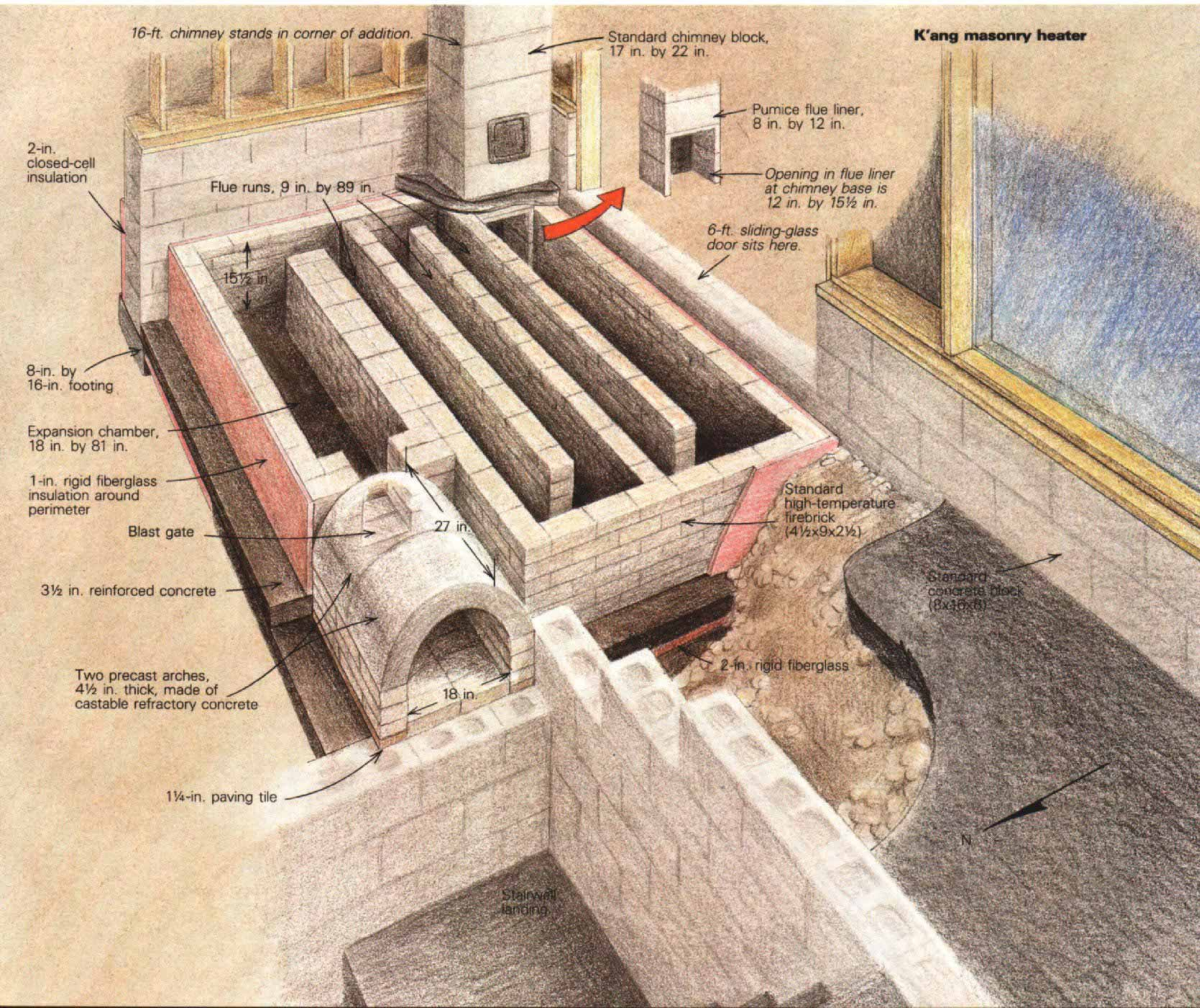
Preparation—As soon as the ground thawed in the spring, Marcus began digging. At the center of the existing exterior wall, he excavated to a depth of 6 ft. below grade. He then laid in a concrete-block stairway, which began at the southeast corner of the house and dropped five steps to a 3-ft. square landing. All along the stairwell's interior wall, Marcus reinforced the existing foundation with concrete. As shown in the drawing, the stairway turned left at the landing and dropped two more steps to meet the existing 3-ft. wide basement corridor. Marcus strengthened his foundation at this entranceway using bond-beam construction with each course of blocks all the way to the floor. He used blocks that had knockout webs so that removing the knockouts in each block created a horizontal channel through the entire course. Marcus then filled this channel with concrete. Next, he tore out the rickety old wooden stairway leading to the living room upstairs.

The concrete stairwell divided the new addition in half, and also framed the west wall of the k'ang stove. Three courses above the stair's landing, Marcus placed the k'ang's 3.1-cu. ft. firebox. He and his wife would be able to stoke the stove while sitting on the stairs.

With the stairway and the exterior frost walls in place, Marcus removed the house's south wall. He rebuilt 12 ft. of flooring to fill in where the back entrance and basement stairway had been. Now he was ready to build the k'ang.

Construction—The stove consists of poured concrete slabs, concrete blocks and refractory brickwork (drawing, below). On the west, it is framed by the stairwell; on the east and south, it is bordered by the concrete-block foundation of the new addition. Marcus first laid 2-in. rigid fiberglass insulation on the packed, leveled earth where he would pour his foundation slabs. He then poured a 3½-in. by 40-in. by 48-in. foundation slab for the stove's firebox. When it cured, he poured another 3½-in. thick slab to support the body of the stove. This 9-ft. by 8-ft. main slab overlapped the firebox slab on one end. Both slabs were mixtures of 3 parts ¾-in. crushed stone to 2 parts sand to 1 part portland cement.

When the Anaconda Copper Mining Co. in Butte, Mont., shut down its smelting operation five years ago, Marcus bought a pallet of new smelter bricks from them. These were top-of-the-line, extremely high-temperature bricks. Except for 50 store-bought refractory bricks that he laid in the south wall of the stove (the wall that would be stressed the least by the k'ang's heat), all of the stove's bricks were smelter



Like the firebox arches, the lids of the first three flue runs were also precast with refractory concrete. To allow for extra expansion and contraction due to the high temperatures, Marcus used nine separate sections to make the lid of the expansion chamber.

bricks. Marcus used Sairset refractory mortar manufactured by the A. P. Green Refractories Co. (Green Blvd., Mexico, Mo. 65265).

Flue runs and firebox—Next, Marcus laid out the elaborate interior flue structure, a labyrinth of vents and channels designed to absorb the firestorm created in the firebox. The fire pours through a 9-in. by 9-in. blast gate in the firebox's double-brick rear wall and enters the first flue run. The blast gate acts as a baffle, creating turbulence and burning up exhaust gases.

The first flue run must withstand great temperature fluctuations as well as occasional sustained, fiery blasts. It's called the expansion chamber because the gases and smoke are actively combusting, and therefore expanding, as they leave the firebox. Marcus made the chamber 18 in. wide—the same width as the firebox and is double the width of the succeeding flue runs. It is 15½ in. tall and runs 81 in. along the north wall, which is insulated with 1-in. rigid fiberglass. This is the only wall backed by packed earth. The interior wall is a double brick wall.

At the end of the expansion chamber, the hot blast collides with a brick wall one brick thick backed by 1-in. rigid fiberglass and the concrete block foundation of the room's east footing. The exhaust escapes through a 9-in. switchback into the next flue, which is also 9 in. wide. This second chamber is 89 in. long and ends in another switchback to the third flue run. The second, third and fourth chambers are identical in width, height and length. The final chamber is 13 in. wide and ends in a standard 17-in. by 22-in. pumice-lined chimney.

Marcus custom built the firebox's twin 4½-in. thick arches (photo, p. 30). The inner (bottom) forms are plywood and stretched galvanized steel. He put a piece of ³⁄₁₆-in. plastic on top of the curved form to keep the concrete from adhering to the steel. The form's outer (top) piece was made by a local plastics manufacturing firm and was designed by Marcus to be held in place with clamps. He poured Refracrete (North American Refractories Co., 1500 Houser Way S., P.O. Box 975, Renton, Wash. 98055), a large-aggregate, castable refractory concrete, through an opening at the top of the arch, and the pieces cured in the same positions they would take above the firebox. The forms are reusable.

Marcus then built forms and poured a series of 2½-in. thick lids for each flue run. For the lids of the first three chambers, he used Refracrete. Marcus poured nine separate sections (9 in. by 27 in.) to cover the expansion chamber (photo above), thinking that the joints would allow for the expansion and contraction due to the high temperatures in this first flue run.

For the second and third chambers, he poured 13½-in. wide slabs that would cover all but 27 in. at the east wall. He needed cleanout ducts there, and he poured these duct lids separately to include 8-in. dia. holes that would accept airtight, sheet-metal lids (top left photo, facing page). The lids that covered the fourth and fifth flue runs Marcus cast from the 3-2-1 portland mixture he'd used for the slabs. He added a small amount of Mason's Blend, a fireclay made by North American Refractories, to the lids to increase their elasticity and heat resistance.

Final steps—When Marcus had mortared the seams in the flue-run lids and had filled in the sides of the arches with vermiculite, he laid a gridwork of rebar over the surface of the stove. He installed the two airtight cleanouts, one at the start of the second flue run and the other between the third and fourth chambers.

Marcus also installed a 3-in. dia. aluminum pipe across the top of the flue runs and insulated it with fiberglass (top left photo, facing page). He was hoping that a 165-cfm fan would blow cold basement air through the pipe to two small ducts along the south wall, where the heated air would emerge and circulate through the house. This turned out to be ineffective. Marcus has since installed a small fan at floor level on the west wall; it simply blows air across the floor, up the wall and back into the house.

There is a carbon-monoxide danger associated with masonry stoves. Some European countries, most notably Switzerland and Austria, have a regulation that chimney dampers on masonry stoves cannot close more than 35%. Marcus is convinced that his k'ang will draft rapidly enough and is effectively sealed against the escape of exhaust gases. But as an extra precaution, he has no damper in his chimney.

When all this was done, Marcus poured a 4-in. concrete slab over the stove. It was made up of the 3-2-1 portland mixture with a small proportion of fireclay. He dyed it black for greater absorption of winter-time solar heat (top right photo, facing page).

The 16-ft. chimney was the last step, and it went up without a hitch. Marcus added an airtight, 8-in. by 8-in. cleanout door just above the floor. His business, Native Rock Design, got busy before he could build and install an airtight firebox door. But that didn't prevent him from christening the k'ang with its first roaring fire. There was no hesitation in the draft, and once established, a pocket of white-orange flames jumped through the blast gate to feed hungrily on exhaust gases to the end of the expansion chamber. Marcus brought out the Irish whiskey to celebrate, and I wished I'd saved one final frame of film to capture his satisfied grin. □

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After the flue-run lids were complete, Marcus laid in rebar and Installed two 8-in. cleanout ducts with airtight lids (left). He also laid in a 3-in. aluminum pipe wrapped in fiberglass that was intended to heat cold air from the basement. Marcus added black dye to the concrete for the finished slab (above) in order to increase the absorption of winter-time solar heat. The k'ang, finished except for an airtight firebox door, is shown below. Photos above: Jeffrey Smith.

Metal stoves vs. masonry stoves

All masonry stoves are designed to have enough mass to store heat and deliver it slowly, over a long period of time. This contrasts sharply with the idea behind cast-iron woodstoves, which are now being used by more than 20 million Americans.

Most cast-iron, airtight woodstoves burn large loads of wood for quick response. Their thin airtight walls radiate the heat into your room. The warmth is stored in your walls, hearth, furniture, carpet, even in you if you linger near the stove. It is your room, then, that heats the air. Since most rooms lack masonry-mass heat-storage systems, you must maintain a fire. To keep the fire from burning too hot, you have to crank down the stove's damper, which deprives your fire of air and causes it to smolder.

Though it does the job for up to 12 hours without refueling, a cast-iron stove wastes much of the wood's energy. Researchers at Auburn University and at the New Mexico Energy Institute have found that one-half to two-thirds of the fuel value of seasoned firewood is in gases and volatile liquids.

The key to using those gases and volatile liquids is high combustion temperatures, 1,100°F to 1,800°F. But many cast-iron woodstoves actually begin to glow red at less than 900°F. Sadly, up to 50% of the fuel you've paid for will vanish up your chimney. And that's the same unburned fuel that is loaded with creosote and air pollutants.

Some cities, like Missoula, Mont., lose a half-dozen residences each winter because of chimney fires, and their officials are beginning to restrict wood burning. When the Missoula health department, for instance, finds more than 150 micrograms of respirable wood-smoke participate per cubic meter of air, they require everyone to switch to fossil-fuel sources of heat. For 10 days last winter, Missoula's wood burners had to shut down their stoves because of air pollution.

Some countries have long traditions of clean-burning masonry heaters. Two-thirds of the new homes in Finland are built with masonry woodstoves. The Finnish government even gives tax breaks to encourage their use.

Also, though few tests of masonry-stove efficiency have been performed in the United States, European tests have placed masonry-stove efficiency at 70% to 90%. That means that almost all of the heat value of the wood (Btus) is used in a well-constructed masonry stove. The fires in these stoves reach 1,100°F in the first three minutes. After an hour, they reach 1,800°F,

—J.J.S.

Photos, except where noted: Wayne Sourbeer