Masonry Heaters: Planning Guide for Architects, Home Designers and Builders.

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Preface

As a custom masonry heater and oven builder, I have to interact with architects, home designers and builders. Quite often I find that there is lack of basic knowledge about masonry heater design and construction principles that doesn't allow these construction professionals to integrate such units into building environment properly. Such lack of knowledge and information creates confusion, misunderstanding, and sometimes leads to unexpected delays and unnecessary expenses. Purpose of this guide is to provide construction industry professionals with basic knowledge and guidance that should help them with planning and proper integration of this fine sustainable technology into their work.

What is a masonry heater?

Masonry heater is essentially a highly efficient heat-retaining fireplace constructed mostly of masonry and/or ceramic materials. Hot gases generated during fast and clean combustion of a fuel load in a firebox equipped with tight-fitted firebox door, pass through series of channels or chambers, saturating masonry mass with heat. The mass then radiates heat into the area around masonry heater for the next 12 to 24 hours. As high thermal mass heat-storage devises, masonry heaters offer steady heat output with typically one to two full loads of fuel per day only. Masonry heaters are, in general, low heat output devices because amount of heat produced from a single load is distributed evenly from 12 to 24 hours. High efficiency and low emissions make masonry heaters an ideal choice for heating energy-efficient houses using renewable fuels such as wood.

A heavy masonry heater is a heating system that works best when used on everyday basis through a considerable period of time. As slow-response high thermal mass system, such masonry heater takes time and several full loads of fuel to be heated up to normal operational temperatures from the cold state and as such is not very suitable for occasional use. Applications with periodic usage such as cottages should use lighter, fast-response masonry heaters with reduced overall thickness of the walls.

Masonry heaters in North America are built in double-wall system meaning that heater has a complete refractory core containing firebox and heat exchanging channels or chambers, and a separate facing done in masonry or ceramic materials. The refractory core is built using refractory masonry units of a heater mason's choice in case of a hand-built unit, or using pre-cast refractory concrete modules in case of pre-manufactured core kit installations.

One of the main differences between open fireplaces and masonry heaters is that the latest are heating units. In contrast with purely esthetic purpose of conventional fireplaces, main purpose of masonry heaters is to provide heat in a highly efficient way. When facing walls of conventional fireplaces never get warm, walls of masonry heaters get saturated with heat and reach average surface temperatures in the range between 100-150F. This fact alone requires a very different approach. Below you will find topics that cover basic information related to masonry heater planning and construction specifics.

Proper location.

As main purpose of any masonry heater is heating, its location should be chosen to provide heat where it is needed and in the most efficient way. Masonry heaters are in fact radiant heaters that deliver most of heat by direct radiation. Therefore, maximum output is achieved when maximum surface area is exposed to the area to be heated. This is why central location is always preferred. A quite common and wise solution is locating a unit to act as a functional space divider between two large open areas such as kitchen and living room or living room and family room. Exposing one side into kitchen makes it possible to locate such functional feature as built-in bake oven (if applicable) where it will be the most convenient – in the kitchen. Depending on heater's design, it can be possible to locate its features such as glass firebox door(s), bake oven, or heated benches at the preferred faces. Although existing pre-manufactured masonry heater core kits offer some options, the greatest flexibility of design can be achieved with a custom hand-built unit. Consult you heater builder or core manufacturer to determine possible location for the preferred features.

Try to avoid locating masonry heater next to an outside wall or what is even worse – locating it in a niche in the outside wall (typical location for a conventional fireplace) if you want to keep heat inside instead of heating atmosphere outside of the building.
If location along a partition wall is preferred, keep back wall of the heater 5" away for better heat output. Heat output of a heater's wall

exposed to a partition wall or a niche can be significantly reduced despite the fact that such niche can be vented. Take a look at the following table to understand effect of such location on heat output of the particular heater's wall. **Please note that a gap of less than 4" between heater wall and a partition described in the table assumes that the partition wall is non-combustible**:

Corrective coefficients for heat output calculations		
Heater surface	Gap	Coefficient
Open	Not applicable	1.00
Facing a wall	> 5"-wide gap open from both sides	1.00
Facing a wall	from 2 3/4" to 5"-wide gap open from both sides	0.75
Facing a wall	from 2 3/4" to 5"-wide gap closed from both sides, with air grill at the bottom and open on top	0.75
Facing a wall	closed from both sides, with air grills at the bottom and top	0.50
Facing a wall	closed from sides but open on top and bottom	1.00

Source: A.E.Shkolnik "Heating buildings with Masonry Heaters", Moscow, 1986

A rule of thumb for rough estimation of heater's output says that one square foot of a heater's surface will emit about 185Btu per hour under two full loads per day firing schedule. If we have a heater wall that is facing 4"-wide niche closed from both sides with some vents at the bottom and the top, heat output of the wall will be reduced by 50% according to the above table. If this wall is 4'x8' (32 sq ft of surface), it will have heat output of 5920Btu per hour if the wall is open. In the niche described above, however, its heat output will be reduced to 2960 Btu per hour. This is how much of the possible heat output we lose with such location. Heat output of a heater's wall located right next to a non-combustible partition will be lost completely resulting in large reduction in the heater's overall heat output.

Proper sizing.

Although task of properly sizing unit should be addressed by your masonry heater builder, this chapter will give you a general idea that

will help you to estimate possible size of a unit during early planning stages.

Masonry heaters can be used as primary or as additional heat sources. Whereas sizing of a unit serving as an additional heat source is most often determined by functional preferences, aesthetic reasons or by the budget, proper sizing for a primary heating option is paramount. Masonry heater's output in this case must match projected heat loss of the area or building.

You may estimate necessary surface area for a heater using the Rule of Thumb Method mentioned in the previous chapter. For example, an area with a heat loss of 20,000Btu will need a heater with 20,000 / 185 = 108 sq ft of surface area. This is roughly a surface area of a rectangular heater with 3.5' x 4' footprint if heater's height is estimated to be 8ft. Of course, heat output depends not only on the heater's surface area, but also on the amount of fuel that is burned in the firebox in one load and number of loads per day. The firebox must be sized according to the heat load. Consult your heater builder to discuss proper sizing and to come up with a proper solution.

In most cases, 30,000Btu per hour is the upper limit for possible heat output for a single-story masonry heater. It is difficult to achieve higher heat output with standard single-story masonry heating systems. A well-designed energy-efficient house of a decent size, however, should not have heat loss higher than this number.
If considerably higher heat output is required, consider having multiple heaters, a multistory heater, or a wood-fired boiler as possible options.

Heaters can be designed as multistory units with a single larger firebox located at the lowest level, or independent units can be stacked one on top of another for complicated heating requirements. In case of stacked option, each independent unit has own firebox and chimney flue. Again, it is only your heater builder/manufacturer who can assess the situation properly and suggest a possible solution.

Please keep in mind that such options as heated benches and/or attached firewood storage should be supported on the same foundation and therefore affect overall footprint of the unit. Check with your client to see if they are interested in such features.

Efficiency vs. Aesthetics

Aesthetic considerations can influence heater design so much that it might have negative effect on efficiency and performance of the unit. It is necessary to remember that masonry heaters are heating units first and foremost. The fact that someone decides to go with a masonry heater versus ordinary open fireplace or woodstove means that they value high efficiency, low emissions and heating capabilities of masonry heaters. Therefore, our goal is to keep the unit as efficient and clean burning as possible. Remember the following quick facts while designing “look” of the heater:

- Firebox for an efficient and clean-burning masonry heater is designed to create ideal combustion environment. Firebox is sized according to the necessary load and cannot be made larger for aesthetic purposes without loosing combustion efficiency and generating higher emissions. This is the reason why masonry heaters have relatively small firebox doors. It is virtually impossible to design an efficient masonry heater with a firebox door equal to standard open fireplace opening of 24”x 32” or more. If large open fireplace is desired, consider a combination masonry heater unit that has open fireplace built-in into the heater’s mass, or consider building a separate open fireplace unit elsewhere in the room;
- Location of the heater adjacent to an outside wall lowers heat output significantly;
- Heat output may be reduced if an air gap between heater’s surface and a partition wall is narrower than 5” (refer to the table in the “Proper Location” chapter);
- For most applications, heater facing should not be thicker than 5”. Thicker facing will decrease rate of heat transfer under typical firing schedule. Surface temperatures will also decrease, and it may result in a heat transfer rate that cannot match speed of heat loss of the given area unless firing pattern is changed. Ideally, a heater should produce necessary heat at the same speed (rate), as heat is lost by the heated building/area. Find more about heater facing in the “Facing Thickness” and “Facing Considerations” paragraphs below.
- Masonry mass that has no heating channels (refractory core) behind, such as shelves or wood storage will act as heat-absorbing screen catching most of the heat before it gets into the room. In extreme cases, when two or three walls of the heater’s core are buried inside elaborate masonry mass forming aesthetically pleasing but heat-stopping inefficient mass, heat output may be reduced very significantly. Some people try to support their design solutions with elaborate heat-stopping mass around the core arguing that energy doesn’t get lost, it still gets

absorbed even in such great mass, and eventually will be released to the room. Yes, mass such as shelves and firewood in an integrated wood storage next to the heater will absorb heat. However, considering amount of this extra mass, this heat energy will be taken to increase temperature of that mass only a few degrees above ambient and/or to evaporate some moisture from the firewood. Therefore, most of this energy will be trapped inside the mass before getting out to the room or will be radiated into the room at a negligible rate that will have no measurable heating effect.

- Although see-through options are possible in masonry heaters, additional glass pane increases amount of heat leaving firebox by direct radiation through the glass and therefore lowers combustion temperatures having adverse effect on emissions. See-through models will overall have somewhat higher emissions.

Facing considerations.

Refractory core of a heater can be faced with any kind of sound masonry material. Possible finishes include: natural full-dimension stone or stone veneer, brick, tile and plaster/stucco alone or in any combination. Natural stone selected for heater facing should be solid. Avoid selection of very soft or flaking types of stone such as soft sandstone or soft slate. A rough brick or block facing is required before application of stucco or tile if regular flat tiles are used. “Kachel”, a special kind of tile developed specifically for tile heaters in Europe, is in fact a structural material that can form facing without additional support.

Remember: Heater facing should be independent from the core. Facing is separated from the core by an expansion joint that allows independent thermal expansion movement of the core, reducing impact of thermal stress on the facing. Therefore, facing cannot be attached to the core by any means such as brick ties etc. regardless of type of masonry material used in the facing!

Avoid supporting any structural members by heater facing! Required clearances to combustibles make such application with wood members impossible in most cases. Supporting structural members of any kind on the heater might expose

them to undesired heat movement and might create a potential problem if the heater needs servicing at any time in the future.

Some masonry materials are better suited for heater facing than others. Clay brick or ceramic tiles, for example, are ones of the best in terms of taking thermal stress. Stucco or plaster finishes are also quite durable if done properly. Stone facing, although often appealing, can be prone to hairline cracking at mortar joints in the areas immediate to firebox and bake oven doors due to different rate of expansion of stone and mortar and uneven thermal expansion of the stone itself. However, it should be noted that such hairline cracks are not very noticeable and as such not visually distracting. Some types of stonework such as “dry-laid” style may help to hide such hairline cracking within very thin or recessed mortar joints.
It also should be noted that depending on firing pattern, a masonry heater in everyday operation might develop a limited number of hairline cracks in facing done in **any** kind of material. Such hairline cracking usually happens in the mortar/grout joints. This should be regarded as normal considering that masonry mass of the facing experiences constant thermal expansion and contraction cycles through everyday operation. These cracks are typically very thin and don’t pose any safety problem nor visual distraction.

Heaters are much more likely to develop substantial cracking if fired beyond designed maximum capacity. Over-fired heater experiences very high level of thermal stress that most residential heaters are not designed to withstand. Over-firing might damage facing and the core alike. This is why it is very important for the owner to follow manufacturer’s or heater builder’s operation manual.

Facing thickness.

It is a common misconception that the thicker the facing is the more efficient the heater will be, and more heat will be produced. It is not true. Heat output depends on amount of fuel burned and on overall efficiency of the particular unit. Thickness of the facing doesn’t make the same heater more efficient, it only affects period of time the heat is stored for. A heater with thicker facing, (i.e. overall heavier heater with more thermal mass) will hold the heat for a longer period of time, but at the same time it will have to be initially fired with much more fuel to get the mass saturated and reach adequate surface temperatures. Facing thickness and overall thickness of heater walls determines responsiveness of the heater and rate of heat output (i.e. how much heat will be released into the room in a period of time).

Heavier heater will be much slower to respond to changes in firing pattern, will have lower surface temperatures and lower rate of heat output (slower heat release) under normal firing schedule, while a lighter heater with overall thinner walls will heat up faster, reaching higher surface temperatures, and will have higher rate of heat output. The lighter heater, however, will cool down faster as well.

Rate of heat output and heater's responsiveness can be adjusted to some extent by adjusting heater's wall thickness. Places with milder climate and common rapid outside temperature changes will benefit from lighter heaters that will hold heat for about 8-12 hours only, whereas colder climate requires heavier heaters able to store heat up to 24 hours. Our experience shows that heaters with facing of 4" to 5"thick offer ideal solution for most applications in our continental climate here, in Canada. Some applications such as cottages will benefit from fast-response lighter heaters with reduced overall wall thickness to provide fast heat-up in periodic use. Note, that super-insulated houses may allow for thicker facing and may benefit from lower rate of heat transfer of a higher thermal mass. Let your heater mason/manufacturer to come up with a proper solution based on the given requirements.

Foundation Requirements

Masonry heaters are heavy and require independent foundation/support system similar to standard site-built masonry fireplace foundations. Finished weight of a typical masonry heater is in the range of 6000-12000lbs depending on size and design. The support system has to be designed according to such load and should comply with clearance requirements of the Fireplace Section of a local Building Code and ASTM 1602-03. Observe clearance requirements of the ASTM 1602-03 for proper location of the heater in relationship to the combustible partitions.

Heater construction in seismic zones may require special additional measures. Discuss them with your heater mason to come up with the solution that will be structurally sound according to the seismic zone requirements and yet will not suffer from thermal expansion problems related to use of steel rebar in the heater facing.

Although masonry heaters don't require combustion air supply from outside or make-up fresh air supply for proper operation, some local authorities or a particular client may require outside combustion air to be brought right to the firebox. In these cases, supporting structural

slab for the masonry heater should be designed with a duct outlet in a place specified by your heater mason. Typically, 4” round duct is sufficient for most applications. However, consult your heater mason for his requirements or consult installation manual for the prefabricated core kit option. If local building authorities allow make-up air duct to exit in the hearth extension right in front of the heater (below the firebox door), the duct can be installed in floor framing apart from the heater foundation.

Another item to be considered while designing support system is ash collection option. Typically, there are two options for ash removal system: dropping ashes down from firebox to an ash box chamber located behind an ash-box door just below the firebox (ashes get collected on the main level) or dropping ashes into a basement ash container through an ash dump well. Units with ash collector located in the basement will need an opening for ash dump well to be incorporated in the design. Consult your client and heater mason/manufacturer for the preferred ash collection option and for proper location of the ash dump opening, if applicable.

Venting

Masonry heaters require chimneys. Depending on particular design, heaters can be vented either through a separate freestanding masonry chimney located at the back or either side of the heater, or top-vented through a factory-built stainless steel insulated chimney.
Advantages of the top-vented option:

- No additional space is required for the chimney.
- No masonry mass covering part of the heater’s radiating surface.
- Savings for the cost of 7 to 9ft of chimney due to the fact that chimney starts on top of the heater 7 to 9ft above its base.

Masonry chimneys should be built according to the requirements of the Fireplace Section of a local Building Code, while factory-built chimney proposed for the masonry heater application should be certified for venting wood-burning appliances and installed according to the manufacturer’s requirements.

Advantages of stainless steel insulated factory-built chimneys vs. masonry chimneys with clay liners:

- Stainless steel chimneys are tested to severe test standards that are impossible to pass for clay flue liners;

- Fast heat-up of the insulated thin liner establishes excellent draft in seconds;
- Smooth round surface of the liner has lowest resistance to gas flow further contributing to strong draft;
- Insulated liner keeps heat inside improving draft and reducing possibility of condensation;
- Great flexibility. Factory-built chimney manufacturers typically allow up to 2 offsets 15^{o} to 45^{o} to the vertical. This helps to vent heaters in tight situations bypassing combustible framing members and engineered trusses.

For aesthetic reasons, such factory-built chimneys can be enclosed in a framed decorative chimney chase on the roof, finished with number of available light-weight materials to create look of a traditional solid masonry chimney. Factory-built chimneys must to be enclosed inside living space in a chimney chase. Proper clearances specified by the chimney manufacturer have to be observed.

Advantage of masonry chimneys:

- Traditional look.

It is advisable to use insulated stainless-steel liners in new masonry chimney construction for improved performance and longevity if masonry chimney is selected.

Most masonry heaters require either 8x12” or 8” round flue. Some heaters can require smaller or larger flues. Depending on manufacturer, factory-built insulated chimneys can have thickness of insulation layer in the range from 1” to 2 ½”. Factory-built insulated chimneys typically require 2” clearance to combustibles. Consult your heater mason for proper chimney sizing and proper clearance requirements. Clearance requirements must be kept in mind while integrating a heater and a chimney into the building to make sure sufficient space is left between trusses and other engineered modules.

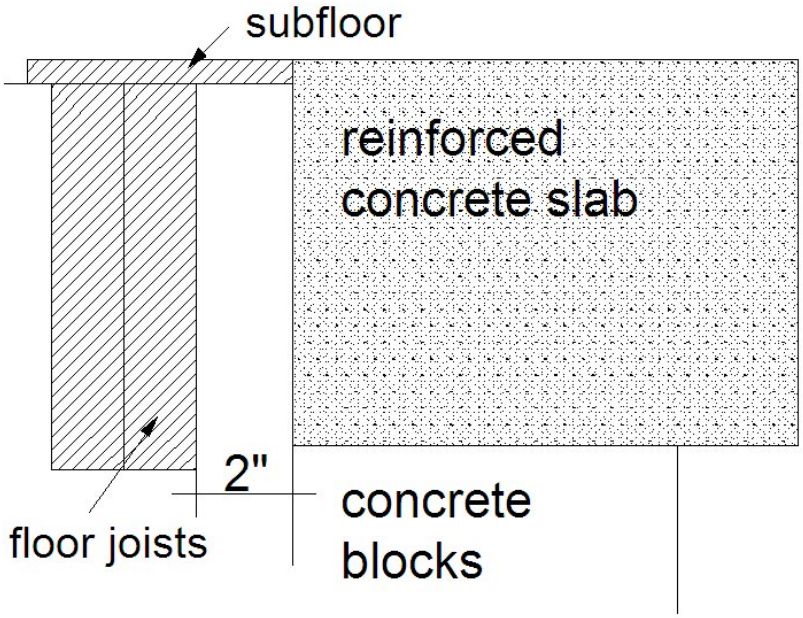
Avoid using exterior chimneys whenever possible. Exterior chimneys create increasing risk of creosote formation and chimney fire, pose condensation problem, and affect draft adversely. Exterior masonry chimneys suffer from deterioration related to condensation of the exhaust gases in the cold chimney flues, and from exposure to inclement weather.

Clearances

Clearances to combustibles for masonry heaters listed in the ASTM 1602-03 must be considered for proper integration of the heater in to the building. Requirements of the Fireplace Section of a local Building Code should also be observed and followed.

ASTM 1602-03 requires masonry heaters to have following clearances to combustibles:

- 4” clearance from walls;
- 8” clearance from ceiling;
- 48” in front of the fuel loading door;
- Non-combustible hearth extension to be minimum 20” in front of the loading door and continue minimum 12” past sides of the loading door;
- 2” clearance to combustibles from foundation of a masonry heater. It is allowed to cross this gap between floor joists and foundation with sub floor and flooring materials (sample picture below).



If it is desirable to continue facing walls to the ceiling, top of the heater’s core must be insulated, and the enclosed cavity should have means to facilitate air movement to avoid possible static heat buildup.

Refer to the ASTM 1602-03 standard for detailed description of rules and clearances for masonry heater construction.

Last tip for efficient planning

Choose a heater builder and arrange for a meeting with him and your clients at the earliest possible stage. Similarly, consult manufacturer of a pre-manufactured core kit as early as possible to discuss your application and all possible finishing questions. This will make the planning process a lot smoother and easier.

For more information and pictures, please visit www.stovemaster.com

Good luck with your project!