Rocket Mass Heater
As-Built Drawings

The Annex: 6" Diameter

duct-heated L-bench
over concrete slab floor

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General parameters:

Footprint: 7 ft (27" wide) by 10ft (30" wide)
= about 35 square feet

Ducting: 6" diameter
Duct length: 25 ft,
with 7 90 degree bends =
effective drag 55 ft
(Vertical rise is additional 25 ft, double and triple-walled stovepipe; compensates for 5-10 feet of drag.)

Fuel feed: 5.5" by 5.5"
Heat riser height: 47"
Burn tunnel length: 21"
Feed tube height: 15"

Bench volume: 60 cu. ft
(2.2 cubic meters)
Approx. weight: 5700 lbs,
dead load 125 to 240 lbs/sf

Working temperatures:
Flame path: 1200-2800 F
Barrel surface: 200-800F
Masonry surfaces: 60-90 F

Performance: Heated 900 SF cottage (with poor insulation, long wall surfaces, and no solar gain) in maritime climate (Portland, OR).

Used 1/8 to 1/4 cord of local firewood per year (Doug fir windfall, orchard trimmings, debris and building scraps).
20 lbs wood for typical winter day (30 to 40 degrees Fahrenheit). Ran about 2-4 hours per winter day, up to 6-8 hours when temperatures were unusuall low (teens F).

We used this heater for about 3 years on site. We cleaned out the fly ash about once per year, an accumulation of several inches in the bottom of the barrel. We also noticed benefits in summer heat waves: we didn't need to get the fans out of the attic for summer cooling.

THE ANNEX - 6" Rocket Mass Heater:

Builder's Notes

This project was originally built in Portland, Oregon, in 2009, in a small 'granny flat' apartment. It was designed as a test case for permitting, so it follows local building codes: the heat shield, clearance behind the barrel, and double-walled chimney are typical of non-certified woodstoves. A 4" gap behind the combustion chamber follows masonry heater standards. The existing 4" concrete slab is more than adequate for the weight.

Design Intentions:

This design is based on Moroccan hospitality rooms, where long benches double as seating and guest beds. The 18" height matches a favorite wooden bench (not shown). Pulling the wooden bench into the angle of the L creates a double guest bed.

Construction is fairly typical of Rocket Mass Heaters, as described in the book by Ianto Evans and Leslie Jackson.

To learn earthen building, we encourage you to join a workshop, private project, or read up and create a small outdoor project to try your technique and test local subsoil mixtures. The following remarks assume some familiarity with Oregon-style cob.

Finished cob, like adobe, weights about 95 pounds per cubic foot. A 4" concrete slab footing can handle dead loads equivalent to about 2-3 feet of cob height. As with any building, a good hat and a good pair of boots (roof and well-drained foundation) will ensure the long life of natural materials.

Recommended Cleanouts:

In designing this system for a small space, we compromised on cleanouts. Two components are removable, in lieue of cleanouts:

- Telescoping exhaust chimney: To access the ash pit below, we remove set screws and slide up lower section; then replace and re-seal. A horizontal cleanout or 'T' behind the barrel would be better.)
- Barrel: We originally set the barrel in earthen plaster, then chipped it out and re-set for maintenance (once in 3 years). This is a chore even if you enjoy earthen plasters. On later projects we have used stove gasket to seat the barrel in a shaped groove, for tidier access. We have also used part of a second, matching barrel to create a rim where the top barrel can be firmly clamped in place, using gasket and often a secondary seal of foil tape.

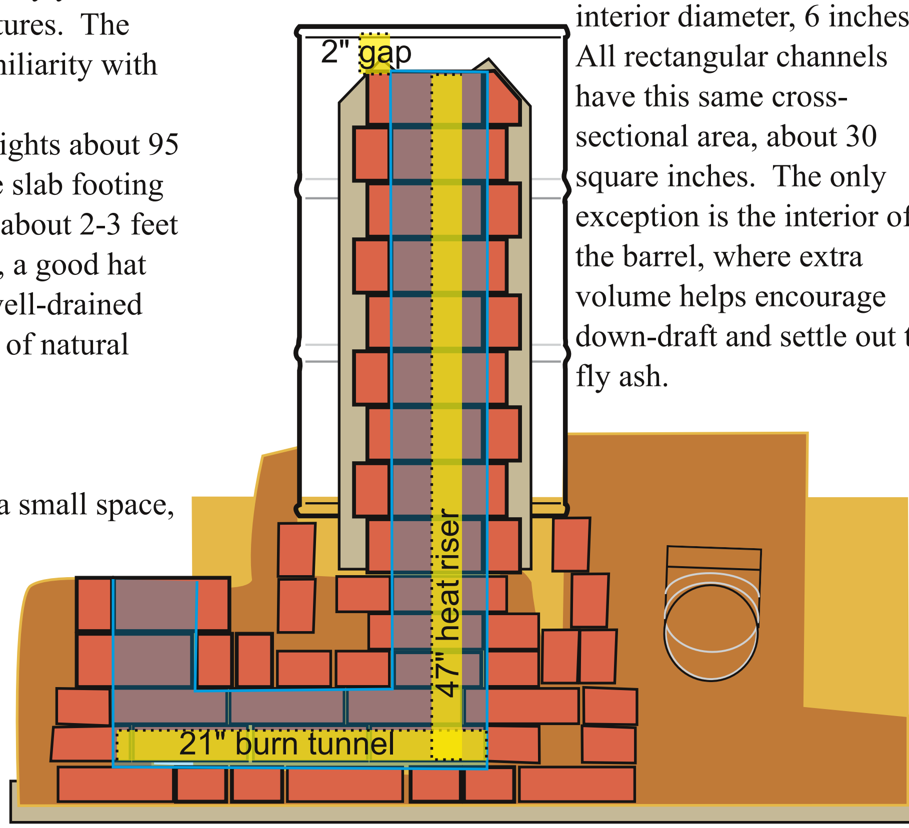
Materials:

(Full materials list at the end of this document.)

The barrel shown is a 35-gallon, 17" diameter steel food barrel. Any similar, clean, metal barrel will do (including a 55-gallon drum, with the bench moved forward to accomodate its larger diameter). The barrel is roughly centered on the heat riser, and raised on masonry or mortar to set a 2" gap between heat riser and barrel.

Other metal components in the drawing include the heat riser and ducting. Note that all metal components are round where they intersect the masonry; this helps to alleviate stress from thermal expansion.

All ducting and stovepipe has the same interior diameter, 6 inches. All rectangular channels have this same cross-sectional area, about 30 square inches. The only exception is the interior of the barrel, where extra volume helps encourage down-draft and settle out the fly ash.



Combustion Area Materials:

The heat riser's internal temperatures may reach above 2500 degrees F, so high-temperature materials are essential.

Heat Riser: Insulated steel pipe may serve as a temporary heat riser, but extended firing eventually warps the metal and/or burns out the carbon in the steel. A more durable alternative is to build the heat riser of kiln-brick, or half-firebricks insulated with refractory felt. Another method (used in the original project) is to create cast-in-place ceramic insulation (clay-stabilized perlite, packed into temporary metal formwork), or to obtain a suitable ID pre-cast refractory insulation tube. The floor plan shows a cast-ceramic insulation cylinder, but we have described the easier-to-obtain brick version in these notes.

Once past the barrel's downdraft area, the temperatures tend to stay below 600 F, so galvanized ducting can be used throughout.

For the combustion area we used soft-fired 'common' building brick. Firebrick may be better. Avoid hard-fired facing bricks as they don't handle heat shock. **Avoid Portland cement and other lime-based products in high-heat areas** (they disintegrate).

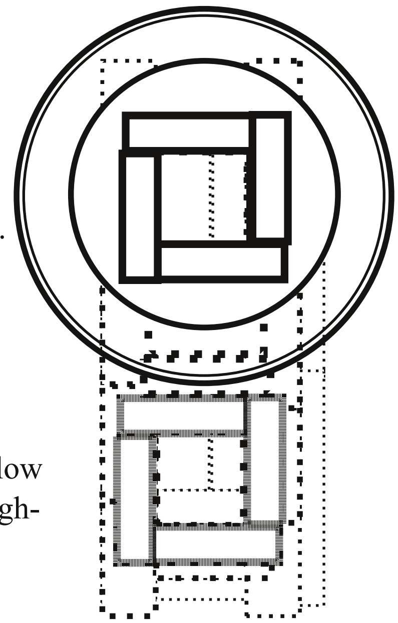
Regardless of material, the first brick in the burn tunnel bridge may crack from heat shock and rough fuel handling. We use gaskets or removable mortar to allow for replacement.

Building the Heater:

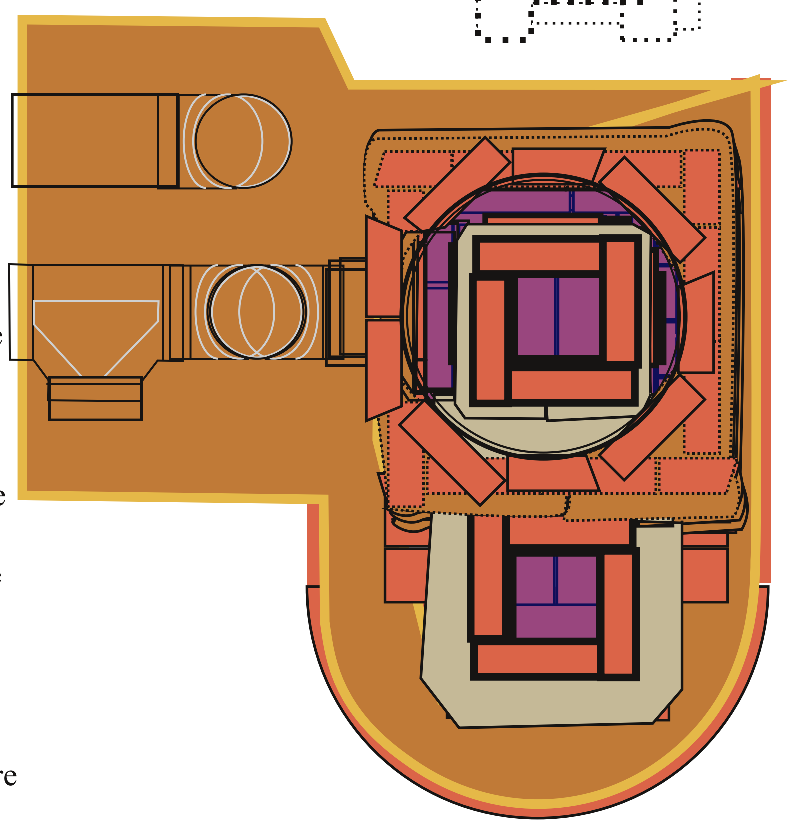
We start by assembling the pieces in place. To set the height of the pipes, and reduce trapped moisture at the floor level, we lay a dry course of brick and rubble.

The combustion area takes special care: 1" of clay-stabilized perlite insulation under the level brick floor, 2" of the same clay-stabilized perlite insulation on all sides of the firebox.

We make a paper template showing the alignment of burn tunnel, heat riser, and barrel, and check each course for proper alignment. The inside of the combustion channel is critical - the dimensions must be right, and the courses should be flush to prevent problems with loading and maintenance. See the diagrams following for brick-by-brick coursework.

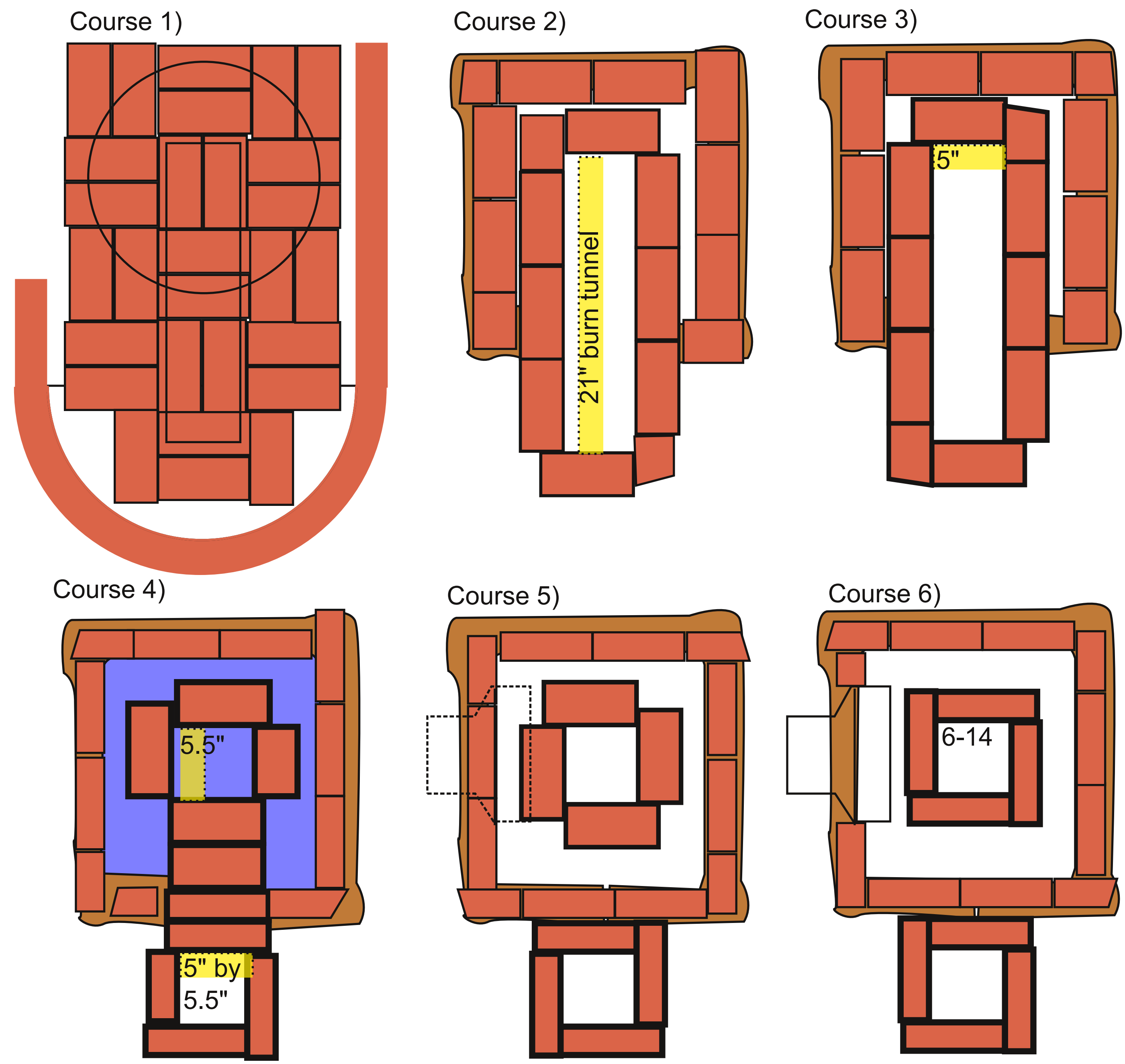


After the combustion unit is laid out, and the exhaust is plumbed through the roof (follow instructions on through-roof kit, or local

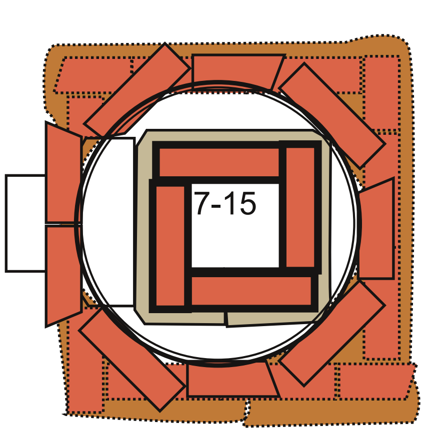


Annex 6" Rocket Mass Heater

combustion unit layout

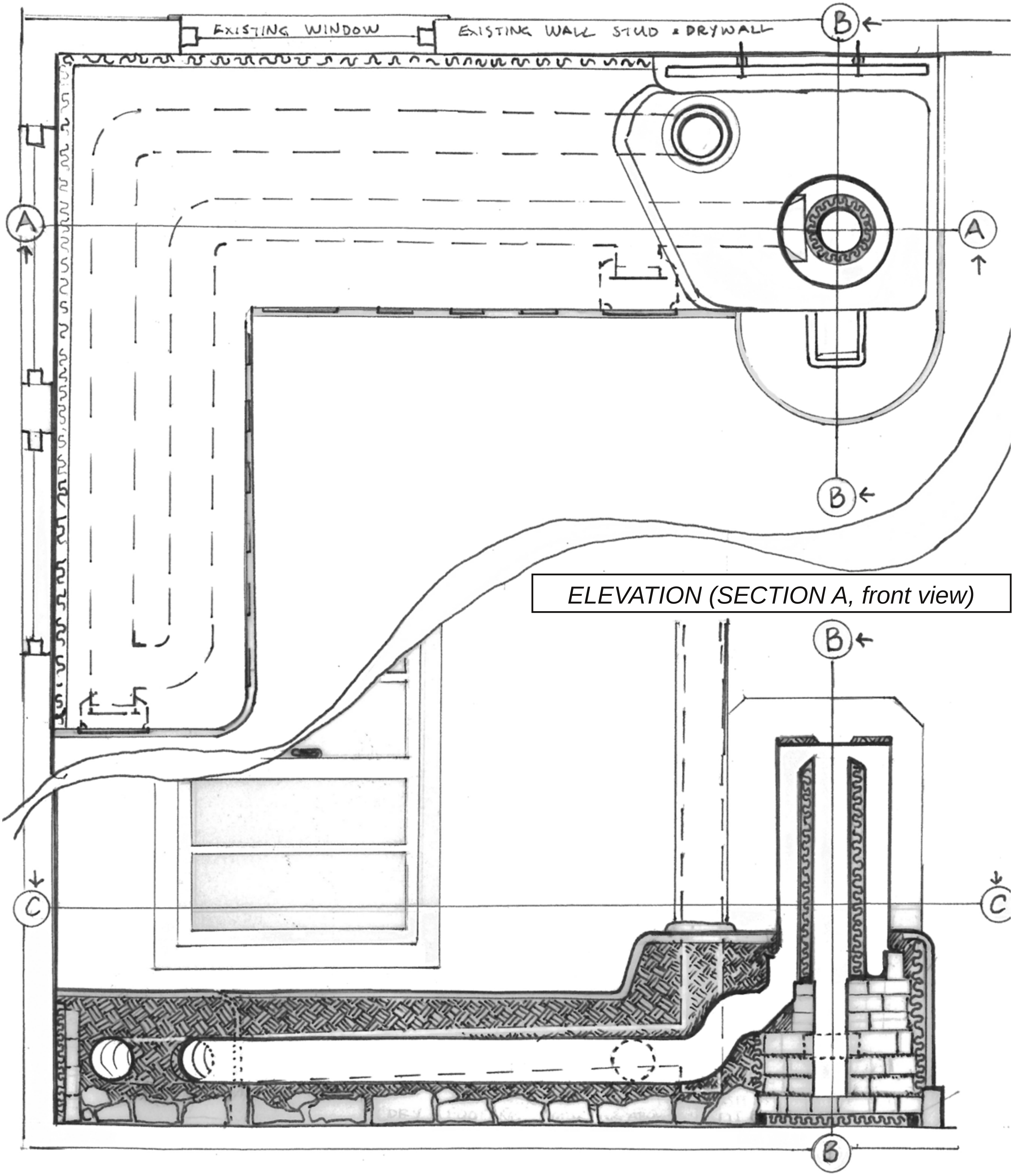


Course 7)



Repeat center of courses 6 & 7:
Heat riser courses continue to 47" height
(measured from burn tunnel floor, course 1)
alternating clockwise and counter-clockwise.

FLOOR PLAN (SECTION C, top view)



ELEVATION (SECTION A, front view)

About these architectural drawings:

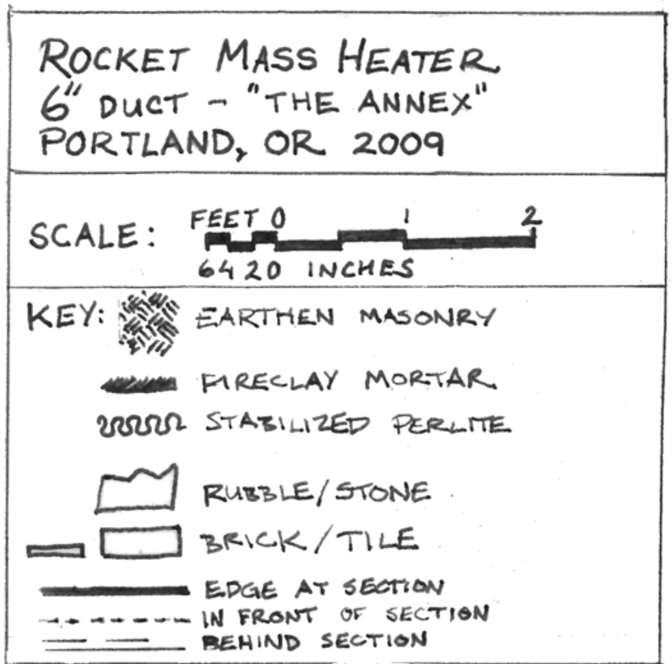
Like a map, the scale is on the side. To find out how big something is in the drawing, measure it and compare it with the scale. Or print a second copy and cut out the scale to use as a ruler.

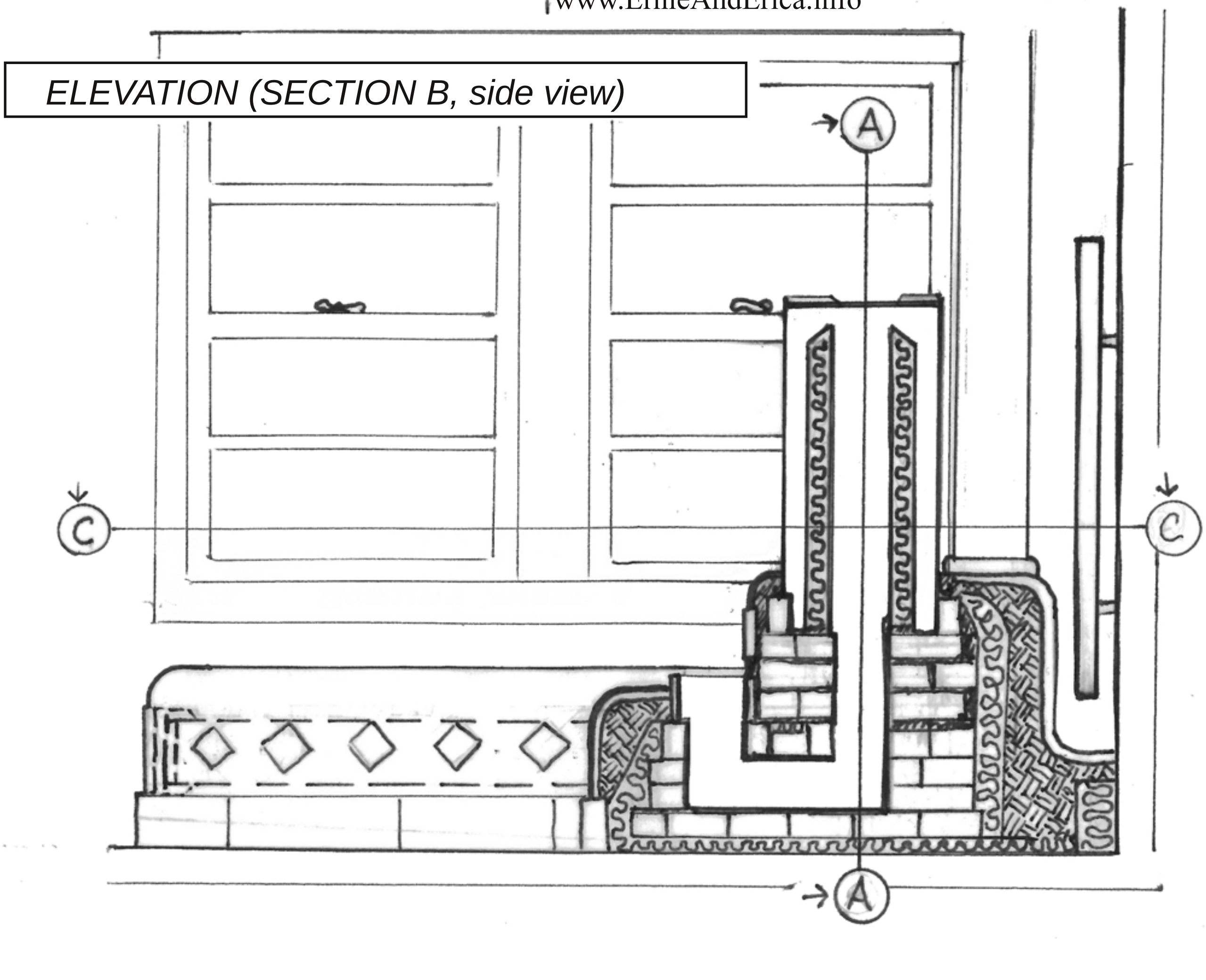
The lines marked with letters show the 'cut' for the curaway view. The arrow pointing to the letter shows your viewpoint.

For example, if you look at the floor plan, you can see that section B is taken through the round heat riser and firebox.

When you look at the side view B, you can see the insides of these parts, and the outside of the bench behind. You can also see that the line for (Section C) slices through the heat riser, barrel, and heat shield.

Dashed lines show objects below the surface.





woodstove codes), the rest of the bench is fairly straightforward.

The bulk of the heater is a dense thermal cob, with no straw, but extra sand and rock aggregate. The ducting is set in a fine mix of this material like fireclay mortar, about 1" around al sides to double-seal the ducts. Rougher material is layered around the ducts in courses, with pieces of masonry rubble when available. Bricks or cardboard serve as forms for the 1-2" of insulation along the exterior walls (to reduce heat loss).

After the core is complete, it is left rough to dry for a week or more, until the surface is no longer cool to the touch. We test-fire the heater at intervals to speed drying; fans and air movement are even more effective.

Once the heater core is thoroughly dry, the outer casing can be added. We score and clay-slip the thermal core to promote a good bond with the new material. Plenty of fiber in the natural plaster provides a durable, crack-resistant, and comfortable surface.

For our finish, we used earthen plaster, with chopped straw and horse dung fiber, iron oxide tint, and a dab of wheat paste for hardness. Ernie steel-floated the wet plaster while Erica set the decorative tiles, including the cleanout covers. Once the finish dried leather-hard, we buffed it with a wet 'plastic float' (trimmed yogurt lid) and added a polish of natural soap (less flammable, stinky, and sticky than linseed oil or beeswax).

Any breathable plaster or tile can be used on a rocket mass heater. Other breathable finishes include lime plasters, gypsum plaster, and facing brick with earthen or lime mortars.

Caution: Portland cement is largely incompatible with earthen materials. If your local jurisdiction wants to mandate the inclusion of Portland cement, concrete, rebar, or outside air feeds, please contact us for a briefing on known problems. Portland cement, for example, interferes with the clay-based bond, so instead of stronger cob, most mixtures act as really poor concrete. These materials may also introduce moisture problems.

Speaking of local jurisdictions: Our woodstove inspectors didn't know what to make of our project. The City of Portland's Alternative Technologies Advisory Committee has since approved a draft building code for rocket mass heaters, with a 1-week pre-installation approval process; this plan should pass with one substitution: firebrick in combustion areas.

If you want to get a building permit or follow existing standards elsewhere in the USA, it's worth knowing about the existing code for masonry heaters: ASTM Standard 1602-03, and Oregon's interpretive ruling 93-47. Mass stoves (>900 kg) were exempted from EPA regulation, as they're clean-burning by design and in operation, site-specific layouts, and hard to ship to testing facilities. Fireplace and woodstove regulations may not apply. RMH loads can be distributed at under 150-200 lbs/sf, fire burns hotter and cleaner, and surface/exhaust temperatures are far cooler than in woodstoves. Local standards for adobe, fireclay mortars, or general masonry may apply. Other exemptions may apply if the appliance is an antique, a building's sole source of heat, or the only way to cook.

Thank you for purchasing this document from www.ErnieAndErica.info. Please visit our site for general detail and updates, including a site planning guide. Don't hesitate to ask us questions. We love project pictures too.

Best wishes for your work and play,

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Construction Alternatives: Working with Various Mateirals

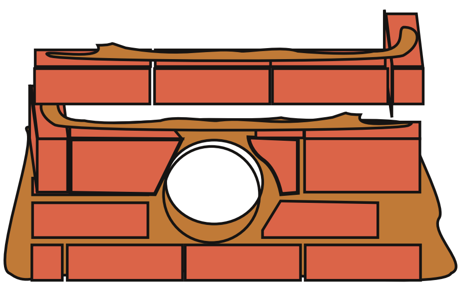
Joining Metal and Masonry:

In general, we pack earthen mortar or 'cob' (monolithic earthen masonry) around the rounded metal parts. We test-fire the heater while the earthen masonry is still damp, and continue to burn intermittently while the material dries and cures. This warm cure-in allows the materials to settle around each other with some allowance for thermal expansion. A properly-made cob with plenty of sand, and a finish layer with fibers, will tolerate a warm cure.

If the build schedule or your local masonry materials will not tolerate hot curing (such as most cement-based products and many refractories), the conventional solution is to create 'expansion joints' at any corners or critical seals.

You can create a very simple expansion joint by using a piece of 1/4" cardboard between two dissimilar layers - for example, between the firebox and the next rigid layer of insulation or casing.

For smaller joints and corners, place a strip of sticky-backed fiberglass woodstove gasket, or a spare piece of rock wool refractory insulation. This flexible material will allow the metal to expand into it, but spring back and maintain a reasonable air seal as the metal cools. Use the woven gasket to pad a corner or edge, and a rock-wool or felted type material around any larger areas that are completely encased in other masonry.



Laying brick around a round duct:
We used a special square-to-round metal fitting to slip under the barrel and connect with the heat-exchange ducting. (3x10 rectangle to 6" round.) We cut and bent parts of the rectangular opening to create tabs that we mortared between brick layers.

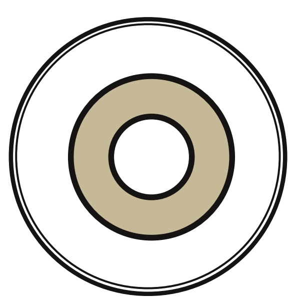
The simpler way to join a brick manifold and the round heat-exchange ducting s simply to build the round duct into the brick as you make the brick courses. You can also leave a 7" hole and mortar the ducting in later.

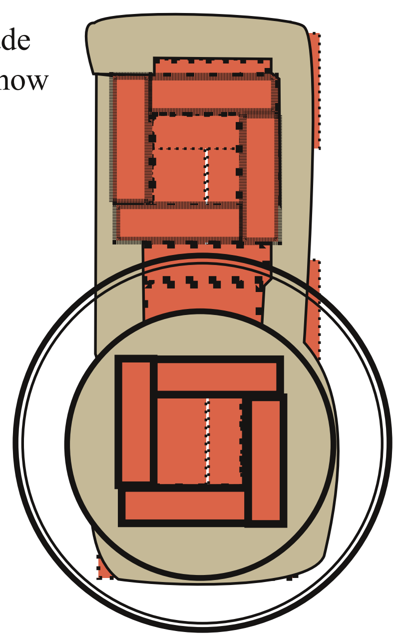
Insulation:

After laying bricks, we pack clay-stabilized perlite all around the firebox. This serves as both insulation and expansion joint. (See back page.)

To insulate the tall heat riser, the original Annex project used a home-made cast refractory tube of clay and perlite. The inner liner burned out in place. We now suggest a ceramic-fiber cast refractory tube for minimal clearance heaters: 6" internal diameter (ID) and 10" OD. (e.g. Fibrefrax moldables). (shown on left)

A brick heat riser is more durable and cheaper. We show a brick heat riser in the brick layouts, and below (right).
For insulation around the brick, we use either
- 2" of perlite, stabilized with clay slip, packed into a large ring of sheet metal or wire cloth,
or:
- 1" of rock wool (refractory blanket).
or:
- 4" of loose vermiculite can also be used, without clay.





Materials Used:

Bench base: Concrete garden pavers and rubble - about 25-30 square feet, 4" to 5" tall; more if available for infill.

Bricks - reclaimed older building bricks (reddish, soft-fired clay, like terra cotta) - about 120 for combustion area, more if available for back of bench / insulation gap.

Perlite - about 10 cubic feet for heat riser and wall insulation

Ducting and stovepipe - all 6" interior diameter unless otherwise noted

Ducting in bench:
- about 25 feet of straight pipe - 4 sections of 5-foot length, plus 2 2-foot sections, 1-foot extension at end.
- 3 T's (6" to 6" all ways)
- 3 T caps (stovepipe)
- 5 elbows
- 6" round to 3" by 10" rectangle duct piece (cut and tabbed into brickwork, to connect ducting with barrel)

Exposed stovepipe:
- 8 foot telescoping double-walled stovepipe
- Ceiling box
- Triple-walled, insulated through-roof pipe
- 'witch's hat' and collar for roof
- roof sealant
- stainless extending 2' above anything within 10 feet
- chimney cap with screen

Barrel: 35-gallon or larger steel drum, with paint removed (ours originally held industrial-grade ascorbic acid, vitamin C)

Clay & Sand:
Desired proportions are about 10-25% true clay, 70% sand, with maybe a little bit of silt or gravel. In our Western Oregon location with its heavy clay soils we used:

Clay - up to 1 yard of local clay-rich soil,
plus - 20 gallons reclaimed pottery clay (or 2 50-lb bags powdered fireclay)

Sand - 2-3 yards of local masonry sand

Straw - 1/2 bale

Plaster materials:
- chopped straw, and/or horse manure - about 3 to 5 buckets,
- concrete pigment (orange 'red ochre', about half of a 5-lb bag)
- remainder of clay and sand
- lime putty or type S lime if

Tile and details:
- Reclaimed tile - 3 10" by 10" or larger to cover cleanouts; 1 6" by 6", assorted 4" by 4"
- Ceramic chimney flue liner piece (8" square interior, cut down to 2-4" height) at fuel feed.
- One or two extra bricks to control air feed.

Heat riser:
NOTE: Original drawings show cast-in-place heat riser using metal forms and packed ceramic clay and perlite.
Other methods for heat riser may be more durable:

- 36 additional bricks,
- 2 ft x 8 ft rock wool insulation, and
- 4 ft x 4 ft wire mesh or thin metal to cover insulation

OR pre-cast 6" ID refractory insulation,

OR original method: 36" lengths
- 6" diameter steel pipe (inside liner)
- 12" diameter duct (insulation container)
- 4 cu ft perlite plus 3 gallons clay slip

Cut slots in base of outer pipe, bend inward, crimp flush with inner pipe, and use foil tape to seal a temporary flat base.
Fill with tamped perlite insulation mixture, thick enough to be self-supporting. Tab top edge likewise, cutting tabs a little extra-long to produce an angled slope.

Tools used:

Layout & Prep:
Measuring tape & yardstick,
Marker/pencil
Level (level & plumb wall marings, heat riser, barrel, adjust horizontal slopes of pipes)
Plumb bob & line (align roof & ceiling holes, plumb the stovepipe)
Cardboard & markers for templates
Masking tape or chalk line for marking on walls

Ducting & stovepipe:
Tinsnips or hacksaw
Crimpers or pliers
Tools for making & supporting the through-roof hole (Drywall saw, wood saw, drill, & screws)
Tight-fitting gloves
Sheet metal screws & drill for duct joints (and/or high-temperature foil tape)

Mixing earthen materials:
Shovel(s),
(optional hoe; mattock or pick)
Wheelbarrow
Tarp(s) (8' by 10', plus smaller ones, bags, or bins for staging materials)
Buckets (5 to 10 or more)
Paint stirrer (to mix clay slip with electric drill)
Screens (1/4" mesh, windowscreen)
Boots & gloves
Dust mask for perlite / powdered materials

Masonry, Mortars, and Plasters
Masonry saw (or hammer and cold chisels, or a lot of broken brick and extra mortar)
Trowel(s) (assorted sizes)
Float(s) (steel + wood or plastic)
Paintbrushes for slip / water

For more photos of rocket mass heater projects, and free online technical discussion, we suggest
- the forums at Permies.Com
- the book Rocket Mass Heaters, www.rocketstoves.com
- and our own website's rocket stove pages at www.ErnieAndErica.info

A complete photo-essay of this heater's building process is available online.