

The ZeroFossilFuel Rocket Stove Heater



Theory of operation and assembly details.

Let me start this document by saying that, if you intend to replicate my Rocket Stove, it is highly unlikely that any two replications will be exactly alike. That is as it should be because, if no one tried anything new, development would cease and there would never be any progress. If you've got an idea that you think will improve on my design, build it! If it works, please share it!

What I will do here as best I can is take you through the steps I went through to determine all of the critical dimensions for building your own stove based on the raw materials you may have found or bought. The photos in this PDF document are fairly high resolution so they can be zoomed in to see finer details.

So what is a Rocket Stove Mass Heater?

There is a wealth of information regarding Rocket Stoves all over YouTube and the web, and numerous variations on the basic design. I encourage you to do some research. Good places to start are <http://www.richsoil.com/rocket-stove-mass-heater.jsp> and <http://www.ernieandERICA.info/rocketstoves>. In the strictest sense, it is generally a wood fired heater with an internal flue or riser, covered by a barrel of some sort with a long exhaust pipe that runs through a cob (mixture of clay and straw) thermal mass which acts as a heat battery, giving off stored heat in between burns usually between evenings and mornings when family are asleep and you don't want to be burning wood then anyway. Key benefits of a Rocket Stove over traditional wood stoves are:

- As little as 1/10 the consumption rate for the same effective heating to your living space,
- Virtually no smoke or carbon monoxide byproducts, just carbon dioxide and steam,
- Very little ash buildup with easy clean-out.

Variations on the design include the “Pocket Rocket” (I'm not terribly impressed with these) and mini Rocket Stoves intended for cooking. I will not discuss either of these here in any detail because neither of them conform very well to the original concept despite that they were named Rockets. Key features that truly define a Rocket Stove are:

- Vertical wood inlet to a small firebox,
- Horizontal burn chamber,
- Insulated internal flue or riser,
- A drum or barrel over the riser for gases to cool and give off heat,
- An exhaust at the bottom that often extends through a cob bench to slowly store & release heat.

How does it work?

Very well, thank you.

Okay, kidding aside, any wood stove needs to create a draft to pull air into the firebox for the wood to burn. The average wood stove sends 80% or more of the heat created by the fire up the chimney flue and out, giving off only left over radiant and convection heat transferred to the body of the stove and into the room.

A Rocket Stove, by contrast, is able to scavenge almost all of that previously wasted exhaust heat without buildup of creosote or other deposits. Here's how.

When a fire is started in the firebox of a Rocket Stove, all it should take is a puff of breath or two down over the firebox to get the hot gases to start traveling through the short horizontal burn tube and up the internal riser. Once they start upward in the riser the process becomes self sustaining. Here is where the Rocket truly differs.

- **All of the draft necessary to make a well designed Rocket Stove function properly is created inside the internal riser.**

I cannot stress this point enough. From the moment the gases exit the top of the riser and down the sides of the barrel they begin to cool. The draft created by the riser behind the cooling gases should be so strong that, not only does it pull in fresh air behind it, it also pushes exhaust gases out ahead of it without the need for any additional draft created by a typical chimney flue. This is why it is so critical that the internal riser (and even the horizontal burn tube) be as insulated as you can practically make it. By so doing it:

- Creates a super strong draft in a very small space and
- Provides the environment for secondary burn of any unburned gases

Some say it creates a plasma burn but that's just not possible at the temperatures we're dealing with here. Even still, the combustion is complete and that's what counts. Smoke and odor are byproducts of incomplete combustion. A well designed Rocket Stove produces virtually no smoke or odor at all, has very low flue temps going outside and exchanges most of its heat into the living space.

So where do I start?

At the beginning, of course. Duh!

Okay, kidding aside again, the first thing you'll need is the tools (or at least access to them) and skills to use them. They include:

- Mig welder (flux core is fine or gas if you can afford it)
- Sheet metal bending brake. Mine is 30".
- Tin snips.
- Angle grinder with grinding wheel and cutting disks.
- Drywall square.
- 12" bubble level
- Sharp indelible marker.

Next consideration is overall size. Ask yourself "How big of a living space do I need to heat?" In my case it was just a 240 sq-ft well insulated workshop with about 2150 cu-ft of air space. So, I scaled down the overall size accordingly from typical whole house heaters that use 30 or 55 gallon drums. While scavenging through a couple of scrapyards I stumbled across a discarded 17 gallon air compressor tank. PERFECT! So...

- **Step 1. Find your own perfect barrel, drum or tank.**

This compressor tank for me was the ideal choice. Not only was it the right approximate size, it was rugged having 1/8" thick sidewalls. My tank measured 12" diameter and about 37" long. Other possibilities include discarded electric hot water tanks, artesian well water storage tanks, slim propane cylinders, stacked and welded 20lb propane tanks, etc. Be imaginative.



Then I asked myself "Self, what diameter riser could my tank support?" With a basic understanding of cross-sectional areas required to make this stove I figured anything from 7" - 9" diameter would be good. This would leave a gap all the way around between 2.5" - 1.5" respectively. In all honesty even 10" would fit and 1" gap going around would be plenty for the exhaust gases to exit freely. I settled on 8" because it was convenient and readily available.



- **Step 2. Determine the internal sizes of your riser, burn tunnel and feed tube.**

Collectively this is known as the J-Tube. A typical 55 gallon drum heater design uses a 8" inside diameter riser. A typical 30 gallon drum heater uses a 6" inside diameter riser. Therefore, I extrapolated that mine should be about 4". I had read about others who had tried making 4" systems with mixed results. Confident that I could make it work I forged ahead despite the naysayers.

I knew that I was going to use some sort of firebrick for the firebox and horizontal burn tube. My first concept for the riser was to use a 4" x 24" galvanized vent pipe as the inside wall of the riser with a 6" x 24" galvanized vent pipe for the outside wall and 1" of fiberglass insulation in between. Several people expressed what I later decided were valid concerns over this choice I had made. They were:

- Emission of poisonous gases from the zinc galvanizing burning off,
- Short life span from rapid rotting under the extreme heat,
- Melting of the fiberglass wool.

With the suggestions from others and knowing that many Rocket Stove builders use firebrick for their risers too, I decided to work through the design using firebrick as a liner and retain the galvanized pipe outer wall. To do so I wanted a cross-sectional area as close to a 4" round pipe as I could get which is 12.56 sq-in. Bricks arranged to get 3.5" x 3.5" square tube ended up being 12.25 sq-in. Close enough for government work. The final drawing illustrated below shows exactly how I arranged my bricks to achieve this opening size.

Everything else about the internal dimensions is all about ratios and cross-sectional areas. In a nutshell, the cross-sectional area that the hot gases must pass through should be the same or increase slightly at every point along the path with the exception of the area between the riser and inner tank wall which is often much greater. So, starting with my riser of 3.5" x 3.5":

- Horizontal burn tube area should be \leq the riser. Mine is 3.5W x 3.25H (11.375 sq-in)
- Firebox opening also should be \leq riser but not $<$ than the burn tube. Mine is 3.5" x 3.25"
- Area at the top of the riser should be between 1.5x to 2x the area of the riser itself.
- Area of the exhaust port should not be $<$ area of the riser. Mine of 4" round or 12.56 sq-in.

The area at the top of the riser is calculated by the circumference of the I.D. x distance to the top of the barrel. Mine is 3.5" x 4 x 2" or 28 sq-in, a hair over 2x the riser area. Once the gases spill over the top, the cross-sectional area going down is the 12" tank minus the 8" riser outer wall. 113 sq-in minus 50 sq-in = 63 sq-in. Then the final exit out the exhaust port at the bottom.

Other ratios that should be observed are:

- Riser height should not be $<$ 3x the height of the firebox tube, 2x the length of the horizontal burn tunnel, or 1x the horizontal burn tunnel plus the feed tube. More is better here.

My riser is about 4x the length of the burn tunnel or the feed tube, each measured at the shortest dimension.

The lower portion of my J-tube was first sized up by stacking fire bricks in different configurations on my bench top until I was happy with the ratios. Starting with the firebox feed tube against the tank outer wall or very close, I made sure the burn tunnel was long enough to center the riser in the tank. The dimensions for me seemed to just fall into place by themselves. You may or may not be so lucky depending on what size tank you end up with. The point is be aware of placement for all



components within the tank as you experiment with brick layout. It's not a terrible thing to place the riser off center in the tank if you must. Just be aware that more heat will radiate from the side with the greatest gap between the riser outer wall and tank inside wall. There is one very special rabbit cut I had to make for everything to fit together precisely as seen to the right and in the drawing below.



My bricks are all assembled free floating inside a welded heavy sheet metal enclosure that is open at the top at both ends. Once I knew the outside dimensions of my bricks I added 1/8" all around and used that as the inside dimensions for the brick enclosure. Pictures are worth a thousand words here.



My brick riser is three groups of 4 firebricks locked into place with a small bead of furnace cement along all inside edges of each group formed where they overlap. The three groups are not cemented to each other. They simply sit atop each other. Notice in the drawing below that the middle group (2) is a mirror of (1,3). This was done so that brick seams crisscross each other when stacked instead of aligned parallel. This inherently reduces the tendency for gases to escape where they ought not. To keep them

aligned while the furnace cement almost fully cured I simply strapped them using rubber bands and masking tape around a uniform 4x4 piece of lumber (which actually measures 3.5" x 3.5") then tapped them out, set the bricks upright and allowed the furnace cement to finish curing overnight.

The next step was to cut my tank. I knew I needed two things

- That the top of the burn tunnel cover be perfectly flush with the top lip of the lower section and
- That I wanted 2" spacing between the top of my brick riser to the top inside of the tank.

All I did was assemble all the bricks to my lower brick carrier, stack the three riser sections, measure from the top edge of the riser to the top of the top burn tunnel metal cover, add 2" and with a drywall square mark that point on the side of the tank every couple of inches from the top. That ended up being exactly 10" from the bottom.

The original platform for the compressor that was welded to the side of the tank was cut off and reused as the base to hold it vertical. A bubble level was used to ensure the tank was plumb before welding the new base into place.

The opening for the metal firebox enclosure needed to be a close fit at 6 & 1/8" so I cut it 6" x 6", ground it slowly to fit, then tack welded it in 3 spots on each side and twice across the bottom to secure it into place. Likewise, a bubble level was used to ensure the box was level so the riser would stand straight in the center of the tank before welding it into place.





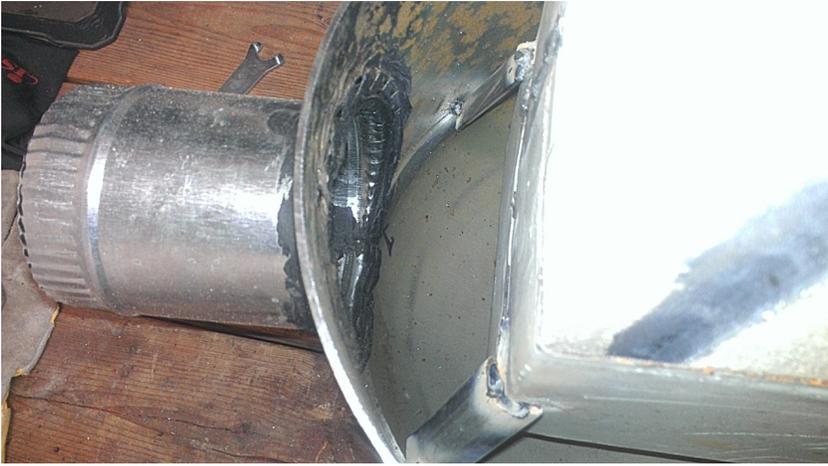
In this photo I've tack welded the fire brick carriage into the square opening cut into the lower tank half. Notice how well centered the riser is inside the diameter of the tank. With the top half assembled it just brushes up against the front feed tube brick. Also noting that the burn tunnel top cover plate is as flush to the top edge of the lower tank half as I could get it. The fiberglass rope will be glued all the way around to seal the top half when assembled.

Here I've cut the 4" opening for the lower exhaust port, added 2 supports to the brick carrier corners and 4 L-brackets made from small pieces of 3/4" angle iron. They were drilled first and preassembled to their upper mates with threaded rod. The top half of the tank was set into place, then the L-brackets were welded. This helped with positioning and ensured they were vertical so that the top half would slide freely off the lower threaded rod studs. To the right you also see I tack welded



more 3/4" angle iron to make a flange that the burn tunnel end cap bolts to. The intent was to make the bricks entirely serviceable.

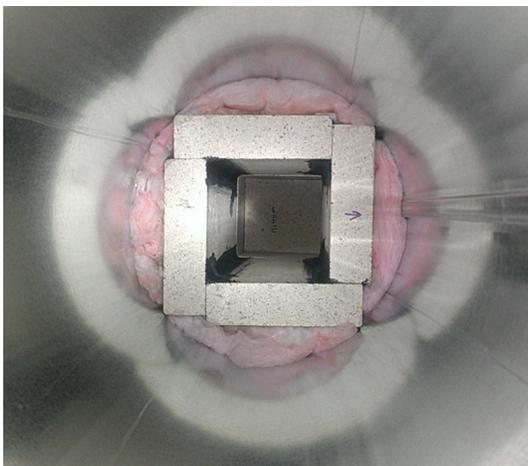




Here is a closeup of the exhaust port starter pipe I made from a dryer vent adapter pipe. Prefab units were not deep enough to accommodate the curvature of the tank. The pipe was inserted into the cut opening first. A line was marked around the pipe to follow the curvature of the tank wall. Then slits were cut every 1/2" or so all the way around up to the line creating tabs. Once inserted again the tabs are bent over to hold in place and cemented with furnace cement. The two braces for the brick

carrier box I felt were necessary due to the rather thin material I used to make it. This portion of the stove is the hottest and the riser stack is quite heavy. Even if the metal softens a little, I'm not worried it will sag. Again, your construction may vary. If I was to do it again I'd probably make the brick carrier box entirely from 1/8" thick plate steel welded all the way along the seams, adjusting the size and placement of my square opening on the lower tank half accordingly.

With the first riser stack on top of the lower section, I slid the 8" riser outer wall pipe over it, marked the locations where the brick carrier corners touched and notched it with tin snips to get past the corners and sit flush atop the brick enclosure. If I was to do it again I'd make the top rim of the box flush with the burn tunnel cover so I wouldn't have to notch the 8" pipe at all.



Here's a look down inside the 8" galvanized vent pipe at the 1st group of 4 riser bricks. Internal groups are stacked one at a time. Fiberglass is stuffed down between the brick and pipe with a thin piece of wood trim, 12" ruler, what ever you have on hand. Higher sections are simply held together by gravity, friction and fiberglass, centered by the 8" galvanized vent pipe against the corners of the bricks. The bricks do not cave in because of the lip created by the furnace cement.



At the left is the completed riser with all three sections. The metal strap at the top is bent roughly 90° every 8.5" into an overlapping square, then screwed through the 8" vent pipe to hold it in place like a halo. This keeps the riser centered should the tank be tipped. Corner to corner is just under 12".

At the right is the same view with the top half of the tank assembled. Notice that the brick against the tank is raised slightly? It's because a bevel has not yet been made to allow clearance for the fiberglass rope that seals the two tank halves.



This is a closeup of the fiberglass rope shown glued to the top tank half. I later changed this design because the rope kept getting hung up on and ripped off by the threaded rods when I lifted the top half off for service. I later glued it to the bottom half which worked out much better.

And now the fun part. Time to fire it up!

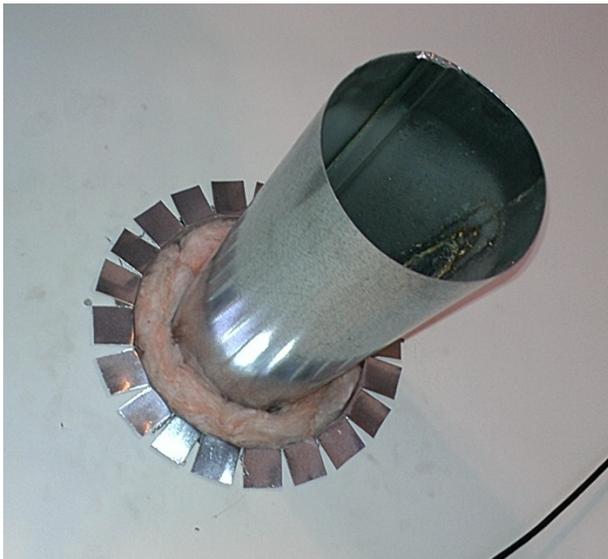


WAHOOOOO!!! First test fire was a total success!

Time to position it inside and finalize the installation.

Here I've laid out the location for my Rocket Stove with concrete brick pavers. The bench ultimately gets moved further left to a safer distance from the stove. The wall corner is protected by two sheets of 3' x 5' cement board, secured to the walls with nails through 3/8" thick wood trim standoffs to insulate them from the walls. They are also 1.5" off the floor to allow cool air from the floor to enter behind the boards through convection releasing even more of the captured radiant heat into the room.

To determine the height of the flue pipe through hole I assembled a standard length 48" section of vent pipe to the T at the back of the stove then the 90° angle at the top and let it rest against the wall. The actual location is a bit left of where you see it here because a stud was available to screw my thimble plate to. My flue pipe thimble is made from two plain 4" vent pipe wall plates and a section of



6" vent pipe cut 2" longer than the wall thickness including the drywall and outside siding. Like the tank exhaust starter pipe, slits are cut to create tabs all the way around, fanned out to hold in place on both sides.

The outside plate was screwed to the siding first, then a 24" horizontal section passed through and 1" thickness of fiberglass stuffed in to create dead air space and seal out drafts. The inside plate gets slipped over the vent pipe and screwed to the drywall. The three left hand screws all catch the stud and the others use drywall mollys.

Somewhere along the line through this next series of photos I spent several days stripping, grinding and wire brushing the heavy red powder coat paint off the top half of the tank and resprayed with high temp flat black.





The flue pipe is completed on the outside with one last 90* bend upward and another 48" vertical pipe with a rain cap. The photo shows only a 24" vertical piece but that was later made longer to elevate the rain cap just above the roof peak. It is held stable with two straps screwed into the vent pipe and to the soffit fascia board.

Because this is not actual double wall insulated wood stove flue pipe which is VERY expensive, and because the Rocket Stove produces so much steam, condensation inside the pipe before the exhaust gases get out the top is a real problem. Without a way to drain them out they would literally flow back into the inside vent pipe, pool in the bottom of the T and drain out onto the floor! To address this what I did was tilt the horizontal pipe downward slightly (only 2-3 degrees) and drill a 3/16" drain hole in the bottom just before the 90*

elbow. That way condensation drains out, not in. Also note that I took great care to ensure that all vent pipe seams were sealed with either aluminum vent pipe tape or furnace cement where appropriate.



In an ill fated attempt to greatly extend burn times between feedings I made up this wire loop frame from a piece of 3/4" flat bar and some coat hanger wire welded to the bar. This worked fine for precut lumber but not so well for irregular lumber and dead tree limbs.

I was also still not happy at this point with how quickly I was able to warm up the room. Wood stoves need air to burn. That air has to come from somewhere. Without a controlled fresh air inlet the only other place it can come from is cracks around doors, windows and outlets because of the negative pressure it creates in the room. From there it cools down the living space first before it finds its way to the firebox. So...

Mod #1 – Fresh air inlet.

Luckily for me the shed is a raised structure. All I had to do to relieve most of the negative pressure created by the stove and bring in fresh air when and where I wanted it was to pop a 3-1/4" hole into the floor with a hole saw. I then ran a 3" flexible aluminum vent pipe up to a shroud around the feed tube that doubled as a small wood hopper. This also confines the inlet air over the firebox where it is immediately sucked down for combustion rather than circulating through the room first.

I believe this is a key point that many Rocket Stove builders miss. The inlet air should enter down and around the wood in the feed tube, not from an inlet down low directly into the firebox burn area. Without a lot of downward air flow, radiant heat and hot gases in the firebox are allowed to rise upward, gasify the sticks in the hopper and can actually start smoking and burning into the room! You may have seen my mishap video. It's not pretty.

Cementing the shroud to the top of the firebox feed tube was a mistake because I still need it to be removable for cleaning out ash. Adding the fresh air inlet was a big boost for heating efficiency but I still wanted more. So...



Mod #2 – Radiator fins

This is simply two 8' pieces of aluminum roofing drip edge cut into 22 sections 10.5" long each, corners ground to allow a large stainless steel hose clamp to pass through, sprayed flat black and clamped around the top of the tank. This one mod alone added almost 700 more sq-in of radiating surface area, dropping flue temps at the wall about 40°F and making it difficult to get the top of the tank any hotter than 500°F, whereas I was getting almost 700°F. Now I'm happy with the efficiency.



Daily operation

It takes about 30 minutes to get my stove up to temperature. From there it raises my 2150 cu-ft of shop space about 15-20°F/hour. Based on rate of temperature rise and heat losses through four exterior walls it is estimated that my stove is putting out between 30,000 and 35,000 BTU/hour. It does this with a wood consumption rate of only about 70 cu-in/hour.

Loading the wood is a bit of an art and takes a little practice. The main idea is to put enough wood in the hopper to produce enough heat but not so much that you choke off air flow and not so close to each other that flames can travel upward between sticks. I also find the sticks do not always self feed but need a slight nudge every so often to get them to drop down. Still thinking about that one.

For right now, to clean out ash I have reduced the number of screws on the front feed tube cover from 7 to 3, tacked the heads from behind and put wing nuts on the front. I lift the air inlet shroud off, spin off the wing nuts remove the metal plate and the front brick. Then I reach in with a hoe I made from a scrap piece of drip edge and the 3/4" flat iron bar that I took off the wood hopper. I can run the stove 2-3 days between cleanings but, ideally, it should be cleaned every day. The only ash that gets any further than the burn tunnel itself is extremely minimal, super light and fluffy. Maybe once a month I'll lift off the upper tank half and suck out the remains. So far I have not even had to do it once.

Still ahead I definitely want to add a better ash collection and clean-out, and very possibly a wood pellet hopper and feeder. I just don't want to use an electric auger feeder because what happens if there's no power? And with gravity feeders I worry about it burning backward into the hopper. Maybe a spring loaded hand crank that can run several hours between cranks?

Still thinking. Always thinking.

I hope I've got you thinking too! Better yet, building!

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All the best,

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