Home Made Insulation For Stoves

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Multiple tests of the Lorena stove beginning in 1983 at the Aprovecho Research Center have shown that placing thermal mass near the fire has a negative effect on the responsiveness and fuel efficiency of a cooking stove. In 1996, Mr. Leoni Mvungi from Tanzania built a Rocket stove from earth, sand, and clay that was a replica of a low mass Rocket consisting of metal chimney parts. His version weighed hundreds of pounds even though the Rocket internal chimney was only eleven inches high. Tests of a low mass sheet metal version scored around 30% fuel efficiency. But the best result achieved by Leoni's test stove was around 15%.

Building Rocket stoves from sand and clay showed little promise of improving on the three stone fire which was scoring around 18% in repeated boiling tests performed by Jim Kness and Dean Still (1994). Unfortunately, metal stove parts also have a major drawback in that the high heat in the combustion chamber quickly destroys thin metal, even stainless steel. Aprovecho consultants were in agreement that a good stove should last for years without requiring maintenance. Replacing metal parts as they wear out was not considered a viable solution.

A women's co-operative in Honduras (Nueva Esperansa) makes ceramic stove parts that have a reputation for working well in stoves. In 1998, Aprovecho consultants Mike Hatfield and Peter Scott contracted with this group to produce combustion chambers for the Dona Justa griddle stoves that they helped to design. This material seemed to work well and, in fact, the Rocket elbow made by Nueva Esperansa has been successful in Honduras and Nicaragua. It is difficult, however, to deliver the fragile combustion chambers without breaking them. Also they are relatively expensive, costing about eight dollars each.

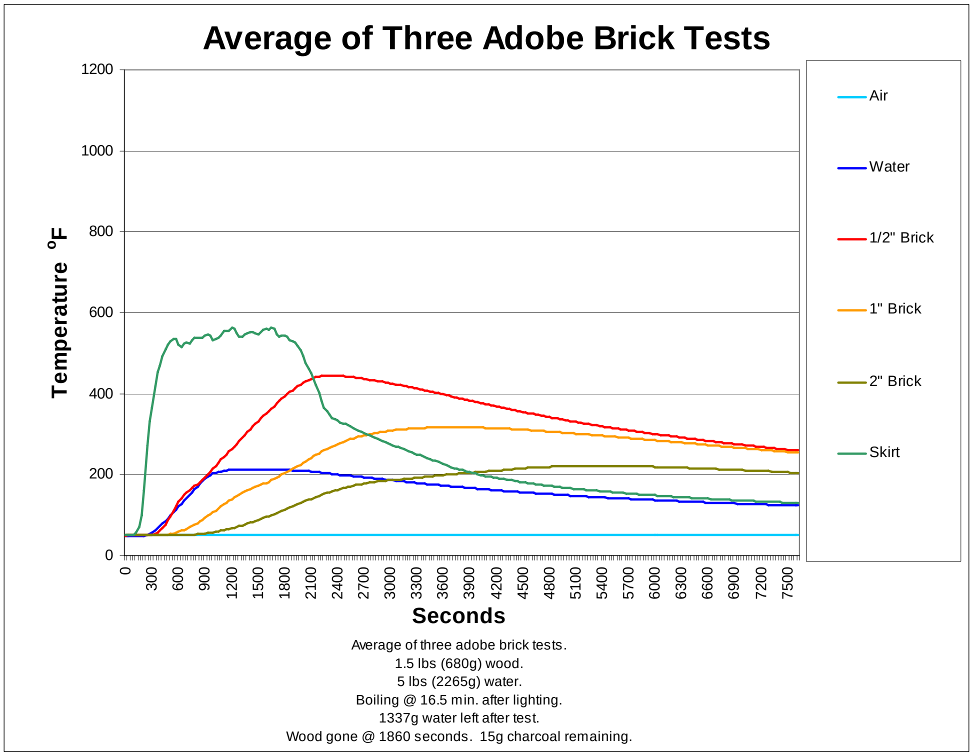
Don O'Neal (HELPS International) and Dr. Larry Winiarski have shown that cast iron combustion chambers, which do last, also have problems. Tests showed that the very conductive cast iron made the fire hard to start. In fact, a group of indigenous Guatemalan women stove testers living in Santa Avelina were unhappy with the expensive cast iron combustion chamber and asked for it to be replaced. They wanted a more responsive stove that started easily, and quickly cooked food in the morning. Don and Larry eventually found an alternative material: an inexpensive Guatemalan ceramic floor tile (called a *baldosa* in Spanish) which functions well when cut up to make the walls of the Rocket combustion chamber. The baldosa was about an inch thick so the combustion chamber only weighed eighteen and a half pounds. Like all Rocket combustion chambers it is surrounded by insulation, either wood ash or pumice rock.

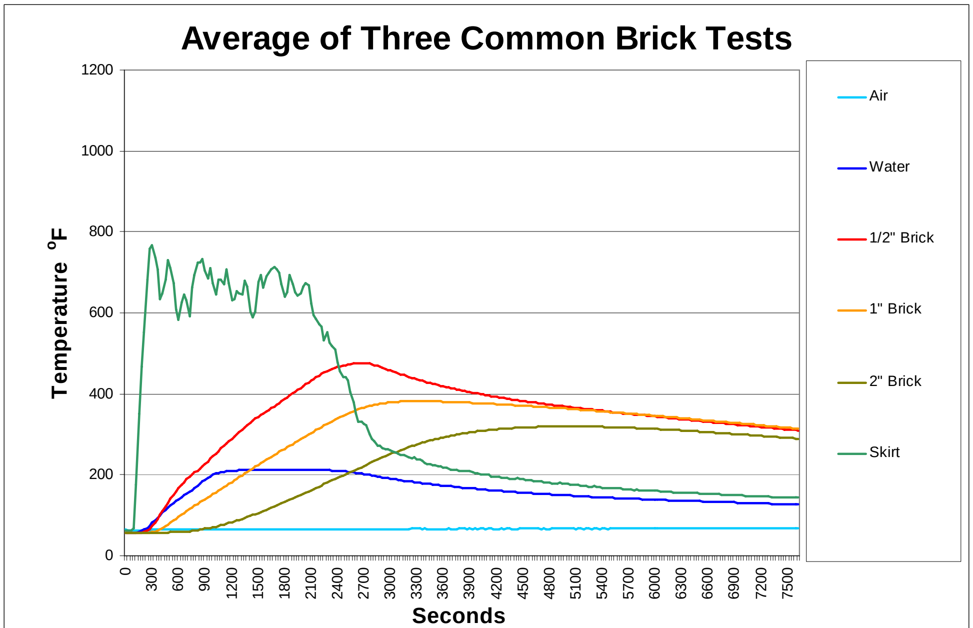
The baldosa tile has done well in test stoves. It seems to be durable and the group of testers from Santa Avelina reported that their stoves are much improved. The thin ceramic material surrounded by wood ash made the stove much quicker to heat up. The women approved the improved stove for general dissemination to neighbors and other villages. The HELPS molded griddle stove now uses a preformed ceramic combustion chamber made by a local baldosa manufacturer. Unfortunately, all baldosa are not equally resistant to heat and it's important to test tiles before using them in stoves. Heating a tile to red hot and then throwing it in a bucket of water seems to be a good test of durability.

Appreciating that clay seemed a promising material for Rocket combustion chambers, Ken Goyer, Damon Ogle, Dean Still and Mike Hatfield created and testing ceramic mixes in the Aprovecho lab and in Central America. This research resulted in many home made insulative clay recipes. Six bricks made from this material combine to make a complete Rocket combustion chamber. Making the chamber from separate bricks has resulted in a greatly reduced tendency to crack. The bricks have held up so far in durability tests and they help to make a clean burning fire.

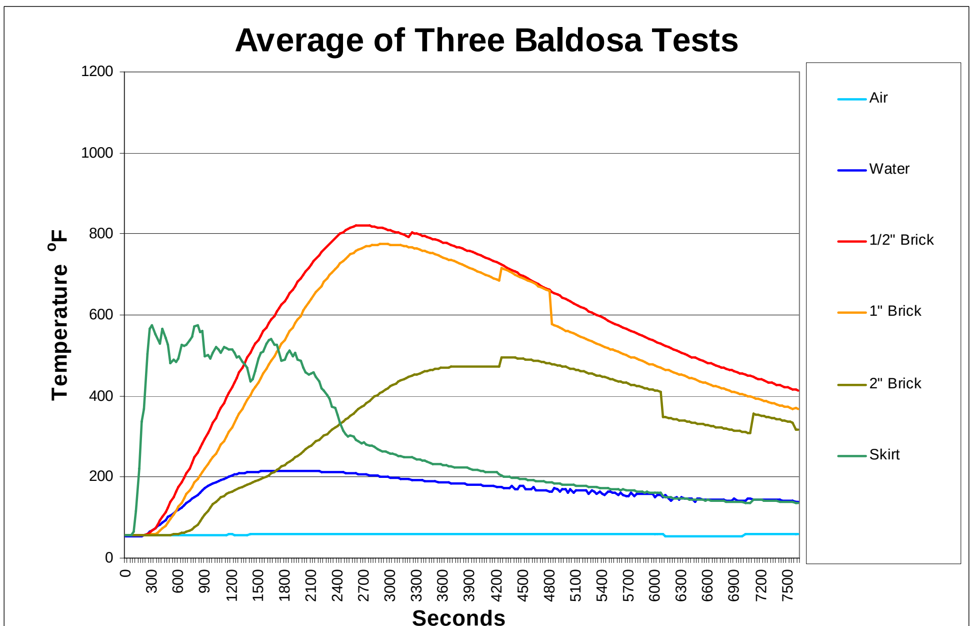
The purpose of this paper is to describe the results of experiments involving same sized brick combustion chambers made from adobe, the home made clay insulation and common ceramic brick material. All bricks shared the same dimensions. Six bricks (11 ½" high by 2 ½" thick) made up a hexagonal cylinder surrounding a four inch in diameter chimney. Sticks of wood entered the bottom of the chimney through a hole sawn in the bricks. A combustion chamber made to similar dimensions was constructed using baldosa tile bought in Guatemala. Vermiculite filled in around the baldosa creating a combustion chamber with approximately the same dimensions as the brick stoves.

The following four graphs show the average results of three tests using each of the four materials. They reflect how heat passed into the four materials as one and a half pounds of wood was burnt. Temperatures rise much higher in the insulated materials (vernacular insulative ceramic and baldosa/vermiculite) but not as high in the denser types (common brick and adobe). through the material.

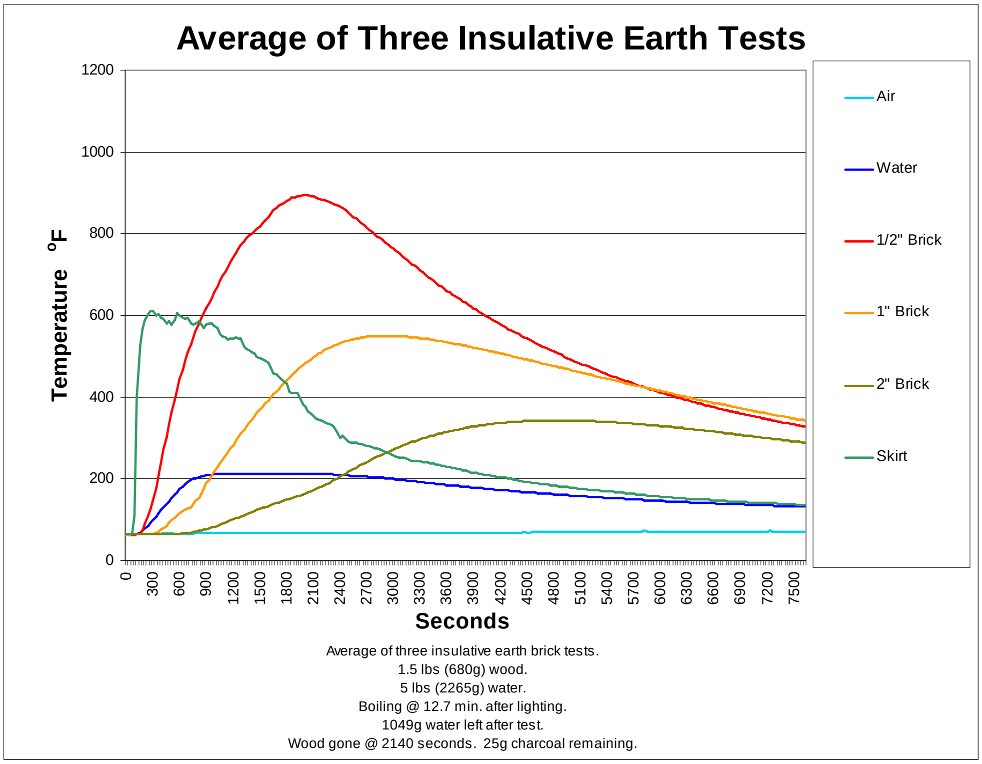




Average of three common brick tests.
1.5 lbs (680g) wood.
5 lbs (2265g) water.
Boiling @ 17.5 min. after lighting.
1304g water left after test.
Wood gone @ 2430 seconds. 31g charcoal remaining.



Average of 3 baldosa tests.
1.5 lbs (680g) wood. 5 lbs (2265g) water.
Boiling @ 19.2 min. after lighting.
1210g water left after test.
Wood gone @ 2240 secs. 12.7g charcoal remaining.
Note: Irregularities due to data loss from sensor failures.



It makes sense that the better insulation would create higher temperatures in the combustion chamber. Walls in a well insulated house should be close to room temperature because heat is passing so slowly though the wall that inner surfaces become almost as warm as interior air. Insulation is made up of pockets of air that cannot hold or pass a great quantity of heat. Denser materials 1.) require more Btu's to rise in temperature and 2.) conduct more heat through the material.

Average temperatures ½ inch from the fire within the home made insulation brick reached 906 degrees F. At the same place the baldosa/vermiculite combination rose up to 764 degrees F. but the sensors ½ inch within the adobe and common brick topped out at 427 F and 487 F. The more massive walls inside the combustion chamber are much cooler. Cooler fires make more smoke.

In these tests the better insulator creates a graph that steeply rises to higher temperatures and the three lines are farther apart, i.e., heat passes more slowly through the material so there are bigger differences in the temperatures recorded at a increasing distance from the heat source. The maximum difference between the furthest apart sensors in the home made clay insulation was 839 degrees F. In the baldosa/vermiculite test the maximum difference was 439 F. But in both the common brick and adobe combustion chambers the greatest difference was much lower. (275F. and 173F). The clay insulation slows down the passage of heat and it creates the hottest temperatures close to the fire.

Fuel efficiency was effected by the weight of the combustion chamber. The combustion chambers weighed in as follows:

- Adobe 50 ¼ pounds
- Common Brick 36 pounds
- Baldosa/Vermiculite 18 ½ pounds
- Home made clay insulation 16 pounds
- Sheet Metal* 3 pounds

The percentage of heat that entered the water in the pot follows a ranking by weight.

- Adobe 22.2%
- Common Brick 22.4%
- Baldosa/Vermiculite 24.16%
- Home made clay insulation 26.5%
- Sheet metal low mass stove 31.9%

The differences in fuel efficiency created by the four earthen materials are not large. When using the boiling test all four ceramic materials do not perform badly. Each Rocket stove with any material in the combustion chamber did better than the laboratory tests of the three stone fire.(The pot skirt helps to raise efficiencies.) A larger difference is seen in an additional test of a sheet metal combustion chamber which scored appreciably better than the higher mass types. But, so far, a long lasting, low cost, metal combustion chamber does not exist. Noting the success of the truly low mass sheet metal combustion chamber reinforces the design principle of lowering the mass around the fire.

4.) The responsiveness of the stove and the speed at which water boiled was dramatically effected by the material used. The five pounds of water boiled at the following times:

- Adobe 16.5 minutes
- Common Brick 17.5 minutes
- Baldosa 19.2 minutes
- Home made clay insulation 12.7 minutes

The clay insulation made a much faster responding stove. If there is a demand for quick service then the first choice is obvious. Also when only making coffee or when boiling food that is rapidly prepared, the fuel savings could be significant. The attraction of the clay insulation is that stoves using this material should be quicker to light and faster to make hot fires.

5.) Does material choice effect combustion temperatures? Follow up tests were performed on the clay insulation, adobe and low mass metal combustion chambers. The stoves were fired as hot as possible without creating excess smoke or coals. During a 45 minute period temperatures were recorded using PICO software at the following places in the adobe and clay insulation combustion chambers:

three inches, eight inches and eleven inches up from the bottom of the combustion chamber at the inside face of the Rocket elbow chimney and at the top of the chimney.

In the adobe combustion chamber the peak temperatures were as follows:

- 3” 1123 F.
- 8” 513 F.
- 11” 622 F.
- Exit 1148 F.

The combustion chamber made from home made clay insulation showed the following peak temperatures:

- 3” 1383 F.
- 8” 1148 F.
- 11” 1113 F.
- Exit 1573 F.

It was not feasible to drill into the low mass stove to replicate the tests done on the two ceramic stoves. But exit temperatures found during a similar test topped out at 1,592 degrees F.

Results from these tests indicate that an insulated combustion chamber is more likely to create high temperatures that should positively effect combustion efficiency. Higher combustion temperatures are known to decrease harmful emissions as well. The lower temperatures in the adobe would certainly seem to be detrimental to assisting secondary combustion within the Rocket chimney.

Summary

1.) The internal surfaces close to the fire of both the home made clay insulation and baldosa/vermiculite get much hotter in less time than the brick and adobe. Hotter combustion chambers should be easier to light and more fuel efficient.
2.) Using the clay insulation results in a faster boiling time which should be appreciated by users. If the stove is used for short term cooking tasks then this material choice could result in significant fuel savings.
3.) Material choice has a large effect both inside the combustion chamber and on exit temperatures at the top of the Rocket elbow. The clay insulation showed maximum exit temperatures around 1575 F but the adobe model was quite cooler at 1148 F. Since higher temperatures assist more complete combustion then the use of a more insulative material can be beneficial.