City of Portland, Oregon
Bureau of Development Services
FROM CONCEPT TO CONSTRUCTION

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To: **Joshua Klyber**

From: **Alternative Technology Advisory Committee:**

Edward Vranizan (chair)	Samir Mokashi (vice-chair)	Aron Faegre
Ron Hays	Kathy Bash	Joshua Klyber (recused)

RE: **Application #09-002 – Final Recommendation**

Date: **January 29, 2013**

Summary of Proposal:

The applicants have requested that the committee review a general proposal for Rocket Mass Heaters which are site-built, high-efficiency, wood-burning heaters constructed from thermal cob. The applicants would like to help those interested in constructing rocket mass heaters in their homes do so in a way that is legally permitted. These heaters are becoming increasingly popular and have previously been constructed without permits.

Applicable Building Code Section(s): 2011 Oregon Residential Specialty Code, Section R1002 and 2010 Oregon Structural Specialty Code, Section 2112.

Committee Findings:

1. Rocket Mass Heaters (RMH) are similar in many ways to Masonry Heaters (MH) which are regulated under Section R1002 of the Oregon Residential Specialty Code and Section 2112 of the Oregon Structural Specialty Code and the prescriptive requirements of ASTM E 1602. RMH are not regulated under any recognized codes or standards.

2. Both RMH and MH use masonry mass to absorb and store heat from hot gasses routed through internal heat exchange channels downstream of the firebox, and then radiate the stored heat into the room. The key differences between the two are:
   a) RMH are constructed using earthen masonry (cob), mixed and formed from local materials on site and recycled 55 gallon drum and steel ducting. MH are constructed of concrete or pre-made solid masonry units.
   b) Fuel wood is inserted at the top of a vertical feed tube where it burns on its own coals in a RMH. MH's the fuel wood is inserted into the front of the unit.
   c) Combustion tube configuration allows for high-temperature fuel burning and creates a pressure gradient which pushes smoke-free hot gasses through the heat-exchange ducting.

3. Equivalent safety for the RMH are based on applying similar code requirements for through-wall penetrations, foundation, masonry thicknesses and clearance to combustibles as prescribed for MH; and clearance from hot metal surfaces are based on code requirements for woodstoves. As with masonry heaters built on-site, Rocket Mass Heaters would be constructed by or under the supervision of a skilled and experienced RMH builder. (See ASTM E 1602.)

4. The proposal provides a standard for construction of Rocket Mass Heaters which, if approved by the authority having jurisdiction, can be used to review building permit applications and obtain inspection approvals.

Final Committee Recommendation:

Based on these findings the Alternative Technology Advisory Committee recommends approval of this technology.

Please note: The Bureau of Development Services and the Administrative Appeal Board is not bound by the recommendations of the Committee. A favorable recommendation of a technology by the Committee does not guarantee approval of a building code appeal.

Further instructions for the applicant:

You may submit your building code appeal to use this technology in a site-specific project at any time by following the instructions found on the BDS website. A building code appeal must be approved by BDS to be able to use this technology in a project. Please submit a copy of this committee recommendation with your appeal application. Please contact the Appeal Board Secretary at (503) 823-7335 if you have any additional questions about the appeal process.

City of Portland, Oregon
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Alternative Technology Advisory Committee Application Form

For information about the Alternative Technology Advisory Committee, instructions, and submittal requirements please see our web site at www.portlandonline.com/bds/atac

Applicant Information:

Name: Joshua Klyber **Company Name: Code Unlimited**
Email Address: JoshuaKlyber@CodeUL.com
Address: 12655 SW Center Street, Suite 350
City: Beaverton **State: OR Zip Code: 97255**
Phone No.: (503)488.5651 **FAX No.: ( )**

Project Information:

This application involves (check one):

XXX A technology not associated with a specific project
A specific project currently under review
Project Address:
Tax Account number:
Building Permit No.:
LU Case No (if applicable):
Other (specify):

I. Overview of Technology

A. Proposed Technology: Please describe the material/product/construction method you would like to have reviewed by the committee

Rocket Mass Heater: a type of wood-fired heating device. Similar to a Masonry Heater.

Key differences: the Rocket Mass Heater uses:

- Insulated J-tube combustion chamber, which creates an internal draft cell (heat riser followed by pressure-drop radiant heat barrel). This allows complete combustion, and provides the draft to send clean, smoke-free flue gas onward to heat-exchange ducting in a masonry thermal mass.

- Earthen Masonry (thermal cob / earthen mortar core, structural cob skin) is preferred for comfort, heat transfer, non-toxic, low-embodied energy, and low-maintenance heat storage.

- Vertical Wood Feed: Small to medium wood is fed into a vertical "feed tube," where it burns on its own coals. Generally, a Rocket Mass Heater is fired for 2-4 hours per session, in the evening, and once again in the morning if additional heat is desired. This is not quite a "batch burn," but is more like masonry heater firing schedules than woodstove or fireplace heating.

- Linear / Pressure Gradient Configuration: European masonry heaters' (and fireplaces) internal voids are often configured as a "cone," with cooling gases channeled down flues of diminishing cross-sectional area. A Rocket Mass Heater is generally built to a single cross-sectional dimension. Thus, a "6-inch system" is built to the equivalent cross-sectional area of its 6" diameter heat-exchange ducting. Themosiphoning (the "pump" effect) is created by an insulated heat-riser with the same system internal cross-sectional area, followed by a large-volume cool-down area inside the radiant heat barrel and/or manifold. This combination of hot stack and cooling, low-pressure cylinder creates a contained "convection cell" that maintains draft without further chimneys, and can serve to "push" flue gas along horizontal pipes over distances of 30-60 feet or more.

See attached PDF diagrams (excerpts from *Rocket Mass Heaters* book) for details. The book, *Rocket Mass Heaters: Super-Efficient Woodstoves YOU can build*, by Ianto Evans and Leslie Jackson, is available as a PDF download at www.rocketstoves.com, or by mail-order from Cob Cottage Company, PO Box 942, Coquille, OR 97423

B. Application of Technology: Please describe the specific application of the technology. How, when and where will this technology be used?

The Rocket Mass Heater is designed for interior heating. It can also be used for emergency heating, cooking, and outdoor or greenhouse warming.

- It serves as a personal warming device (thermal storage is usually designed as a bench, bed, or wall), or as part of a home-heating system.

- It can also serve as a cooking device: depending on design, temperatures at the hottest part of the barrel may be adequate to boil water or perform simple cooking operations. This is usually a secondary benefit, not primary use.

- It can be installed in earthen and other masonry buildings, straw-bale, or wood-framed homes, and almost any structure, with adequate fireproofing and foundations. Appropriate precautions should be taken against damp, such as a dry masonry foundation and breathable plasters.

C. Code Conflicts: Please describe any known building code issues related to this technology.

The original design of Rocket Mass Heaters calls for all natural and recycled materials. This is a key aspect of its developers' dedication to resource-efficient, safe, and sustainable building practices. It also keeps down the cost, an essential element in encouraging its adoption by building owners, with resulting benefits for a resilient, locally- and renewably- fueled, and smoke-free city.

Code officials would likely want to consider the following aspects, and whether they can be approved for Portland buildings.

– Most of the considerations in building a Rocket Mass Heater are similar to other Masonry Heaters or masonry walls. Is a Rocket Mass Heater (RMH) considered a type of Masonry Heater?

– Vertical Fuel Feed: This distinction may not matter, but it has confused some building officials. Is a RMH's vertical wood feed considered a fireplace, batch-burn, furnace, 'masonry stove,' or its own special system?

- Earthen Masonry: *Rocket Mass Heaters* (*RMH book*) calls for 2-3" of "thermal cob" (sand-clay mortar) around the heat-exchange ducting. The rest the mass provided by a combination of masonry rubble and "structural cob" (sand, clay, and straw, in hand-tested proportions). Is 2-3" of thermal cob (without cracks or gaps), formed in place around a metal flue liner, and reinforced with structural cob to 4-5" total depth, an acceptable masonry flue?

  Cob is an ancient, well-developed, earthen masonry technique, particularly suited to Rocket Mass Heater design because it is monolithic (without running cracks or gaps). Is earthen masonry, specifically "Oregon Cob" (prepared on-site in small, hand-tested batches), considered suitable masonry material for fire, earthquake, sanitation, and life safety?

- Heat-Exchange Ducting and Barrel: The *RMH* book calls for recycled steel ducting and a 55-gallon metal drum or similar barrel, in good condition (no holes or big rusty defects). The ducting is completely lined with "thermal cob" or clay-sand mortar, and the barrel is seated in mortar to a depth of 2-4". Is this an allowable alternative to conventional ceramic-lined or stovepipe flue gas channels? (Flue-gas exhaust temperatures are generally around 110 degrees F, similar to flue gas or a dryer vent.) Do building codes specify a minimum thickness for the steel barrel, or any similar device that might be used to channel hot flue gas from a combustion device toward exhaust ducts?

- Masonry Thickness and Clearances: Some Masonry Heater codes call for an 8" minimum thickness of masonry between the internal void-liner and the exterior surfaces. 8" is also a reasonable minimum thickness for surrounding the combustion area on a rocket stove. But parts of the heat-exchanger area may need a thinner layer (3-5") in order to reach comfortable surface temperatures on a typical firing cycle.

  Can the thickness of earthen masonry in the heat exchange unit be left to builders' discretion, or reduced to a minimum of 3-4", with 8" minimum around the combustion unit?

- Horizontal Mass (not vertical masonry chimney): Foundation codes for masonry heaters are designed to support massive vertical masonry chimneys. The earthquake hazard presented by a freestanding vertical column is much greater than the hazard presented by a low, horizontal mass. The horizontal mass spreads the dead load, with fewer pounds per square foot. Can the earthen mass heat-exchanger be treated as an adobe sculpture, slab, or freestanding wall, for load calculation and reinforcement?

- Clearances to Combustibles: The Rocket Mass Heater is designed to produce radiant heat at the barrel, plus contact heat at the thermal mass. Clearances to combustibles should be maintained around the radiant heat barrel; it can reach several hundred degrees (200-400 degrees F). However, the thermal mass heater and exhaust generally stay below 100-120 degrees F. Most users like to place cushions or bedding directly on the thermal mass. Users have never reported any problems with fabric flammability, though obviously, delicate low- temperature synthetic fabrics are not advisable. (Minor melting or sintering has been reported under extreme heating conditions.) Can suitable fabrics be allowed for comfort and convenience, provided clearances are maintained to the radiant heat barrel itself?

Most users also prefer to locate this built-in bench next to a wall, with sufficient insulation to prevent heat loss. Can 1-2" of masonry insulation (refractory insulation, Perlite, or similar material) be considered sufficient for protection of wood-framed walls, with a small "wing wall" of cob sealing the gap to prevent insulation loss?

- Horizontal Exhaust: For maximum heat storage efficiency, a Rocket Mass Heater pulls all residual heat from flue gas, and the gas exits at 60-90 degrees F. (This has been done, and reported by builders in various areas.) At this temperature, flue gas is too dense to rise in most conditions. The system needs a horizontal exhaust instead, to allow flue gas to exit safely at lower temperatures. Can horizontal exhausts be allowed? (with sufficient protection from wind and vermin, and at sufficient distance from any neighboring air intakes?)

II. Sustainability

A. <u>Sustainable Elements</u>: Describe how this alternative substantially reduces the environmental impact on the planet over similar technologies currently allowed by the code? ***Please attach any documentation that supports your answer.***

- Clean burning. Avoids air-quality, health and nuisance problems associated with woodsmoke.
- Efficient. Uses a fraction of a cord of wood to heat a small dwelling all winter, with complete combustion and multi-hour (sometimes multi-day) storage of heat.
- Locally renewable biofuels. Can be fueled sustainably from about a ¼ acre backyard woodlot (orchard trimmings, construction wastes, coppiced nut or fruit trees, arbor wastes).
- All natural and recycled materials. Construction involves far less embodied energy than other existing technologies.
- Non-toxic: Substantially less hazardous for builders and homeowners than conventional masonry insulators, paints, and furnace cements. Recycled metals must be cleaned and handled in a responsible manner, and ordinary precautions should be taken with any silica dust or alkaline mortars.
- Can be rebuilt, modified, recycled, and re-used: cob and plasters can be re-used or composted. Metal components can be recycled following useful life. Repairs generally can be done by remixing existing materials. There is little construction waste beyond wear and tear on buckets, shovels, trowels, and tarps.

Clean & Efficient: Documentation is largely anecdotal, but impressive. Examples in use are available for testing, and specific recommendations for further tests are welcome.

- No smoke (except for 2-3 minutes at start and end of burn session). DEQ inspectors and trained smoke-readers have admired the particulate-free, clear gas or white fog produced by working rocket mass heaters. There is rarely a smell of smoke, only a slight odor of damp charcoal, which one smoke-reader identified as a 9-methyl ketone (the last organic molecule to crack in a hot fire). Currently seeking written testimony, or suggestions for on-site testing.

- Substantially reduced fuel loads; rural users report using 1/4 to 2/3 cord to heat a home previously requiring 4-5 cords per winter. In our experience, less than 1 cu ft (about 5 lbs) might be burned for a 2-4 hour session in a 6" system. An 8" system can burn slightly more, up to 1.5 cu ft. per 3-hour burn session.

- Temperatures inside combustion chamber, specifically at the top of the heat riser, have been estimated at 1500-1800 degrees F based on slumping of metallic components in test beds. This temperature range allows complete combustion of wood and smoke/wood-gas.

- Temperatures of exhaust typically measure at 90-110 degrees F. This is comparable to a dryer vent. The difference in temperature represents heat captured and retained inside the building.

- Provides overnight heat, without the smoke associated with "airtight" woodstoves. (Any woodstove can be burned clean, if it is provided with the right mix of air and fuel at a high enough temperature. But most users want long-term, low-temperature heat. So they resort to "damping down" or "banking" the fire (reducing airflow): attempting to create a smoldering, smoky, one-log-lasts-all-night fire. Masonry heaters avoid this problem by providing convenient 8- to 24-hour heat retention from a brief, clean fire.)

B. Reason for Alternative: Describe why this alternative is desired?

- Comfort: a heated bench or floor is amazingly comfortable. A person gets warmer, faster, by direct contact with the heat source than by radiant or convective (air) heat.

- Efficiency: heats the body more effectively, uses less wood, takes less time to operate than most other wood-burning heaters.

- Cost: materials and fuel are less expensive than conventional alternatives. By sourcing recycled scrap metal, a heater can be built for under $100. All-new materials bring the cost up to around $3000, still substantially less than the commercial masonry heater 'kits'. We hope to provide an officially-approved building path that maintains the affordable nature of this technology.

- Clean air: avoids adding to particulate emissions, reduces conflicts with neighbors, avoids creating health problems for asthmatics and others vulnerable to respiratory problems; maintains urban air quality. Once smokeless exhaust has been proven in tests, we hope this heater can be approved for use even in stagnant air conditions.

- DIY: many rocket stoves are owner-built. Earthen Masonry is user-friendly, non-toxic, locally available, and (a key difference from concrete) can be modified after installation if the owner's design does not perform as expected.

- Emergency /security option: Provides heat and basic cooking / boiled water in case of power failure or other emergencies. Not dependent on city infrastructure or international fuel trade. Can be repaired on-site in the event of earthquake damage.

By developing a permit process for Rocket Mass Heaters, we hope to create opportunities for local contractors and homeowners to choose a much cleaner, more efficient, locally-fueled, safe, insurable, and affordable home heating alternative.

C. Comparison to Other Technologies: How does this technology provide equivalent life safety and/or fire protection than the current technologies allowed by the code?

- Fire Protection: Safer than a woodstove or fireplace. Fire is contained within masonry. Brick or firebrick, lime mortar, nonflammable insulation, and unbroken metal line the flame and flue-gas paths and prevent accidental contact or ignition. This entire, sealed gas-flue system is then surrounded in non-flammable earthen masonry to a depth of 4-8", sometimes with additional, nonflammable decorative plasters around that.

  To burn oneself on this heater, a person would have to touch and hold the hottest part of the metal barrel for an appreciable amount of time, or insert a hand more than 6" into the wood feed to reach glowing embers. It is almost impossible for a person to “fall into” the fire or hot surfaces, or for the fire to “fall out of” the feed tube or combustion chamber.

- Thru-wall connections, foundations, masonry thicknesses, and clearances to combustibles can be based on comparable elements in established masonry heater code, with reference to woodstove clearances for the hot metal surfaces. Exposed metal surfaces are generally cooler than comparable metal surfaces in woodstoves or chimneys; exposed masonry surfaces are generally about the same temperature as a warm clothes-dryer or masonry heater.

- As with any wood-fired device, the operator of a Rocket Stove should not leave it unattended while burning. Once lit, the attention required is similar to that needed for a candle or oil lamp (check periodically for flare-ups or fuel settling), and far less attention than is needed for a fireplace. A lid may be provided which regulates airflow, or allows emergency shutoff, somewhat like a modern woodstove. But the best way is to keep the fuel feed full, and watch the stove, during its brief evening burn.

- Smoke / Flue Gas protection: Steel liners are used to convey flue gases safely out of building envelope. Flue gas is substantially cleaner than other wood-burning devices, and may be comparable to natural-gas or fuel-oil devices.

- Some users report “Smokeback” from the fuel feed. Smokeback may indicate inadequate draft, obstruction of firebox or ducting, failure to pre-warm the draft zone, or improper loading of fuel. Smokeback can be prevented by monitoring fuel and air feeds, and by partially or completely closing the air flow lid. Some rocket stove builders also install a secondary draft device, such as a chimney warmer or forced-vent fan.

- Life Safety:

  - Difficult or impossible to accidentally contact fire; children cannot easily "fall into" or "play with" fire.

  - Low, comfortable, continuous temperatures are provided. Barrel is only source of high-temperature radiant heat, and tends to be comparable to or cooler than conventional woodstoves.

  - Non-toxic materials and fuels.

  - Little or no environmental impact: can be operated carbon-neutral when on-site wood fuels are sustainably harvested. (A windstorm on our street typically drops about a winter's worth of firewood.)

  - Seismic safety: low center of gravity means thermal mass can't fall onto people or threaten building integrity. Historic cob buildings generally perform better in earthquakes than historic adobe or fired-brick masonry.

    Proper cob technique creates strong, durable masonry mass. (Proper cob technique includes hand-tested batches of masonry sand and clay subsoils. Straw should be included for tensile reinforcement, only in outer 2" of sculpted mass. Earthen masonry can be finished with rounded or reinforced corners for better wear. And like any masonry mass, earthen masonry needs adequate foundations to support its weight.)

III. Supporting Documentation

<u>A. Testing Data</u>: Describe any testing that has been performed on this technology to show how it may be able to meet code requirements. ***Please attach all available testing data.***

Anecdotal / owners and experimenters:
Temperature / Time:
[Call Ianto for temperature reports on longest-running Oregon stoves]

Wood Combustion: Ash test:

Ernie Wisner and Ron Wisner conducted a comparison between their two home heating devices, using comparably dry, mixed hardwoods and softwoods:

- a 6" rocket stove burned 57 lbs of wood and produced 7 oz. of white ash

- a conventional woodstove burned 57 lbs of wood and produced 12 oz. of grey ash. (2008-9)

Ernie Wisner, Kirk Mobert, and the research team at Cob Cottage Company observed slumping or melting on the top 2" of a mild steel tube they used for a heat riser in test beds, indicating temperatures of over 1800 degrees F. (c. 2006)

Fire Resistance and Strength: Earthen Plasters

Earthen Plasters are typically used with cob, straw-bale, timber-frame, and other structures where low-embodied-energy, vapor-permeable techniques are desired. They are vapor-permeable, but seal out liquid water.

Fire-resistance tests and strength tests were conducted on earthen masonry samples in conjunction with Straw Bale wall systems by a number of organizations. Results include:

Compressive test done in-house by Odisea Civil Engineering, an earthen building group: compressive failure of their earthen finish plaster (composed of mostly crusher fines, with some added clay, wheat paste, and cow dung; no straw) at approx. 215 PSI. http://www.odiseanet.com/eplaster.htm

Straw seems to enhance strength: see Bruce King's engineering pages at www.ecobuildingnetwork.org.

Fire-resistance, shear, compressive, and erosion tests on earthen plasters (for use with straw-bale wall systems) have been published by Bruce King at http://www.ecobuildnetwork.org/strawbale.htm

Another study on strength of earthen plasters, this time by a Canadian building research team:

> "This study investigated the importance of initial plaster moisture content, drying time, clay content and, moisture content at the time of testing. Clayey silt soil, bagged ball clay and lime-cement are compared as plaster binders for straw-bale applications. Compressive testing was conducted on 50-mm plaster cubes and 100-mm by 200-mm plaster cylinders. It was found that as initial moisture content increased, strength and modulus of elasticity was unaffected for the earthen plaster. As the drying time increased between 10 days and 18 days, strength was unaffected but modulus of elasticity increased proportionally. As clay content increased, strength increased proportionally and stiffness was unaffected. As moisture content at the time of testing increased, both the strength and the stiffness decreased proportionally. Plaster made with soil was found to have greater strength than the plaster made with bagged clay or lime-cement plaster. "
>
> http://www.springerlink.com/content/v2617u3114653136/
> abstract from study published in "Advances in Engineering Structures, Mechanics, and Applications," published by Springer-Netherlands in 2006, volume 140 of "Solid Mechanics and Its Applications," ISSN # 0925-0042
> Study by: Brendon Taylor[5], Stephen Vardy[5] and Colin MacDougall[5]
> Department of Civil Engineering, Queen's University, Kingston, Ontario, Canada

An article on Cob and Building Code appeared in the ICBO's *Building Standards* magazine, in the January-February 2000 issue, pp. 33-35, and is reproduced here: http://www.dcat.net/resources/buildingstandards_cob_articles.pdf

> It called for an introduction of cob into building code, and pointed out that as a non-proprietary material, there is no obvious way to fund the tests required for such an undertaking.   Cob and clay-straw out-perform wood on strength, longevity, fire-resistance.

Some thoughts on code considerations for Cob, Adobe, and other Earthen Building Systems:

Fred Webster, PhD:
http://www.deatech.com/natural/cobinfo/adobe.html

An ambitious proposal for cob testing, posted by John Fordice of Other Fish Architect:
http://www.deatech.com/natural/cobinfo/cobcode.html

Among other quotes, "Fred [Webster] estimates that an approximate material strength of 30 psi will be what is needed to meet Zone 4 seismic strength requirements... Bob [Bruce] estimates a material strength of appx. 10 psi may be what is needed to resist an eight Richter earthquake (Zone 4 maximum). ... "

The experts disagree, but fortunately test data on earthen plasters (100's of psi) suggests earthen masonry's strength far exceeds the suggested minima (10's of psi).

For only NZ$399, you can obtain a set of 3 Earthen Building Codes (Engineering, Methods, and Non-Engineered Buildings, documents 4297, 4298, and 4299) from the New Zealand Standards organization. These cover adobe, pressed brick, poured earth, and rammed earth. http://www.standards.co.nz/ For $444, we can get an online library subscription, which can be used by 1 concurrent user (probably as many people as are likely to read it at once on this project). I vaguely recall a traveling cobber saying that NZ's poured earth is very similar to Oregon cob.

B. History of Use: Describe all known instances where this technology has been applied to a constructed building, including approximate date, location and building type. ***Please attach any documentation that supports your answer.***

Cob Cottage Company, Coquille Oregon:

Experimenters built over 400 test-bed stoves, 1970's to 2006, to determine operating parameters and dimensions for publication in the book, *RMH*.
Approximately 7 full-scale installations remain on site, in small cob cottages or teaching facilities.
Sizes range from 4" diameter (fringe operating parameter) to 10". Building sizes

range from a tiny office, approx. 12' x 8' oval cob building (6" system with about 20 feet of heat-exchanger) to a 2-story loft apartment (8" system, approx. 40 feet of heat-exchanger with horizontal exhaust).

The longest-installed Rocket Mass Heater at this site is the Myrtle bench, which is an 8/7" system with approx. 35 feet of heat-exchanger, horizontal exhaust with an external stovepipe chimney, about 15 years old.

These stoves are not officially permitted. One visiting inspector suggested they could be exempted, either as cooking devices, or on the grounds that the buildings are mainly teaching facilities, not dwellings.

Heart House, Cottage Grove, Oregon:
This 8" Rocket Mass Heater in a cob cottage is approximately 20 years old. Current condition unknown.

Tryon Life Community Farm, Portland Oregon:
an 8" Rocket Mass Heater was constructed in 2006 as part of a demonstration outdoor kitchen. A larger roof has since been added. This heater was initially proposed for indoor heating of a nearby residence, but built outdoors instead to avoid permitting and design hassles.

Fox Circle Farm, Bay Area, California:
an 8" Rocket Mass Heater was built in 2007 in a converted garage/office, stick-frame and concrete slab floor, in a cool redwood valley. It operated successfully for 6 months, following which the property was sold. Current condition unknown.

Dana Annex, Portland, Oregon:
a 6" Rocket Mass Heater was built under a Woodstove / Mechanical permit, winter 2008-9, permit status remains undetermined. Winter test-firings successful.

Photo documentation is available of Rocket Mass Heaters in Georgia, Canada, and northern Europe. Buildings include conventional homes, cob and masonry houses, and industrial applications such as a wood-drying kiln or furnace.

Many other Rocket Mass Heaters have been built and described by owners across North America, Europe, and alpine Africa and South America. See www.rocketstoves.com for downloadable copies of the book, *Rocket Mass Heaters,* which describes the stoves and includes case studies.

Responsibility Statement:

As the applicant submitting this application I am responsible for the accuracy of the information submitted. I have submitted all the relevant information available about the technology I am requesting the Alternative Technology Advisory Committee to review. I believe the information submitted to be a complete and accurate representation of the proposed technology and I am aware that any omission (either voluntary of accidental) could cause the application to be denied. I understand that more information may be requested before the committee can make a recommendation on my application.

I understand that the recommendation from the committee is not binding. In addition a favorable recommendation from the committee is not a guarantee that the Administrative Appeals Board will approve a subsequent building code appeal. The City of Portland and the committee members have no implied or expressed liability associated with the conclusions of the Alternative Technology Advisory Committee. By my signature, I indicate my understanding and agreement to the Responsibility Statement.

Applicant's signature: **Date:**

Electronic signature: Erica K Wisner, 6/20/2009
Joshua J Klyber 12.19.12 **Date:**

Property owner's signature (if applicable):

For Office Use Only:
Received By: Date Received: Receipt No.:

Rocket Mass Heaters

A Guide to site constructed Rocket Mass Heaters

Authored by:
Joshua Klyber, Code Unlimited
Ernie Wisner, ErnieAndErica.com
Erica Wisner, ErnieAndErica.com
12.28.12

1. Scope:

1.1 This guide covers the design and construction of Rocket Mass Heaters, a subset of solid fuel burning masonry heaters. It provides dimensions for site constructed rocket mass heaters and clearances that have been derived by experience and found to be consistent with safe installation of those rocket mass heaters.

1.2 Values given are in English measurements, and are regarded to be standard. All dimensions are nominal unless specifically stated otherwise. All clearances listed in this guide are actual dimensions.

2. Definitions:

2.1 Combustion unit: The area where fuel is consumed and clean exhaust produced; comprising the fuel feed, burn tunnel, heat riser, barrel, and the manifold.

2.2 Combustion unit base: Area composed of the fuel feed, ash pit, burn tunnel, insulation and casing.

2.3 Fuel/air feed: Area where fire is lit and fuel is added. This is the sole air intake.

2.4 Ash pit: Optional depression located at bottom of fuel air feed and/or manifold.

2.5 Burn tunnel: Horizontal area where initial combustion occurs.

2.6 Heat riser: Internal chimney, insulated for high-temperature combustion and draft.

2.7 Barrel: Metal or masonry envelope around the heat riser that radiates heat.

2.8 Manifold: The connection between the combustion unit and the heat-exchange ducting.

2.9 Heat-exchanger: The volume of mass that absorbs heat from the heat exchange ducting and re-radiates it over an extended period of time. Comprised of the heat exchange ducting, thermal core and casing.

2.10 Heat exchange ducting: The flues that carry hot exhaust gas through the thermal mass.

2.11 Thermal core: Area directly around heat exchange ducting.

2.12 Flue exhaust: The portion of the ducting after it leaves the thermal core.

2.13 Casing: Durable external layers to protect thermal core, provide additional thermal mass, maintain desired surface temperature, and allow decorative expression.

2.14 Cleanout: Capped opening for maintenance access.

2.15 Damper: A duct valve that regulates airflow.

2.16 Make up air: Air that is provided to replace air that is exhausted.

2.17 Combustion air: The air provided to fuel burning equipment for fuel combustion.

3. Guidance and use:

3.1 This guide can be used by code officials, architects and other interested parties to evaluate the design and construction of rocket mass heaters. It is not restricted to a specific method of construction, nor does it provide the principles to be followed for the safe construction of rocket mass heaters.

3.2 This guide is not intended as a complete set of directions for construction of rocket mass heaters.

3.3 Construction of rocket mass heaters is complex, and in order to ensure their safety and performance, construction shall be done by or under the supervision of a skilled and experienced rocket mass heater builder.

4. Requirements:

4.1 Sizing:

4.1.1 6" flue rocket mass heaters can be installed for any heated space 1000 sq. ft. or less.

4.1.2 8" flue rocket mass heaters are typical and appropriate for any installation.

4.1.3 Cross sectional area shall remain consistent throughout the system except in the barrel and manifold, where it may be larger.

4.1.4 Ducting may be tapered to reduce diameter by 30-40% in the final third of its length to improve gas flow.

4.2 Foundation: The combustion unit base and heat exchanger shall be supported by a concrete slab or equivalent. Any alternative configurations or foundations shall be engineered.

4.3 Combustion unit: Shall be constructed in either earthen masonry or refractory materials. If refractory materials are used, an expansion joint shall be included between combustion unit and earthen masonry.

4.3.1 Mortars, when used, shall be clay-sand, fire clay or suitable refractory mortar. Mortars may be omitted if using monolithic earthen masonry as an external seal.

4.3.2 Fuel feed:

4.3.2.1 Shall be constructed of dense firebrick, clay brick or equivalent refractory material able to withstand 2200˚ F.

4.3.2.2 Shall have a closure that serves as an emergency shut down lid.

4.3.2.3 Shall be the sole air intake.

4.3.3 Ash pit:

4.3.3.1 If included, shall be located at bottom of fuel feed.

4.3.3.2 Shall be of a depth no greater than 4” below the burn tunnel.

4.3.4 Burn tunnel:

4.3.4.1 Shall be constructed of dense firebrick, clay brick or equivalent refractory material able to withstand 2200˚ F.

4.3.4.2 Shall be insulated with 2" of clay-perlite insulation or equivalent underneath, above, and on all sides except the fuel feed and heat riser openings.

4.3.5 Heat riser:

4.3.5.1 Shall have a minimum height of twice the burn tunnel length.

4.3.5.2 Shall be at least three times the height of the fuel feed.

4.3.5.3 Shall be constructed of firebrick, clay brick, metal flue or equivalent refractory material able to withstand 2200˚ F.

4.3.5.4 If constructed of metal flue, it shall be free from holes, wrinkles, burrs, jagged edges or other obstructions. Metal shall be high-temperature stovepipe or steel.

4.3.5.5 Shall be insulated with minimum of 2" (or the maximum amount that does not restrict airflow) of clay-perlite insulation or equivalent.

4.3.6 Barrel:

4.3.6.1 Shall be free from holes, wrinkles, burrs, jagged edges or other defects.

4.3.6.2 Any existing paint or surface coatings shall be removed. High-temperature coatings rated for woodstove application such as stove enamel, cast-iron seasoning oils may be used.

4.3.6.3 A cleanout shall be located near the base of the barrel that allows access to the manifold and initial ducting, or the barrel shall be configured for removal.

4.4 Heat exchanger:

4.4.1 When the heat exchanger mass is made of earthen masonry it shall rest on a stabilized masonry base with a minimum height of 2 inches.

4.4.2 Ash pit: If included, shall be located directly below the manifold and within easy access of the cleanout.

4.4.3 Ducting:

4.4.3.1 Shall be metal flue, ceramic flue liner, well-pointed brick, earthen block, or equivalent alternative. Metal flue shall be free from holes, wrinkles, burrs, jagged edges or other defects. Metal flue shall be at least 26 gauge.

4.4.3.2 Shall be embedded in a continuous layer of earthen masonry for both thermal contact and gas seal.

4.4.4 Cleanouts:

4.4.4.1 Shall have a sufficient number of cleanouts such that all sections of the ducting shall be accessible.

4.4.4.2 Cleanouts shall be the same minimum size as system: e.g. 6" diameter for a 6" flue rocket mass heater and 8" for an 8" flue rocket mass heater.

4.4.5 Thermal core shall be encased with a minimum of 2" thermal earthen masonry around the ducting.

4.4.6 Casing:

4.4.6.1 Total thickness to surface from ducting, for a 6" system shall be at least 4" depth around the first 10 feet of ducting, and 3 inches around the remainder.

4.4.6.2 Total thickness to surface from ducting, for a 8" system shall be at least 6" depth around the first 10 feet of ducting, and 4 inches around the remainder.

4.5 Flue exhaust:

4.5.1 Shall be composed of metal flue, clay flue lining or equivalent.

4.5.2 Shall be equipped with a ferrous metal damper and shall be operable from the same room as the rocket mass heater

4.5.3 Shall have a flue priming port or other means to ensure proper drafting.

4.5.4 Exhaust termination:

4.5.4.1 Exhaust termination shall be at least 2’ higher than any portion of a building within 10’.

4.5.4.2 Exhaust termination shall be protected from precipitation and vermin.

4.6 Make-up air:

4.6.1 Rocket mass heaters shall be supplied with an exterior air supply unless the room is mechanically ventilated and controlled such that the indoor air pressure is neutral or positive.

4.6.2 Exterior air supply:

4.6.2.1 Shall be capable of supplying all combustion air from outside the dwelling or from spaces that are within the dwelling that are non-mechanically ventilated with air from outside the dwelling.

4.6.2.2 Shall be in the same room as the rocket mass heater.

4.6.2.3 Shall not be located more than 1’ above the height of the fuel feed.

4.6.2.4 Exterior air supply inlet shall be protected from precipitation and vermin.

4.6.2.5 Exterior air supply shall have a shut off valve to prevent cold air infiltration when not in use.

4.7 Clearances:

4.7.1 Fuel feed: A minimum clearance of 18" shall be maintained from combustible materials.

4.7.2 Combustion base: A minimum clearance of 4" shall be maintained from combustible materials.

4.7.3 Barrel:

4.7.3.1 A minimum clearance of 18” shall be maintained from all walls without a heat shield. A minimum clearance of 12" shall be maintained from all walls with a heat shield including 1" air gap.

4.7.3.2 A minimum clearance of 36” shall be maintained from ceiling.

4.7.4 Heat exchanger:

4.7.4.1 Minimum distance between ducting and combustible wall shall be 6".

4.7.4.2 Any fabric used on seating surfaces shall be heat tolerant.

Inspection Points:

An inspection should be performed after ducting has been installed and while it is still exposed.

Confirm measurements:

1. Proper ratio of heat riser to burn tunnel and heat riser.
   Heat riser is twice the length of the burn tunnel.
   Heat riser is three times the height of the fuel feed.
2. Confirm proper cross sectional areas.
   Consistent cross sectional area throughout system except barrel, manifold, and possible 30-40% decrease in final third of flue length.
3. Confirm clearances.
   18" from fuel feed to combustibles.
   18" from barrel to walls without heat shields.
   12" from barrel to walls with heat shields with a 1" air gap.
   36" from barrel to ceiling
   4" from combustion base to all combustibles.
   Room for sufficient masonry thickness around ducting.
4. Confirm suitable footing and foundation.
5. Confirm appropriate cleanouts.
6. Confirm presence of flue priming port or other means to ensure proper drafting.
7. Confirm exhaust flue is protected from precipitation and vermin.
8. If pressure controlled mechanical ventilation is not present, confirm exterior air supply.
   Inlet is located outside dwelling or in non-mechanical ventilated space.
   Inlet is protected against precipitation and vermin.
   Outlet is located in the same room.
   Outlet is located below fuel feed.
   Air supply has shutoff valve.
9. Confirm existence and orderliness of maintenance and operation manual.

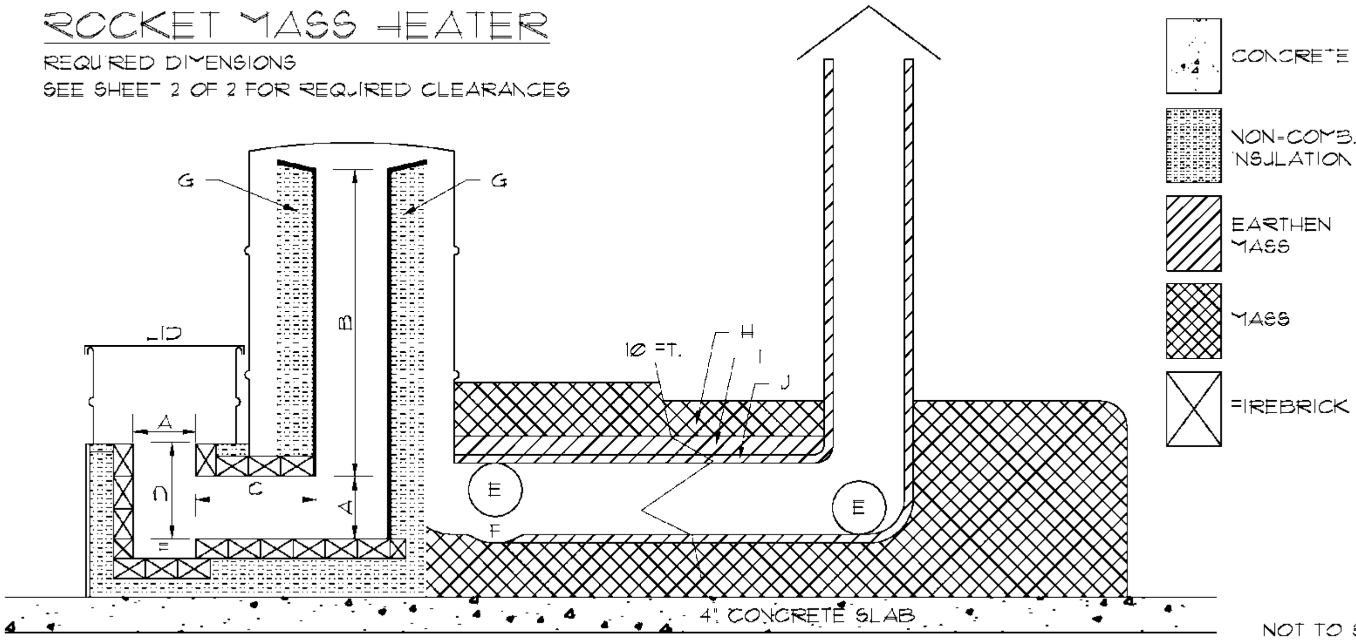
	FOR 8" FLUE	FOR 6" FLUE
A	6' X 8' OPENING	6" X 5" OPENING
B	HEAT RISER	SAME
C	BURN TUNNEL, B=2XC (MIN)	SAME
D	FUEL FEED, B=3XD (MIN)	SAME
E	CLEANOUTS (MUST BE LOCATED FOR EASY ACCESS TO ALL DUCTING)	SAME
F	OPTIONAL ASH PIT	SAME

	FOR 8" FLUE	FOR 6" FLUE
G	NON-COMBUSTIBLE INSULATION, MIN 2"	SAME
H	CONTINUOUS EARTHEN MORTAR	SAME
I	COB, 2" MIN THICK	SAME
J	CASING, 6" MIN THICK FIRST 10 FT. FROM MANIFOLD AND 4" THICK THEREAFTER	CASING, 4" MIN THICK FIRST 10 FT. FROM MANIFOLD AND 3" THICK THEREAFTER

ROCKET MASS HEATER

REQUIRED DIMENSIONS

SEE SHEET 2 OF 2 FOR REQUIRED CLEARANCES

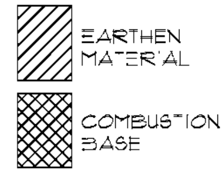


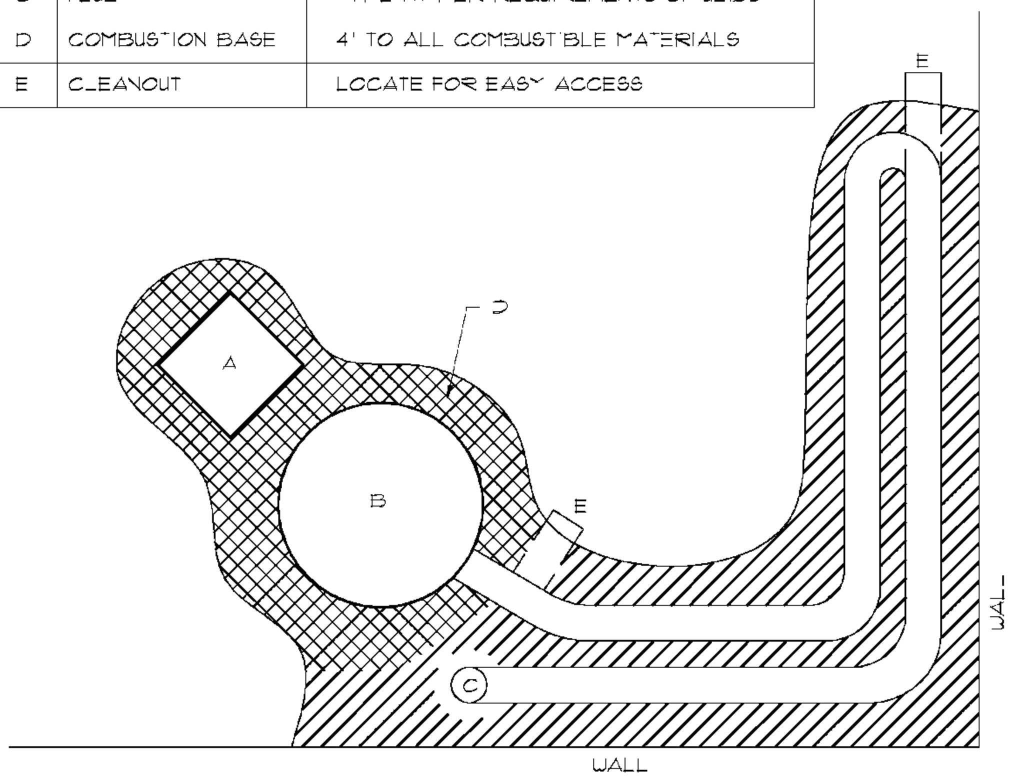
NOT TO SCALE
DECEMBER 2012
SHEET 1 OF 2

ROCKET MASS HEATER

REQUIRED CLEARANCES
SEE SHEET 1 OF 2 FOR REQUIRED DIMENSIONS

A	FUEL FEED	18' TO ALL COMBUSTIBLE MATERIALS
B	BARREL	36' TO ALL COMBUSTIBLE MATERIALS OR 18' TO HEAT SHIELD WITH 1" AIR GAP
C	FLUE	TYPE HT PER REQUIREMENTS OF UL103
D	COMBUSTION BASE	4' TO ALL COMBUSTIBLE MATERIALS
E	CLEANOUT	LOCATE FOR EASY ACCESS





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DECEMBER 2012
SHEET 2 OF 2