Building a Tiled Masonry Heater

Hot combustion, heat-exchange channels and six tons of brick for energy efficiency and a clean bum

by Vladimir Popovac

A century ago, Mark Twain declared that masonry heaters could heat a home comfortably all day after one firing, consuming "no more fuel than a baby could fetch in its arms." In comparison, he called the American woodstove "a terror" that wastes so much wood it makes you "think you have been supporting a volcano." No wonder he was perplexed that the U. S. had yet to adopt the masonry heater as its own.

Nowadays, site-built and factory-built masonry heaters are appearing in the U. S. with a flourish that would have dazzled Twain. Nevertheless, they are still virtually unknown in my hometown. That's why I set out to build a showcase model (photo right). As a masonry contractor, I wanted to demonstrate how effectively such a fireplace (as opposed to a standard masonry fireplace) produces and stores heat, releasing it uniformly over a long period of time. I also wanted to show how adaptable it can be to a home's style and decor.

My clients, John Hosemann and Joan Carney, were ideal. They were in the early stages of designing a new home and were searching for a fireplace that would actually heat it. John had lived with conventional masonry fireplaces in two previous homes and didn't want another "hole-in-the wall." Joan insisted only that the fireplace be beautiful. They both wanted to be able to view the fire.

They also gave me an excellent location to work with—right near the center of the house. The front of the fireplace would face the living room, dining room and kitchen; the back would face the master bedroom. Not only was this spot ideal for heating, it would make the fireplace the focal point of the house.

When I first looked at the house plans, it was clear that a simple box-like fireplace would not do. The design would have to feature intersecting planes and angles galore (like the house), while incorporating a suggestion of raised levels.

Patterned after the typical Finnish masonry heater, this energy-efficient, clean-burning fireplace can be the focal point of a home.

Working out such a design is not merely a matter of erecting an elaborate facade around a square firebox. For heat to be effectively transferred in a masonry fireplace, internal heat-exchange chambers must fall into alignment with the fireplace's outside walls. Fortunately, I had many prototypes to choose from.

Following the Finns—Efficient masonry heaters are not new. Hundreds of models have evolved of necessity around the globe, whenever and wherever wood-fuel supplies have been threatened by vanishing forests. These heaters have one common denominator—a huge mass of masonry that holds heat. This heated mass supports combustion temperatures that exceed 1500° F, hot enough to burn wood completely (including the volatile gases that comprise more than two thirds of the wood's fuel value). In fact, the efficiency ratings of masonry heaters begin where those of the best metal stoves quit, and range from 80% to more than 90%.

Masonry heaters are designed to be fired once in the morning and once in the evening, yet deliver heat evenly over a 24-hour period. The fires burn hot and fast, producing no buildup of soot or creosote; what comes out the chimney is virtually smokeless, non-polluting and invisible (for more on masonry-heater emissions, see the sidebar on p. 54). Most masonry-heater manuals recommend burning wood that's a maximum 3 inches in diameter.

The fireplace I designed for my clients is modeled on a Finnish prototype described by Albie Barden and Heikki Hyytiainen in the book, *Finnish Fireplaces; Heart of the Home* (available from Barden's Maine Wood Heat Company, Inc., R. F. D. 1 Box 640, Norridgewock, Me. 04957; 207-696-5442). This prototype is the product of decades of study, including a long-term research project conducted at Finland's Tampere University of Technology.

My version can be thought of as three brick shells nestled one inside the other (drawing facing page). The inner shell, within which combustion takes place, is a solid tower having three chambers: the ash box on the bottom, the firebox or primary combustion chamber in the middle, and the secondary combustion chamber on top.

The fire originates in the firebox, drawing *primary* oxygen from the ash box below through the firebox floor grate. Replacement oxygen is sucked into the ash box from inside the house through a damper in the ash-box door. The top of the firebox is slanted to a throat that links the firebox to the secondary combustion chamber. This configuration forces heated gases from the firebox, including *secondary* oxygen drawn through dampers in the

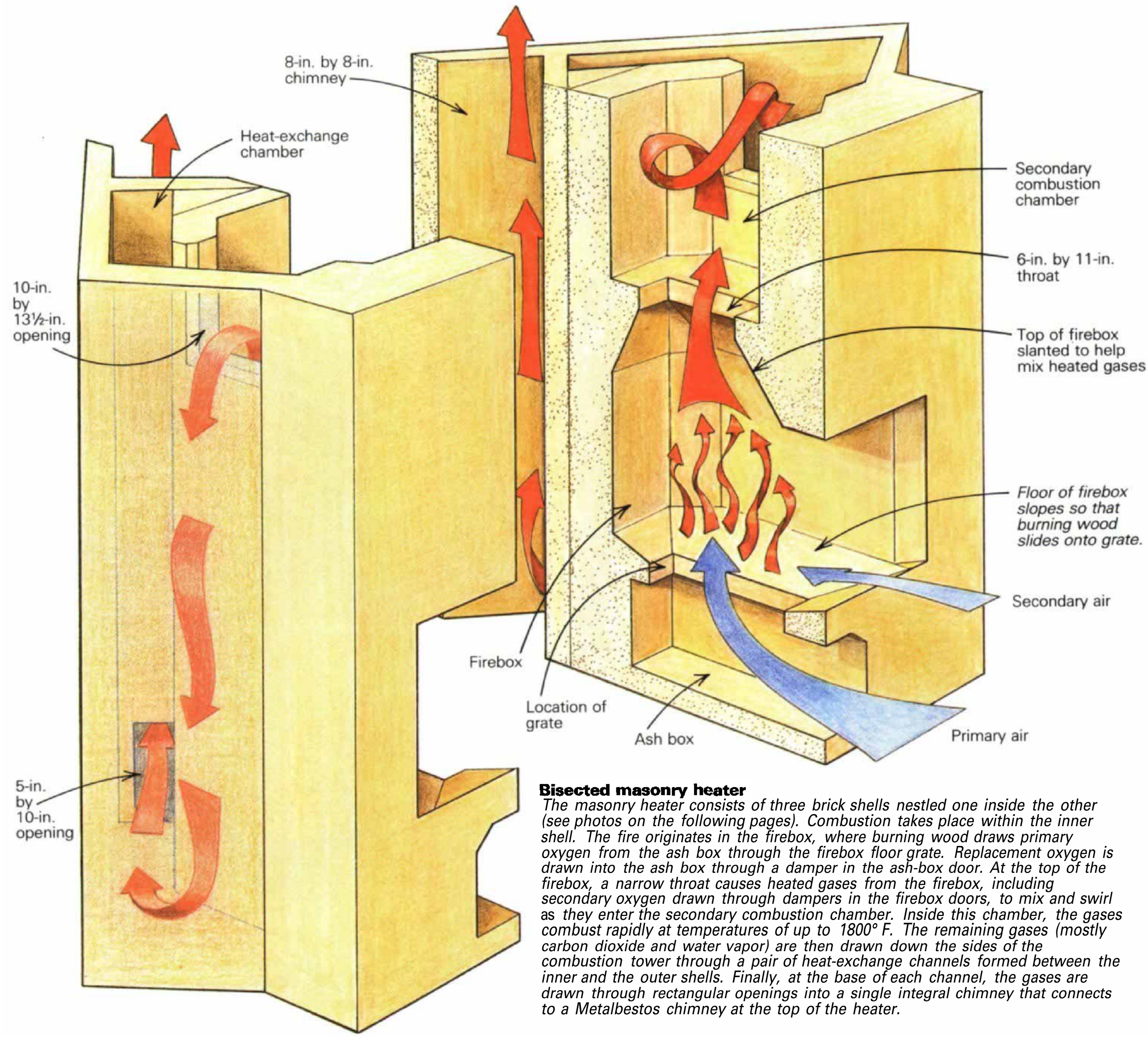
Photo: Rich Miller

firebox doors, to mix and swirl as they enter the secondary combustion chamber. The thoroughly mixed and heated gases combust rapidly and completely inside this chamber, where temperatures soar to about 1800° F.

From the secondary chamber, the heated gases (which now consist mostly of carbon dioxide, water vapor and excess air) are forced down the sides of the combustion tower through two heat-exchange channels formed between the tower and the outer masonry shells. Finally, at the base of each channel, the gases are drawn through rectangular openings into a chimney built within the rear of the heater. This integral chimney is aligned vertically with an external flue that connects to the top of the heater and exhausts the gases above the roof. By the time the gases enter the external flue, their temperature has dropped to about 350°, just hot enough to sustain the draw.

Making a good thing better—Though my heater mimics the Finnish prototype, it differs from it in a number of significant ways. For starters, the heater presented in Barden's book is basically rectangular, has no internal chimney and comes equipped with a bypass damper that, when opened, directs combusted gases directly into the chimney from the secondary combustion chamber, sidestepping the heat-exchange channels. This damper is supposed to allow quick start-ups, prevent smoking during foul weather and permit warm-weather fires for viewing without heating the mass. However, the damper is subjected to extremely high temperatures that tend to break it down. I think these dampers are the one flaw with the Finnish design, so I decided against installing one in my heater. When I told Barden I was eliminating the bypass damper, he assured me that some masons in Finland also leave it out, with no ill effects. I incorporated the lower portion of the chimney into the body of the heater to add a third heat-exchange channel to the heater, as well as extra mass for heat storage.

The most drastic design change I made, however, was in configuring the middle and outer shells, which reflect the shape of my clients' house. The angular profile of these shells produced two symmetrical heat-exchange channels having highly irregular cross sections. In sizing these channels, I adhered to mathematical principles set forth by David Lyle in *The Book of Masonry Stoves; Rediscovering an Old Way of Warming* (Brick House Publishing Co., Box 2134, Acton, Mass. 01720; 800-446-8642). The book provides information on the sizing of masonry-heater openings, including the ash-box door; the firebox grate, door and throat; and the rectangular openings at the tops and bottoms of the heat-exchange



Bisected masonry heater

The masonry heater consists of three brick shells nestled one inside the other (see photos on the following pages). Combustion takes place within the inner shell. The fire originates in the firebox, where burning wood draws primary oxygen from the ash box through the firebox floor grate. Replacement oxygen is drawn into the ash box through a damper in the ash-box door. At the top of the firebox, a narrow throat causes heated gases from the firebox, including secondary oxygen drawn through dampers in the firebox doors, to mix and swirl as they enter the secondary combustion chamber. Inside this chamber, the gases combust rapidly at temperatures of up to 1800° F. The remaining gases (mostly carbon dioxide and water vapor) are then drawn down the sides of the combustion tower through a pair of heat-exchange channels formed between the inner and the outer shells. Finally, at the base of each channel, the gases are drawn through rectangular openings into a single integral chimney that connects to a Metalbestos chimney at the top of the heater.

Drawings: Bob Goodfellow

The combustion tower. **The inner shell, or combustion tower, is built of standard firebrick and refractory mortar. The base of the firebox (photo above) slopes downward so that burning wood will slide onto the grate in the firebox floor, where primary oxygen is drawn from the ash box below. Iron lintels provide support over the ash-box and firebox-door openings. The beveled bricks at the edge of the firebox promote air flow.**

The middle and outer shells. **Once the inner shell was completed, the middle and outer shells were laid up alternately a few rows at a time, following plumb lines suspended from the ceiling joists. The ¼-in. thick mineral wool visible in the bottom photo at the left ensures the integrity of the expansion joints provided between adjacent masonry shells.**

channels. It also offers guidelines for sizing the cross-sectional areas of the hot-air chambers, from the firebox to the flue. Barden wasn't keen about my altering the shapes of the outer shells. In fact, he advised against it, fearing the results of "drifting into uncharted waters."

I gleaned the dimensions of the firebox and secondary combustion chamber from Barden's book, primarily because I bought all the Finnish-stove hardware for it from his Maine Wood Heat Company. This included the ash-box and firebox doors, as well as three cleanout doors that provide access to the heat-exchange channels. I also bought some mineral-wool insulation from him, which would be used for isolating adjacent masonry surfaces and filling expansion joints.

I made two more alterations worth noting. To promote the mixing of fuels and oxygen as they enter the secondary combustion chamber, the Finns slant the top of the firebox inward at the front and back toward a 2-in. wide rectangular throat. Barden claims that better flow is achieved if the firebox top is slanted on the sides instead of the front and back. I saw merit in both alternatives, so I sloped all four walls above my firebox, ending up with a throat that slightly favors the front-to-back alignment. Finally, Barden's prototype has an exterior finish of brick. Mine is tiled.

A matching foundation—This fireplace is a heavyweight, tipping the scales at over 12,000 lb. It's supported by a hefty foundation shaped to the perimeter of the fireplace and slightly larger. Anchored to solid bedrock, the foundation consists of 8-in. thick concrete walls reinforced with ½-in. rebar spaced 12 in. o. c. both horizontally and vertically. The top of the foundation is capped by an 8-in. thick concrete slab laced with ½-in. rebar. The cap is level with the subfloor, giving me maximum flexibility in positioning the stove.

A separate foundation wall around the perimeter of the stove supports the bench, firewood bin and hearth I planned to construct in front of the heater and the ends of the floor joists. This way, the floor joists were kept clear of the stove's foundation (local codes require a 2-in. gap between a stove and combustible materials).

I requested that the chimney foundation be extended 5 in. beyond the outer shell on the side of the fireplace that would face the master-bedroom closet. This extension would support a 3½-in. thick insulating block wall, with enough room left over to accommodate a 1½-in. vented air space between the block wall and the outer wall of the stove. I bought the insulating block from Graystone Block Company, Inc. (316 W. River Rd., Modesto, Calif. 95351; 209-523-6462). A screened vent at the top of this air space would allow warm air to escape into the living room.

Bricks and mortar—Because each of the heater's three masonry shells would have different expansion rates, it was critical that I not tie them together in any way (except at the base). Where the shells come close to touching, they're separated by a ¼-in. layer of mineral wool, thin enough to create a noncombustible expansion joint without obstructing the transfer of heat.

The inner and middle shells, which are both exposed to high temperatures, are built of firebrick (good to 2700° F) and mortared with refractory cement (good to 3000° F). I bought standard firebrick (measuring 2½ in. by 4¼ in. by 9¼ in.) and refractory cement from North American Refractories Western Division (5798 Stoneridge Mall Rd., Suite 200, Pleasanton, Calif. 94566; 415-463-1600). I chose this company because it has local branch offices and offers first-rate technical support.

Almost any type of brick would suffice for the outer shell, because its temperature would never exceed 250° F. Here I used high-fired dense brick (available at masonry suppliers) and regular masonry mortar consisting of three parts sand to one part cement, adding a little local clay to the mortar for improved workability and flexibility.

Hot gases that are pushed into corners or over right angles tend to swirl and eddy, impairing the draw. Wherever a smooth flow was desirable, I eliminated all 90° angles by either beveling the edges of the bricks or cementing in brickbats (brick scraps) cut at a 45° angle.

Laying up the tower—Before I started to lay the bricks, I snapped chalklines on top of the foundation cap to represent the inner and outer shells. The layout of the outer shell was especially critical; its dimensions were calculated so the tile patterns in the dining area and master bedroom would work out just right.

Construction began with the laying up of a high-fired dense-brick footing for the three shells. That done, I turned to the construction of the inner shell, or combustion tower (top photo, facing page). I started by laying the first two courses of firebrick, embedding a nail between the courses at each corner around the outside perimeter. This allowed me to string plumb lines from the nails to the ceiling joists above to help keep everything in line. I then laid the rest of the inner shell to the top of the secondary combustion chamber. As I worked my way up, I installed two lintels in this shell: a 3-in. wide iron plate over the ash-box opening, and a length of 3-in. by 3-in. angle iron over the firebox opening. Angle-iron lintels would also be installed in the middle shell over the firebox opening and in the outer shell over the firebox and ash-box doors.

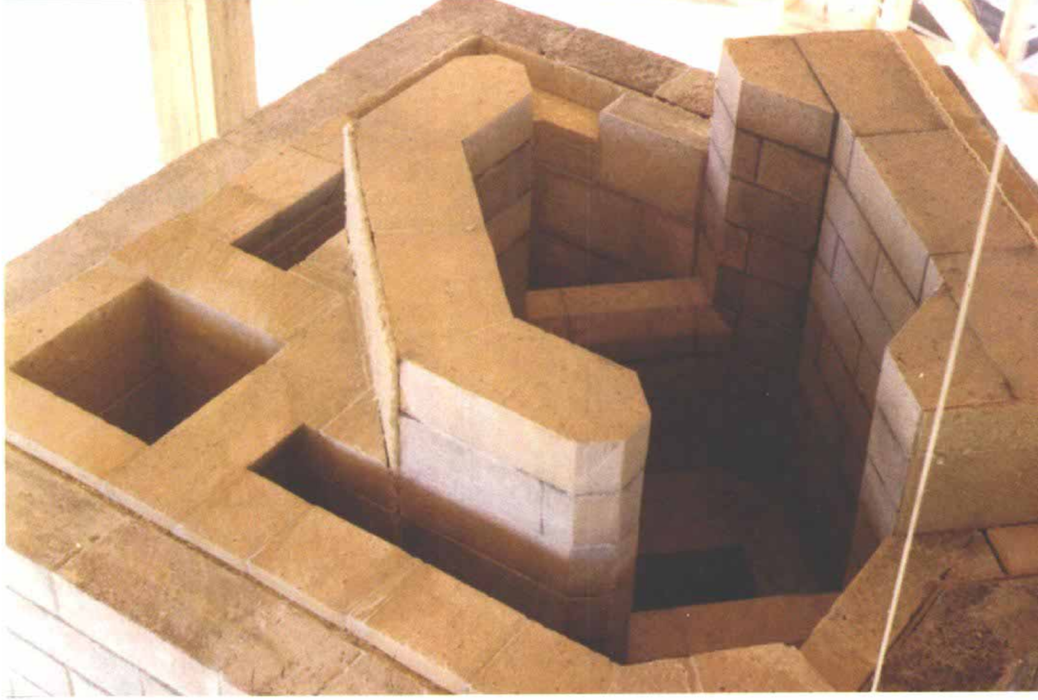
Some masons mix their refractory mortar to a creamy consistency and, instead of troweling the mortar, dip their bricks in it. This saves time, but it's also sloppy. For this stove, I troweled the mortar to avoid unwanted clumps of mortar that could interfere with air flow. I cut the bricks using a 10-in. wetsaw fitted with a continuous-rim diamond sawblade.

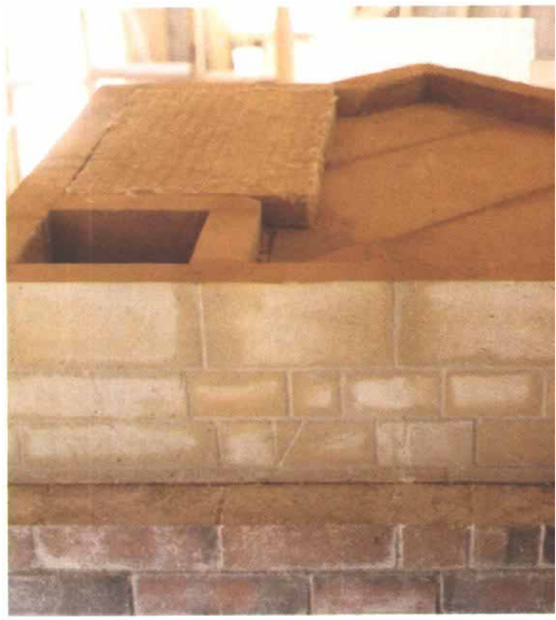
Wrapping the core—The middle and outer shells (bottom photo, facing page) were laid up simultaneously, again following plumb lines at the outside perimeter. I laid up a few courses of the outer shell, then a few courses of the middle shell (including the chimney), alternating back and forth in this way until I approached the top of the combustion tower.

While laying up the outer bricks, I bent 8-in. long pieces of tie wire into "U" shapes and bedded them 12 in. o. c. in every other course of mortar, allowing the ends of the wires to dangle out about 2 inches. These wires would allow me to tie stucco wire to the outer shell for supporting the ceramic-tile mortar bed, and to anchor the cleanout-door frames to the shell.

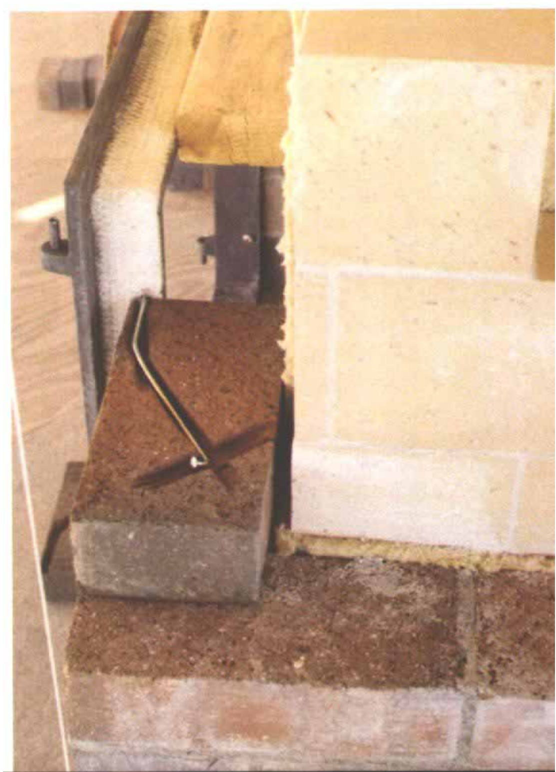
To promote heat transfer, I built the middle shell and chimney walls just 2½ in. thick by laying the firebricks on edge. The top three courses of the middle shell are progressively thicker and slope inward, pinching the tops of the heat-exchange chambers. This promotes air flow and provides maximum support for the 12-in. wide by 24-in. long firebricks that cap the heat-exchange channels and the secondary combustion chamber. These extra-long firebricks (middle photo, right) butt against the middle shell. They were lap-jointed at the edges and laid dry on a bed of mineral wool. On top of these bricks, I laid a 2¼-in. thick layer of mineral wool, followed by a 1½-in. thick reinforced precast-concrete slab that laps 2 in. over the top course of the middle shell.

The outer shell extends about 1 in. higher than the concrete cap. I ended up with a ¾-in. expansion joint between the concrete cap and





Top courses. **The top three courses of the middle shell slant inward, pinching the tops of the heat-exchange channels (photo above). This promotes the flow of air from the secondary chamber (center of photo) into the heat-exchange channels on either side. It also provides maximum support for a firebrick cap on top (photo right). A layer of mineral wool on top of this cap will provide an expansion joint between the firebrick cap and a second cap made of precast concrete. The square opening in the photo is the chimney.**



Door detail. **The firebox-door frame is anchored to the outer shell with motorcycle spokes notched into the brickwork and mortared in place. The spokes are conveniently threaded to receive an inconspicuous nut that's ideal for securing the frame.**

the outer shell into which I stuffed strips of mineral wool. Then I laid ¼-in. mineral wool over everything (except the chimney), and set 18-ga. stucco wire over the mineral wool. Finally, I poured mortar over the whole works, flush with the top of the outer shell. I then lifted and set this cap, with a little help from a friend.

The internal chimney protrudes 2 in. above the top of the outer shell. I rounded the inside top of the chimney to an 8-in. diameter using mitered brickbats and refractory cement, then bolted down an anchor plate over a mineral-wool gasket to support a Metalbestos chimney flue. I bought the anchor plate and flue pipe from a local hardware store.

Hanging the doors—While laying up the outer shell, I installed the door frames for the ash box, firebox and cleanout doors. Before installing the frames, I wrapped each one with a high-temperature fiberglass rope, which allows expansion of the frames without disturbing the adjacent bricks. The cleanout frames were anchored to the outer shell with the embedded U-shaped tie wires. I anchored the ash-box and firebox frames with motorcycle spokes notched into the brickwork and mortared in place (photo right). The notches were cut using the wetsaw. I used spokes instead of tie wire for these bigger doors because the spokes are sturdier and are conveniently threaded to receive an inconspicuous nut that is ideal for securing the frame. The outside edges of the frames were set 1 in. out from the brick to allow for a ½-in. thick mortar bed for the tile, as well as the 7⁄16-in. thick tile itself.

I installed the three cleanouts as insurance—just in case my design proves inferior (heaven forbid), the owner burns wet or green wood, fly ash accumulates from burning paper, or the owners' pet rattler decides to crawl in for the winter.

Tiling—My clients wanted a tile finish on the fireplace and a tiled wrap-around bench out front. So did I. They chose the color of the tile, and I chose the tilemaker: McIntyre Tile Company (55 W. Grant St., P. O. Box 14, Healdsburg, Calif. 95448; 707-433-8866). I discovered this top-notch company only after making dozens of inquiries all over the country. I had been searching for a molded tile similar to that found on traditional European masonry heaters. As far as I can tell, this kind of tile just isn't manufactured as a stock item in the U. S. McIntyre offered to make it for me promptly, from my drawing, for just $7 per lineal ft. In comparison, a similar Italian-made tile that I came across costs $65 per lineal ft. I purchased the rest of the tile from McIntyre as a stock item.

The interior decor of the house was to be clean and muted, with elegant lines, so the mosaic patterns (photos, p. 50) could not be loud or garish in any way. They had to invite discovery. The bench would deliver the promised "suggestion of levels" and provide a place for wood storage as well as a seat for snuggling up against the warm tiles.

Before building the bench and installing the tile, I tied the 18-ga. stucco wire to the exposed surface of the brick (using the embedded tie wire), then troweled a ½-in. thick mortar bed over it. Next, I shaped the sides of the bench out of cut block and poured a small concrete slab to serve as a bridge over the wood-storage bin. I then filled the cores of the block with concrete and parged all surfaces level and plumb with mortar.

I set the tile using a dry-bond thinset from Laticrete (Laticrete International, 1 Laticrete Park North, Bethany, Conn. 06525; 800-243-4788 outside of Conn.), mixed with their latex additive 3701. This mixture has good hang and grip, as well as the necessary flexibility to absorb expansion and contraction. According to Laticrete's technical consultants, this thinset will endure continuous temperatures of up to 300° F and intermittent temperatures of up to 700° F when mixed with the additive. The same additive was used in the mortar bed and grout.

Before setting the tile mosaics, I drew layout lines right on the mortar bed, carefully marking the positions of key tiles. These key tiles were set and held with the help of masking tape. Once the keys were set, I set the intermediate tiles, adjusting and holding them in position with 3⁄16-in. spacers and wedges.

Before setting the tile around the firebox door, I added an extra strip of high-temperature rope, then grouted normally. Around the door and anywhere else that the grout touches metal or an interior partition, I smeared a 1⁄16-in. thick layer of silicone-base grout over the regular grout. That way, if the regular grout ever pulls away from an adjoining surface, the cracks won't show.

Firing it up—The fireplace was completed in October at a cost of $7,000. My clients waited a month before lighting a fire to allow the mortar to cure. In November, they built small fires only. By mid-December, full fires were permitted.

As it turns out, the tile heats up and stays warm with a small evening and morning fire. The house is located in the foothills of the Sierra. Winters are relatively mild, with lows dropping only occasionally below freezing. I estimate the temperature of the heated tile to be about 110° F, warm to the touch, but not as warm as hot tap water. That's warm enough, however, to heat the living areas and master bedroom without the need for backup heat.

A rectangular brick Finnish heater can be built in one week. Working alone, it took me about a month just to complete the three complicated shells of this project. During construction, I did worry. "An untested design at the very focal point of the house"..."drifting into uncharted waters"..."no bypass damper".... Before installing the tile, I tested the draw.

What if, after all my labors and the purchasing of $4,800 worth of material, there was no draw? When the time came to strike the first match, I held my breath. My courage melted and I turned away. I handed a match to my 12 year-old daughter and had her light the first fire, for luck. It was, perhaps, a needless precaution. The fire drew instantly, from the first flicker of the match, and still does, every time. In fact, the entire fireplace heats up from a dead-cold start within three hours—a sure sign that all the gases are moving along at the right pace. ❑

Vladimir Popovac is a masonry contractor in Sonora, Calif. He built his first fireplace on the family patio when he was 13. Photos by author, except where noted.

Masonry-heater emissions and the EPA

by Norbert Senf

Masonry heaters were virtually unheard of in North America until about 15 years ago. In Europe, on the other hand, there are a number of established trade guilds that date back several hundred years. These guilds offer apprenticeships that lead to certification as a journeyman and, eventually, as a master stove-setter. Several European countries also address masonry heaters in their building codes.

In North America, Washington state is currently the only jurisdiction that includes site-built masonry heaters in its building code. In response to this, a group of about 20 heater masons and other interested parties joined forces in 1985 to form ASTM task group E-6.54.07 (Masonry Heaters). Six years later, a draft "Standard Guide for the Construction of Solid Fuel Burning Masonry Heaters" is now in the final balloting stage. Once consensus is attained, this standard should influence the recognition of masonry heaters in North American building codes.

The Masonry Heater Association of North America (MHA) was formed as an offshoot of the ASTM group. To date, the MHA has about 40 voting members (who pay $200 in dues per year) and about 15 associate members. So far, local politics in communities throughout the U. S. have served as the primary catalyst for MHA activities. For instance, on smoggy "no-burn" days in Washington state, the law permits the burning of wood in EPA-certified appliances only. Because masonry stoves have yet to be certified by the EPA (at present, only woodstoves are EPA-certified), the fledgling association worked hard to forge an agreement with state legislators that would give its members a blanket certification for their masonry heaters—*if* they could prove that the units were at least as clean-burning as EPA-certified non-catalytic woodstoves.

Eventually, a suitable emissions test was developed by Shelton Research, Inc. of Santa Fe, New Mexico, and the Mechanical Engineering Department at Virginia Polytechnic Institute (VPI) in Blacksburg, Virginia. Under the auspices of the Wood Heating Alliance and the Fireplace Emissions Research Coalition, two masonry heaters were tested at VPI: one that draws its primary combustion air through the firebox door, and another that draws the air through a grate in the firebox floor. The results? The former emitted an average of just .99 grams of particulate matter per hour, while the latter emitted an average of just 2 grams per hour. In contrast, the current EPA standards for woodstoves are 4.1 grams per hour for catalytic stoves and 7.5 grams per hour for noncatalytic stoves. (Most woodstoves manufactured during the late 1970s emit *40 to 60* grams per hour.) As a result of these tests, Washington state's Department of Ecology awarded masonry heaters a blanket certification.

Besides promoting the attributes of masonry heaters, the MHA holds annual meetings, publishes a quarterly newsletter, shares information about masonry-heater construction, and recently formed a committee that's charged with creating an education and certification program for masons. For more information, contact the MPA at 11490 Commerce Park Dr., Reston, Va. 22091; (703) 620-0010.

—Norbert Senf is vice president of the MHA. He has designed and built masonry heaters since 1978.