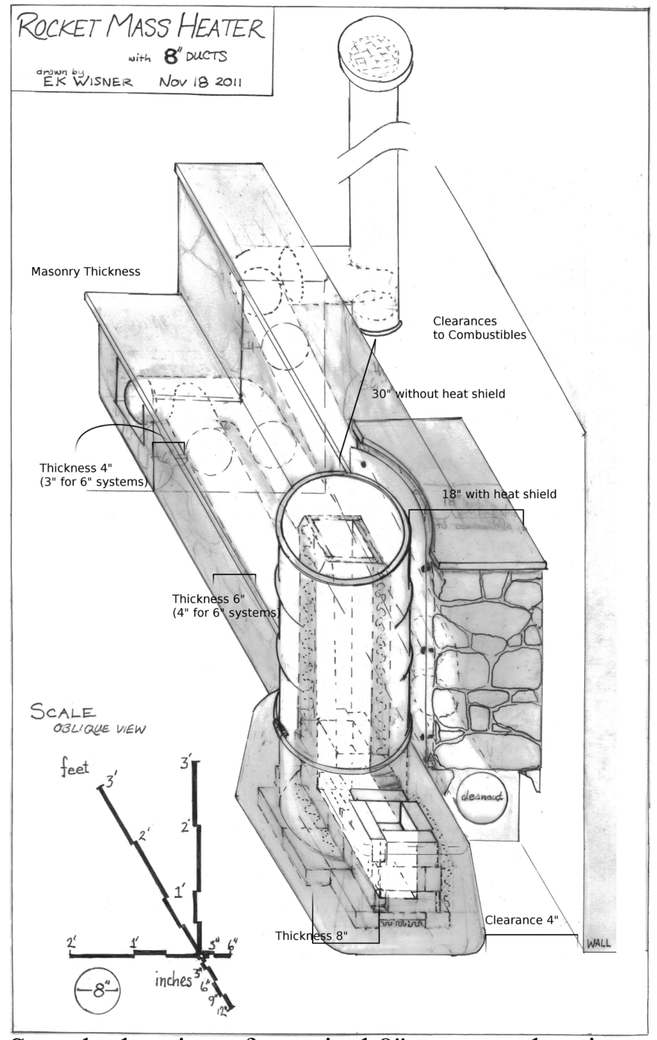
General system parameters:

Footprint: Approx. 4 ft by 20 ft
Bench volume: 70 cu. ft (2.5 cubic meters)
Approx. weight: 9500 lbs
(3500 lbs brick, 6000 lbs earthen masonry,)
dead load 120 to 250 lbs/sf

Ducting & stovepipe: 8" diameter
Duct length: 25 ft,
with 3.5 90 degree bends =
effective drag 45 ft
Fuel feed: 7" by 7.5"
Heat riser height: 56"
Burn tunnel length: 25"
Feed tube height: 12" (shown) to 16.5"

Working temperatures:
Flame path: 1200 to 2800 F
Barrel surface: 200 to 800F (hottest in upper third)
Masonry surfaces: 60 to 90 F

Heats 3000-5000 SF in coastal redwood valley (typically damp weather, year-round low temperatures in 40s F)
Firewood consumption (including 2 other wood-burning stoves) dropped from 8 cords per year to 2 cords per year.
Burns approx. 2 loads of wood per day, 6-8 hours daytime burn (oak/madrone).



Sample drawing of a typical 8" system, showing general clearances and dimensions.

Rocket Stove Resources:
For more photos of rocket mass heater projects, and free online technical discussion, we suggest
- the forums at www.permies.com
- the book Rocket Mass Heaters, www.rocketstoves.com
- and our own website's rocket stove pages at www.ErnieAndErica.info
(Photo galleries are linked from the Rocket Mass Heaters page.)

Technical discussion of heating, thermal mass, and wood:
Woodheat.org, ChimneySweepOnline.com (has cordwood comparisons for BTU's)
Calculating heat storage capacity: http://www.engineeringtoolbox.com
Building code compliance: ASTM standard 1602-03, local regulations

This heater's building process was filmed by Calen Kennett of VillageVideo.org.

Rocket Mass Heater As-Built Drawings

Bonny Convection Bench: 8" Duct diameter

with room-air circulation channels
over reinforced wood floor

by Ernie and Erica Wisner
http://www.ErnieAndErica.info

Materials used:
Brick: 375 building bricks, 67 firebrick*
- air channels: 315 (130 for legs, 285 above)
- manifold: up to 60 bricks
- firebrick: 25 (burn floor) + 40 (J-tube) + 2

To substitute all-brick heat riser, add 32 firebricks

Concrete pavers - 4 pavers 2 ft square
Perlite - 12 cu ft - half for underneath.
Aluminum foil - 2 rolls
Building felt - 1 roll
Clay - local clay-rich subsoil, about 1 yd
Sand - local sand from old arena, about 3 yds
Straw - 1/2 bale
Local facing stone, large tile, rubble
Horse dung - 2 wheelbarrows
Natural earthen pigments, mica
Bar soap and water for buffing

8" diameter Ducting / Stovepipe:
- 4 straights 5 ft long, 2 straights 3ft long
- 4 elbows
- 2 T's
- 3 cleanout caps (stovepipe)

Measure to fit ceiling height & roof pitch:
- Stovepipe for vertical exit chimney
- Through-roof kit with screened chimney cap

Insulation container: ducting 12" dia., 3 ft lenght
Sub-floor supports (timbers, pier blocks, etc)

Tools used: *(optional)*

Layout and prep:
Tape measure
Level
(Plumbline, Square)
(Cardboard, markers, masking tape)
(Tinsnips, crimpers, foil tape or metal screws)

Earthen masonry:
Shovel(s)
Wheelbarrow(s)
Tarp(s) - 8 ft by 10 ft, extras for staging
Water hose

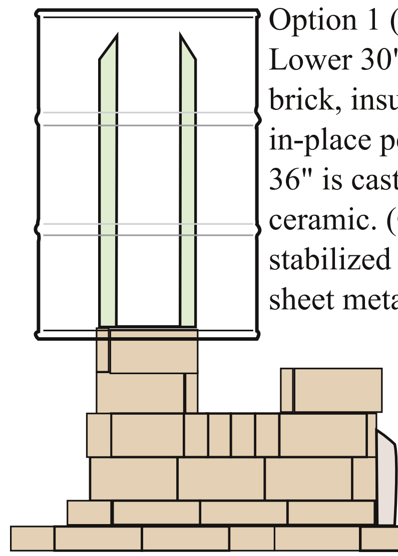
Buckets (about 10)
(Paint stirrer & drill)
(Boots, gloves, dust masks)

Brick & plasters:
Trowel(s), (Steel float)
Cold chisel and hammer
(Circular saw w/ masonry blade)
(Plaster/mortar screen - 1/4" mesh, 1/8" mesh)

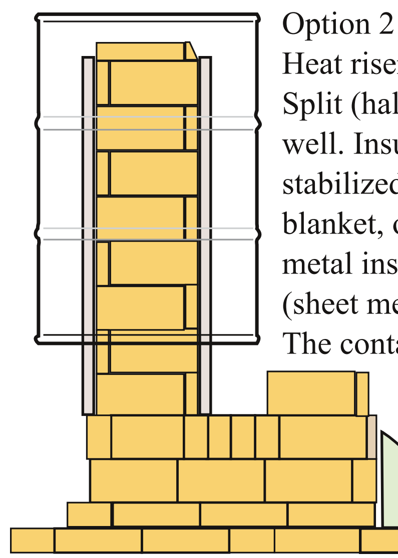
Through-roof, sub-floor:
Carpentry tools & fasteners
(Skilled carpenter / roofer)

Heat Riser Details

Heat riser is extra tall (almost 5 feet) to guarantee good draft in mild coastal weather.



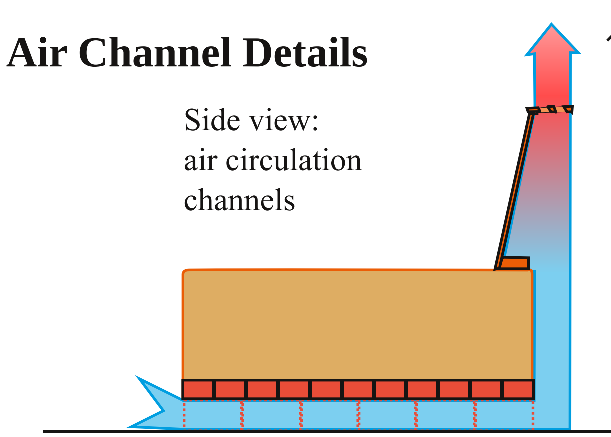
Option 1 (as built):
Lower 30" of heat riser is brick, insulated with formed-in-place perlite/clay. Upper 36" is cast-in-place refractory ceramic. (Originally clay-stabilized perlite contained in sheet metal forms, 8" ID and 12" OD; we now recommend refractory rated for 3100 F or higher, with insulation.)



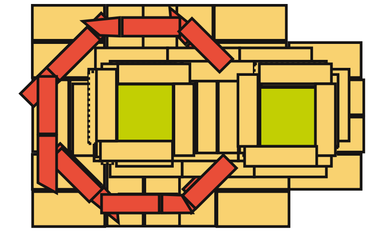
Option 2 (most durable):
Heat riser entirely brick. Split (half) firebrick works well. Insulate with clay-stabilized perlite, refractory blanket, or rock wool, with a metal insulation container (sheet metal or wire mesh). The container holds insulation in place and protects it during maintenance.)

Air Channel Details

Side view:
air circulation channels

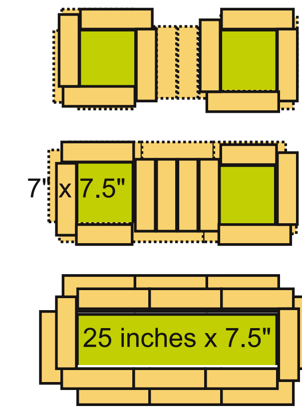


Brick and paver layouts

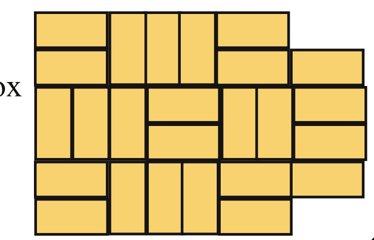


Interior dimensions are critical. The outer corners don't match up, and don't matter.

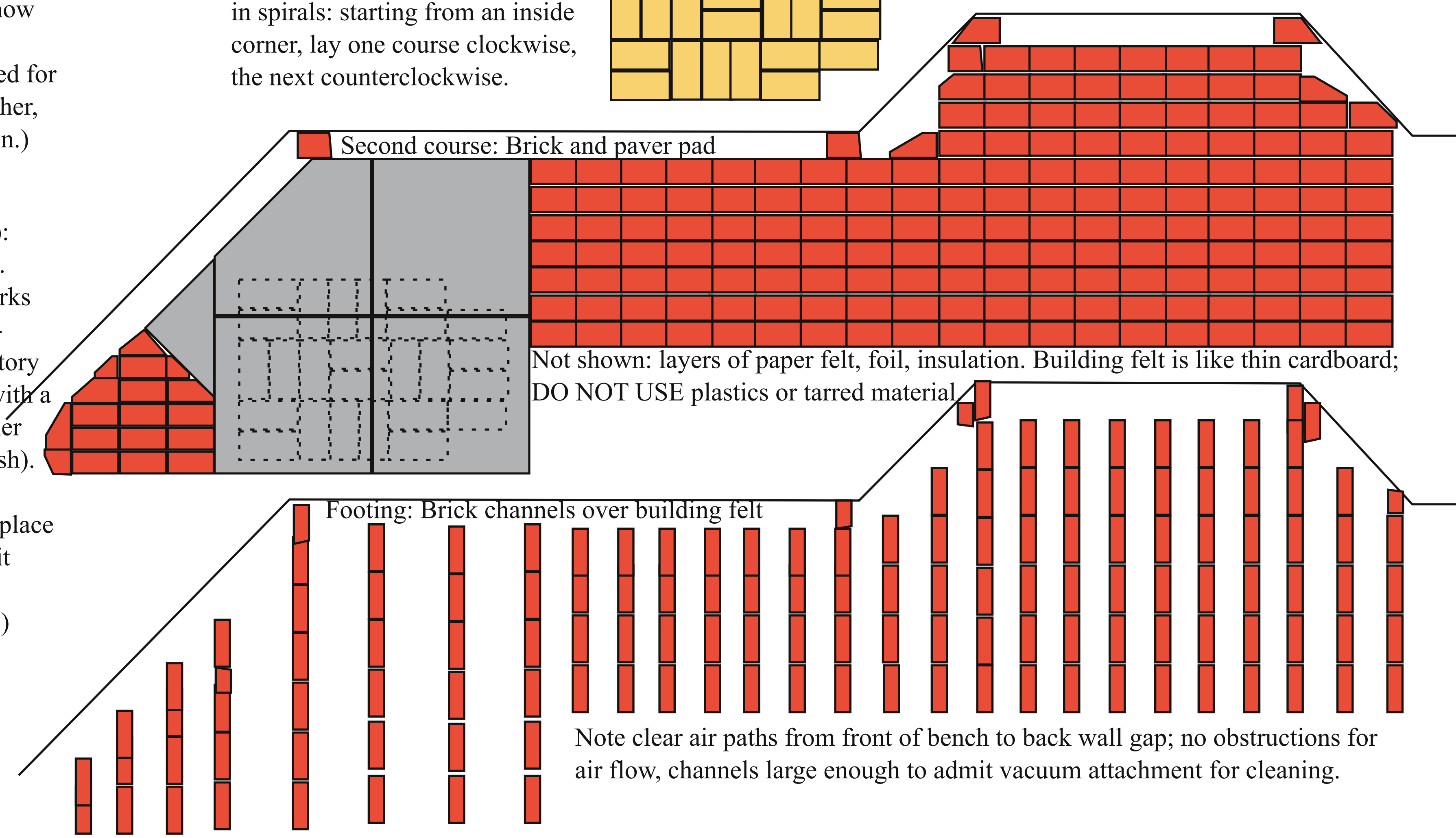
Avoid 'running joins' – lap each course's bricks over the joints below for stability. Lay the firebox in spirals: starting from an inside corner, lay one course clockwise, the next counterclockwise.



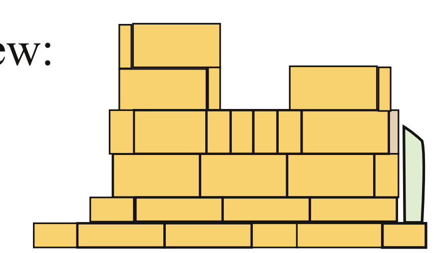
Combustion unit courses:
Firebrick burn floor (32 matched firebricks);
Burn tunnel - 16 full-size firebrick),
Bridge: 10 firebrick (2 cut to 7" length)
Feed: 8 firebrick (2 courses of 4)
Heat riser: 32 split firebrick + 4 trimmed pieces
Manifold: approx. 40-50 mortared building bricks, including numerous partial or broken bricks.



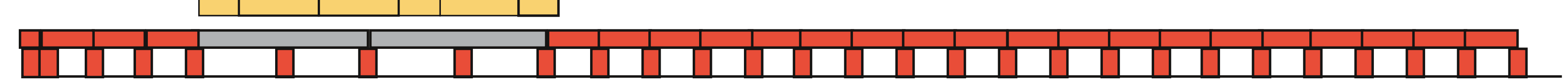
Top views:



Side view:



Side view - brick and paver layouts
(Note the combustion unit is 'floating' on a layer of clay-stabilized perlite insulation. This insulation is 2" thick under combustion unit, 1" under remainder of bench.



intervals to speed drying; and use fans.

Finishes:

Once the heater core is thoroughly dry, the outer casing can be added. We score and clay-slip the dried layer to promote a good bond with the new material. Plenty of fiber in the natural plaster provides a durable, crack-resistant, and comfortable surface. We often use a layer of long-straw cob for tensile strenth and resilience.

We did a thin 'scratch coat' of earthen plaster to level out the rough surfaces, and set the facing stone along the foot.

For our finish, we used earthen plaster, with chopped straw and local horse dung fiber, local ochre clay with mica and grit, and added buff-colored sand from an old horse arena. We steel-floated the wet plaster, and made sample tiles on scrap wood to practice painting, sculpting, and surface coatings. Leftover plaster was set aside in small 'biscuits' in case of later repairs.

We steel-floated the wet plaster, let it dry leather-hard, and floated it again to buff the mica clean. Erica detailed the facing stone, while Ernie mixed a test batch of polish. We heated a paste-like mixture of natural (glycerin) soap and water, and used a cloth to smear the thin, warm paste onto the surface. It goes on smooth and clear. The result is glossy, spot-washable, and more heat-stable than most oils or waxes.

Any breathable plaster can be used on a rocket mass heater, such as lime plaster, dung plaster, clay paints, and light straw-clay. Gypsum plasters, and mosaics with small tiles and natural grouts, are breathable enough, but conduct heat faster.

Aside from the learning experience with hot fuels and thin benches, this project followed known building codes for clearances, masonry heater detailing, and structural support.

If you want to get a building permit, or to meet existing standards for various reasons, it's worth knowing about the existing code for masonry heaters: ASTM standard 1602-03, and Oregon's interpretive ruling 93-47. (Other states are not bound by this finding, but this one makes a particularly clear statement that a masonry heater is not a woodstove nor a fireplace.)

Mass stoves (>900 kg) were exempted from EPA regulation, as they're clean-burning by design, layouts are site-specific, and shipment of heavy unique units to testing facilities is prohibitively difficult. Fireplace and woodstove regulations may not apply: dead load is distributed at under 125 lbs/sf in the bench area, and up to twice that in the combustion unit depending on footings. The fire averages hotter, and most 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.

If a local jurisdiction mandates the inclusion of cement, rebar, or other materials not compatible with earthen masonry, please contact us for a briefing on known problems. Adding cement to earthen materials reduces the clay-based bonding and heat tolerance, and instead creates very poor concrete.

Earthen masonry is surprisingly well-suited to this application, and the quality standard can be quite high using the Oregon cob method, with its simple, on-site testing of every batch. Keep a few samples around, to demonstrate the resilience, density, and durable finish of your project.

Thank you for purchasing this document from www.ErnieAndErica.info. Our website contains other useful general info, and may offer updates on this and other projects.

Please don't hesitate to ask us any questions. We love project pictures too.

Best wishes for your work and play,

Erica and Ernie Wisner

questions@ErnieAndErica.info
http://www.ErnieAndErica.info

BONNY CONVECTION BENCH - 8" Rocket Mass Heater:

Builder's Notes

This project was originally built in California, in a forested area with year-round, cool, coastal weather. It was designed to fit with the redwood and oak aesthetic of the main room, while contributing substantial heat to all 3 floors of the multi-family house. Channels underneath the bench passively circulate warm air up through the vents in the redwood back, cooling the hardwood floor and jump-starting the heat transfer to the rest of the house (via a conveniently located stairwell, not shown). To reinforce the existing wood floor, an 8x8" beam was laid along posts and piers in the crawl space, shimmed as needed, and toenailed to the floor joists.

The project combines typical Rocket Mass Heater techniques with conventions taken from woodstove and masonry heater design. Natural building elements include laying the brick with fireclay mortars (or clay-sand in the low temperature areas), cob thermal mass, and earthen plasters made with a gorgeous, mica-flecked golden subsoil we found on site, and ochre-painted surface art. Woodstove elements include a double-walled stovepipe, and heat shielding and clearances around the barrel. Masonry heater elements(ASTM 1602-03) include the brick channels, double-walled combustion unit with expansion-tolerant perlite insulation, and 4" clearance to combustible walls, bridged by narrow stem walls for earthquake stability.

To learn earthen building, we encourage you to attend a workshop, private work-party, 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 lbs per cubic foot. Most floors are rated for dead loads of 100 to 180lbs per square foot, so a bench less than 18" tall may fall within your home's design parameters - just barely. We consider it wiser to reinforce suspended floors, or use a masonry foundation where possible.

This particular home is a shared space, and the residents wanted to preserve the beautiful wood floors in case of future changes. Owners, neighbors, family, and friends were involved in the building process; workshops and work-parties with guest instructors kept the work fun.

The air channels perform superbly, but they also create a design challenge: It is difficult to fit an 8" duct, with adequate masonry thickness around it, into an 18" tall bench that includes 4" of brick channels underneath. A taller bench is harder to sit on. This led to a Hot Spot, described below.

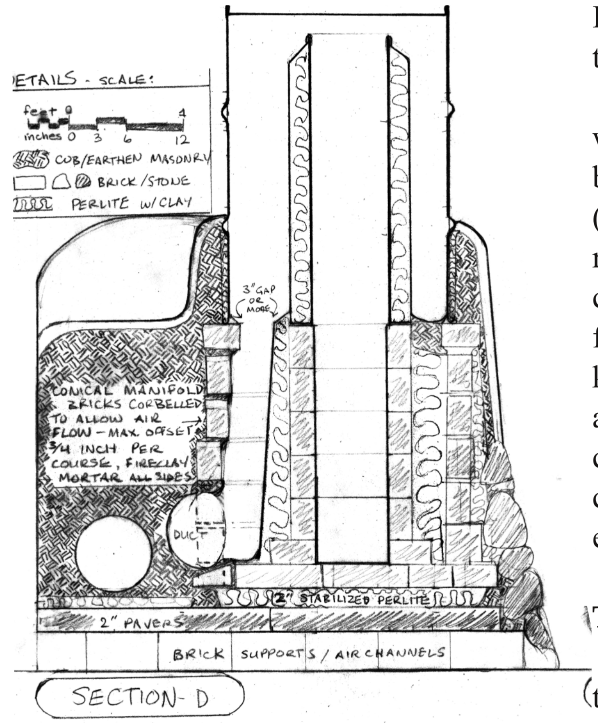
The air channels are sized in part to allow a vacuum hose in for cleaning, as the residents have young children who like to hide toys. Their volume also matches the 4-5" deep vertical pocket behind the bench; the draft from this warm space steadily draws air in from the floor, up along the warm back, and out through the upper vents. Larger channels help cool the firebox area.

Air-channel Footing:

The channels are made with bricks, laid edgewise in neat rows, on pads of builder's felt (like rough, thick paper; DO NOT use tarred or plastic materials). A second course of brick (and some larger pavers to support the firebox area) bridge across the channels, creating a solid pad underneath the entire footprint of the heater. We filled some gaps with earthen mortar.

Insulation was next: we rolled out builder's felt and aluminum foil to make a continuous level basin for insulation. Around the edges we added a small 'screed lip' of cob at the desired height. Then we poured in a clay-stabilized perlite insulation (mixed outdoors on tarps), screeded and compacted it down to a thickness of 2" below the burn area, and 1" below the remainder of the bench.

With slab-on-grade or in-ground foundations, the bench ducting rests on cob and rubble, and heat can be stored both below and above the ducts. In this case, we needed to protect the wood floor and limit our bench height for seating. The insulation and foil focus heat back upward into the bench, protecting the floor.



Combustion Unit:

With 2" of compacted perlite-clay insulation in place, we leveled the brick floor pad for the combustion unit. (We had already laid everything out to scale, and made ourselves a paper template showing where each part goes: fuel feed, burn tunnel, heat riser, barrel, and brick manifold. (The manifold is the 'box' that supports the barrel, with many-fold shapes and openings for exhaust flow, ducting, and fly ash cleanouts).)

Firebrick was purchased for the combustion chamber; reclaimed red brick was used for the manifold and bench areas. Uncle Jerry the 'retired' bricklayer cut the necessary angles for our fancy octagonal plinth. A rectangle would do as well and be simpler, if it clears the return ducts.

Manifold Options: Metal or cob can also form a sealed chamber here; but do allow an expansion joint or plenty of fiber in the casing cob.

Important: Do not use Portland cement, concrete pavers, or lime mortars **in the burn area**: the lime in these products will turn back to powder at high temperatures, causing crumbling.

When the manifold's hollow column reached the right height (leaving a 2" gap from the heat riser mouth to the barrel's inside surface), we re-checked the alignment, and placed the barrel. It's a standard 55-gallon drum, about 23" in diameter. The barrel is deeply set in earthen plaster up to 1/3 of its height, for aesthetics and childproofing. Extra insulation was included on the side facing the room, below the barrel only. We made a broad base to help support this additional cob height - you want the cob ring around the barrel to be at least 4" thick.

Insulation should not be used around the barrel.

The main exhaust path is toward the windows, with a cleanout facing backwards opposite the firebox. (There is another cleanout on the return duct at the base of the exhaust chimney, and one at th U-bend on the far end.). This cleanout orientation keeps most of the mess contained, and also allows a way to 'prime' the chimney in case the mass becomes colder than outside air during an extended absence.

Thermal Materials:

The heat riser's internal temperatures may reach above 2500 degrees F, so high-temperature materials are essential. Insulated stainless steel pipes may work for many years, but extended firing will eventually warp or damage the metal, or crack the surrounding mortars due to thermal expansion. A more durable alternative is to build the heat riser of kiln-brick, or half-firebricks insulated with refractory felt. Some builders prefer cast-in-place ceramic insulation or high-temperature refractory insulation around a sacrificial cardboard form. For this project, we made a fireclay-stabilised perlite insulation for the metal-lined heat riser, providing a stable ceramic material in case the steel liner fails. Hot fires are certain in this area: the primary firewoods are oak and madrone.

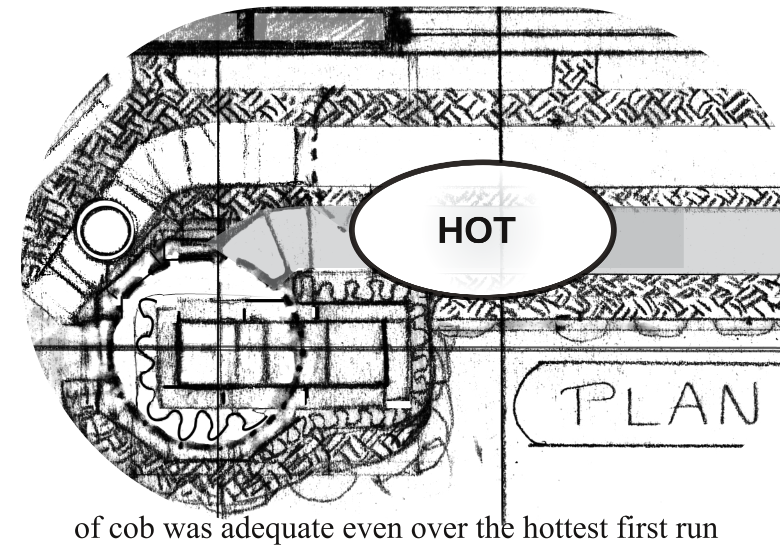
In the manifold area, a double casing helps protect masonry and metal joins from thermal shock. Temperatures drop rapidly in the barrel.

Once past the barrel's downdraft area, the exhaust temperatures are well below 600 F, so ordinary mild steel ducting can be used.

Hot Spot Warning:

We discovered a spot that gets too hot for comfort (or cushions) over the first section of ducting.

On previous benches in smaller homes, 4"



of cob was adequate even over the hottest first run of 8" ducting. Using rich oak and madrone fuels to heat a much larger space than previously attempted (about 5000 sf), this heater burns longer and hotter. We now recommend at least 6" of cob if the heater is intended to provide heat to a larger home. Fuel value listings at chimneysweeponline.com or woodheat.org will also help determine whether local fuels burn significanly hotter or cooler than the inventors' typical fuels like Doug fir, pine, cedar, or fruitwoods.

How to fix the hot spot: The simplest way would be to add an arm rest or back support, or just a thicker platform, to bring the bench up to 6" thickness over the first 5 feet of duct.

It might also be possible to squash the duct to a slight oblong: a 1" deviation does not sacrifice much flow, and 6" of cob would bring the bench height to 19". A small step-hearth could be provided around the firebox for convenience.

On this project, we found the hot spot after test-firing, so we mitigated it by spreading the heat with an insulating plaster mix (perlite aggregate). The almost-dry cob in the original 'bathtub' shape was so comfortable, the owners decided to keep it.

To fit a seat-height bench above an air-cooled footing involves tight clearances. With 4.5" of brick, 1" of perlite, and 8" of duct, in an 18" bench, there is only room for 4.5" of cob above the duct. We packed a scant 1/2" to 1/4" of earthen mortar under the ducts for support and seal, and laid the ducts close together. Most of the cob is around and above the ducting. We took special care not to raise any part of the ducting higher than necessary. One trick was using a flat half brick where the ducting meets the manifold floor.

Bench:

All ducting is sized to the same interior diameter, 8 inches, and all rectangular channels have this same cross-sectional area, about 50 square inches. The only exception is the interior of the barrel, where extra volume aids with down-draft and fly ash settling.

We avoid aluminum, or galvanized, ducting in the first 5 to 10 feet; any smooth metal ducting (non-corrugated) can be used in the remainder. Avoid holes or rusty areas, and seal well with earthen mortar.

We laid the ducting from the roof backward, to ensure the exit chimney was plumb. After assembling the ducting in place, we use foil tape or tap screws to temporarily secure the connections. We test-fire as soon as all gaps are sealed, to troubleshoot any problems like bottlenecks or dropped material in the pipes.

The main bulk of the heater is a dense thermal cob, with no straw, but extra sand and rock aggregate. We start by setting the bench ducts in a fine mix of clay and sand, like fireclay mortar. 1" around all sides is enough to double-seal the ducts, but limits of space on this project dictated a scant 3/4" layer underneath. We sealed around the outside of the bench with cob as well.

Next, rougher material is layered around the ducts in courses, with masonry rubble infill and earthen mortars. Forms or hand-held boards help to keep the sides vertical: the 4" channel at the wall particularly benefits from formwork. The front edge rises plumb or with a slight overhang; with a decorative rock facade set in earthen plaster.

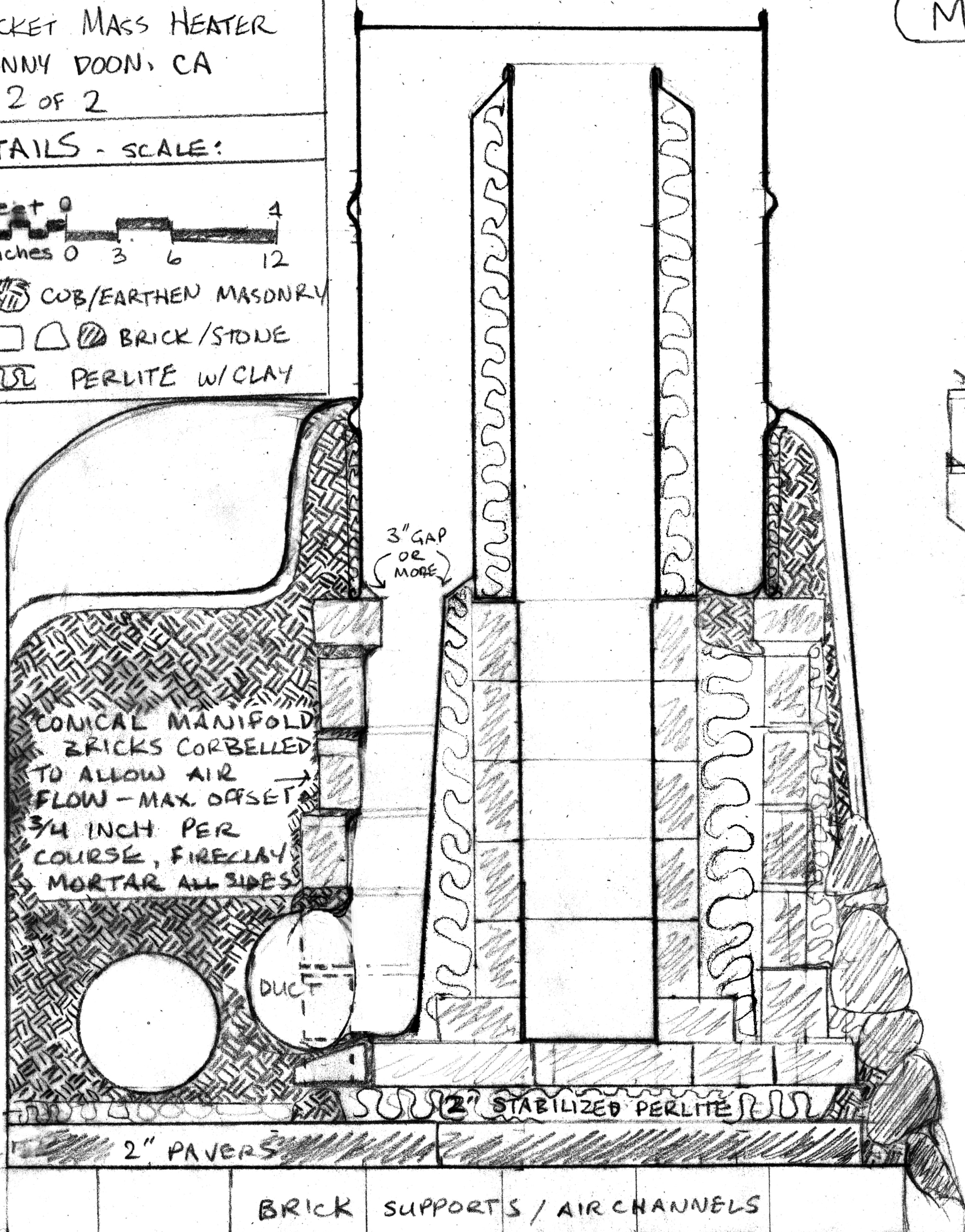
After the rough core is complete, we let it dry for a week or more, until the surface is no longer cool to the touch. We test-fire the heater at

ROCKET MASS HEATER
BONNY DOON, CA
P. 2 OF 2

DETAILS - SCALE:

feet 0 4
inches 0 3 6 12

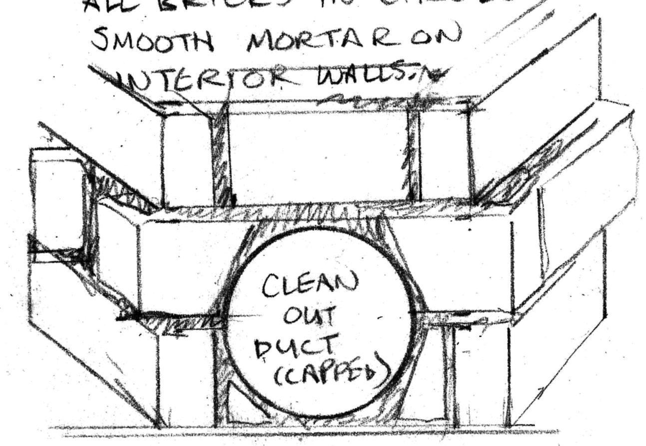
COB/EARTHEN MASONRY
BRICK/STONE
PERLITE W/CLAY



SECTION- D

MANIFOLD

RED BRICK SHOWN (2¼"x4"x7½")
MAY USE FIREBRICK (2½"x4½"x9")
MUST USE (FIRE)CLAY MORTAR
CORBEL UPPER COURSES INWARD TO MEET BARREL DIAMETER
→ NO MORE THAN 3/4" OVERHANG PER COURSE, AND BRACE WITH ALL BRICKS IN CIRCLE.
SMOOTH MORTAR ON INTERIOR WALLS.



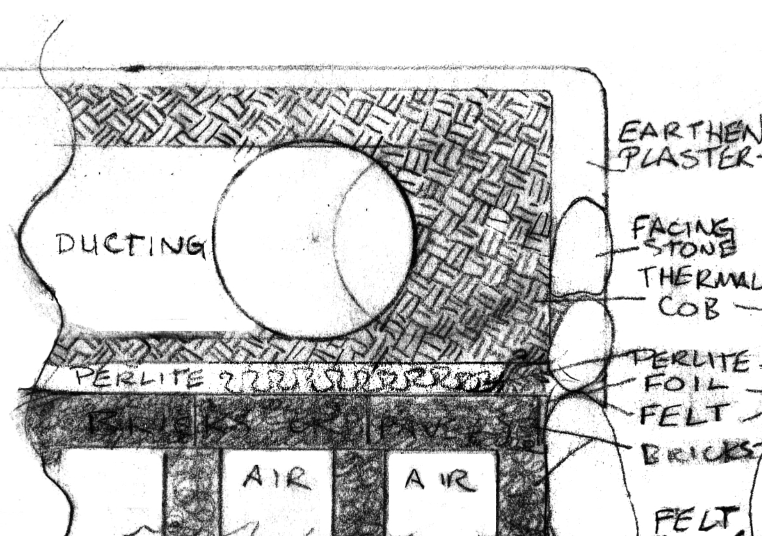
MANIFOLD - CLEANOUT W/ DUCT JUNCTION

CRITICAL DIMENSIONS:

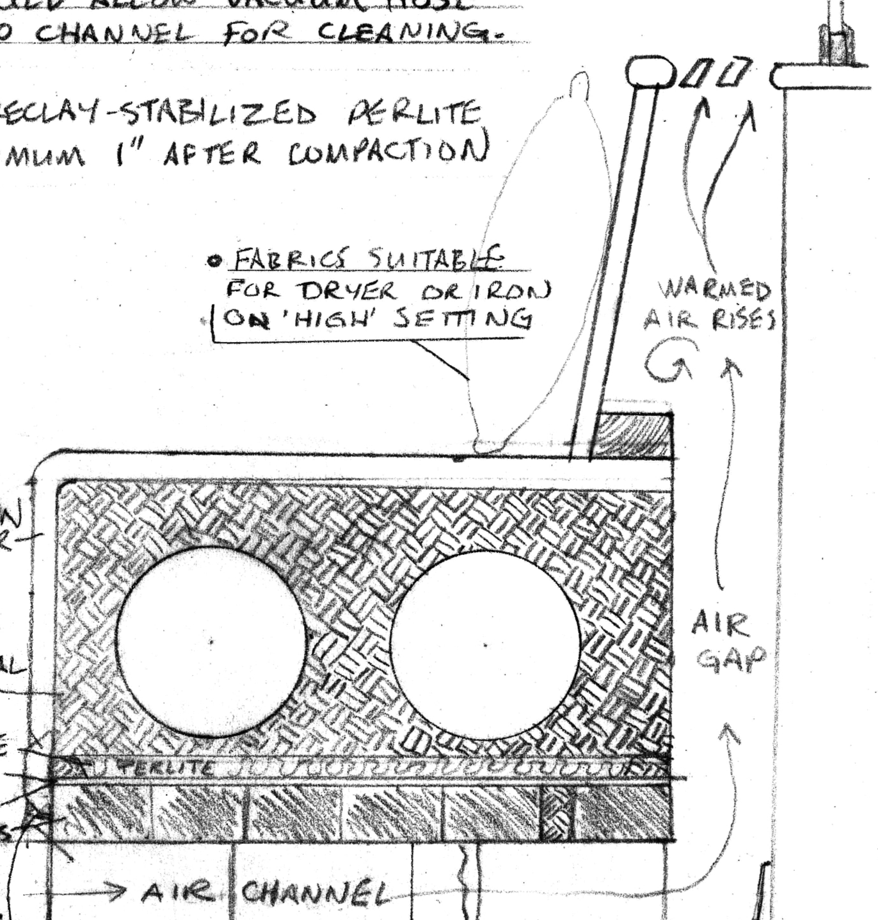
- FLOW AREAS ≥ 50 in²
- INSULATION MIN. 1" UNDER BENCH, 2" UNDER COMBUSTION UNIT
- EARTHEN MASONRY 4" AROUND METAL COMPONENTS (TO HANDLE HEAT EXP.)

OTHER NOTES:

- 4" AIR GAPS ALLOW AIR FLOW TO COOL FLOOR. FACING ROCK SHOULD ALLOW VACUUM HOSE INTO CHANNEL FOR CLEANING.
- FIRECLAY-STABILIZED PERLITE MINIMUM 1" AFTER COMPACTION

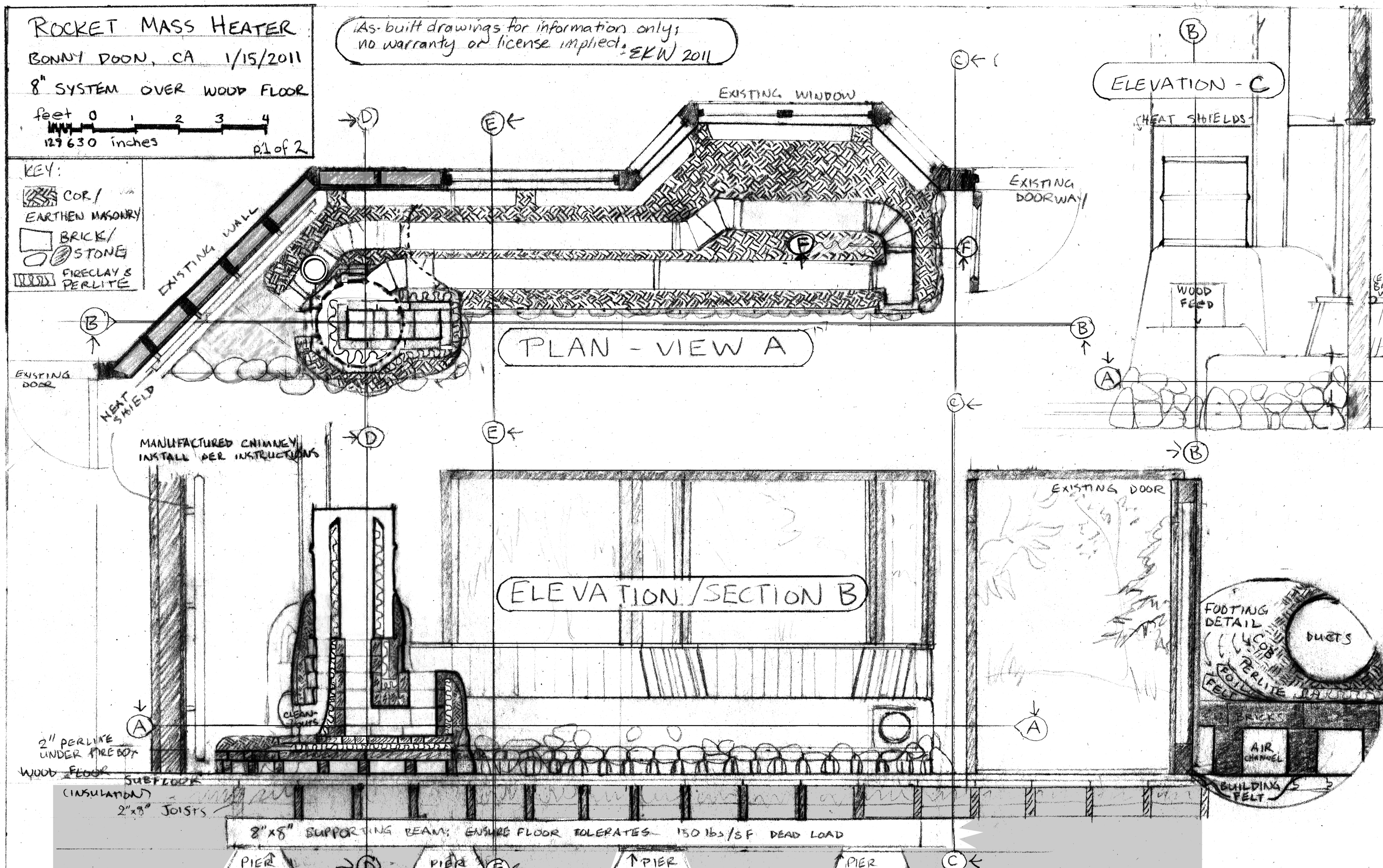


SECTION - F



DETAIL-SECTION E

AS-BUILT DRAWINGS FOR INFORMATION ONLY, NO WARRANTY OR LICENSE IMPLIED.
FOR MORE INFORMATION, SEE *ROCKET MASS HEATERS* (EVANS/JACKSON).



ROCKET MASS HEATER
BONNY DOON, CA 1/15/2011
8" SYSTEM OVER WOOD FLOOR
feet 0 1 2 3 4
12 9 6 3 0 inches
p.1 of 2
KEY:
COB/ EARTHEN MASONRY
BRICK/ STONE
FIRECLAY & PERLITE
As-built drawings for information only; no warranty or license implied. EKW 2011
EXISTING WINDOW
EXISTING DOORWAY
EXISTING WALL
EXISTING DOOR
HEAT SHIELD
PLAN - VIEW A
ELEVATION - C
HEAT SHIELDS
WOOD FEED
EXISTING BAY WINDOW
MANUFACTURED CHIMNEY INSTALL PER INSTRUCTIONS
ELEVATION / SECTION B
EXISTING DOOR
CLEAN-OUTS
2" PERLITE UNDER FIREBOX
WOOD FLOOR
SUBFLOOR
(INSULATION)
2"x8" JOISTS
8"x8" SUPPORTING BEAM; ENSURE FLOOR TOLERATES 150 lbs/SF DEAD LOAD
PIER
PIER
PIER
PIER
FOOTING DETAIL
DUCTS
COB
PERLITE
FOIL
FELT
BRICKS
AIR CHANNEL
BUILDING FELT