How does increasing the riser above a top-lit, updraft gasifier affect gasification rate and fuel bed temperature?

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OBJECTIVE: How does riser height affect gasification rate?

The choice of riser height of the gas burner is a fundamental decision when designing a ND-TLUD cook stove.

It is important to have the riser tall enough to create draft, protect the flame, and minimize flame contact with the bottom of a cooking pot (where the flame can cool and deposit soot). On the other hand, a short riser maximizes radiant heat transfer from the flame to the pot.

Various dimensions of the gas burner affects the amount of buoyancy in the gas flame, and the flow-rate of gases. In turn, this can alter the rate of gasification in the reactor below. This study focused on how riser height affected char yield, gasification rate and peak fuel bed temperature, during the gasification of softwood pellets over wide range of primary air supply.

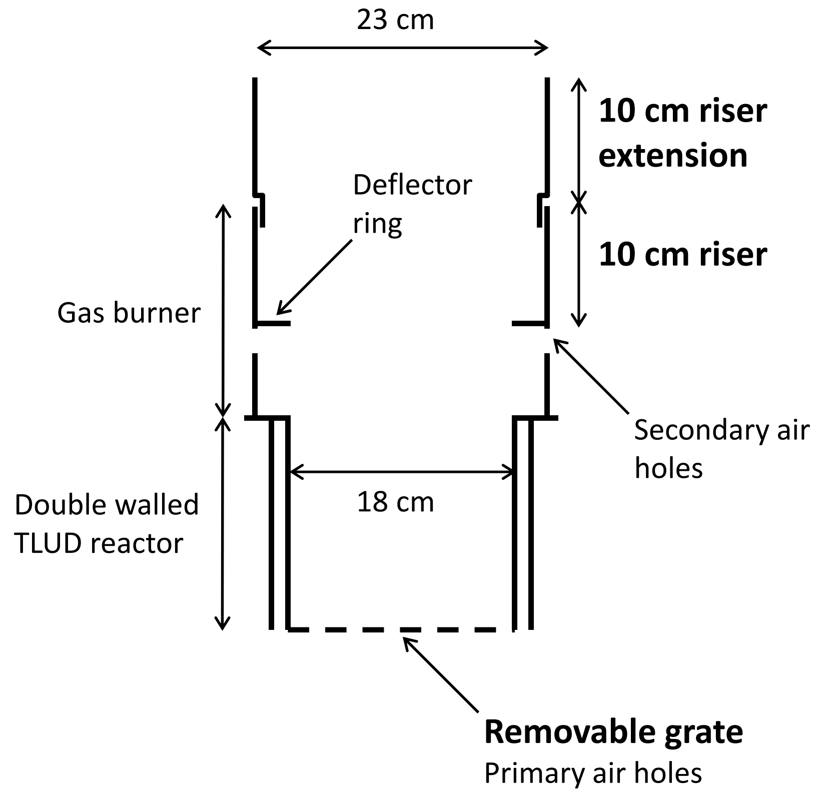
METHODS

Gasification rate and bed temperature was measured in factorial experiment with two treatments:

1) Riser height above the burner x 2
2) Reactor grate aperture x 7

Riser height: The gas burner had a built-in riser that extended 10 cm above the secondary air holes. A 10 cm extension was used to increase the total riser height to 20 cm.

Primary air supply: The reactor had exchangeable bottom grates that varied the amount of open space for the passage of primary air. A series of seven grates were used to create a 'power curve' or 'turn down' for the size of the gas flame.

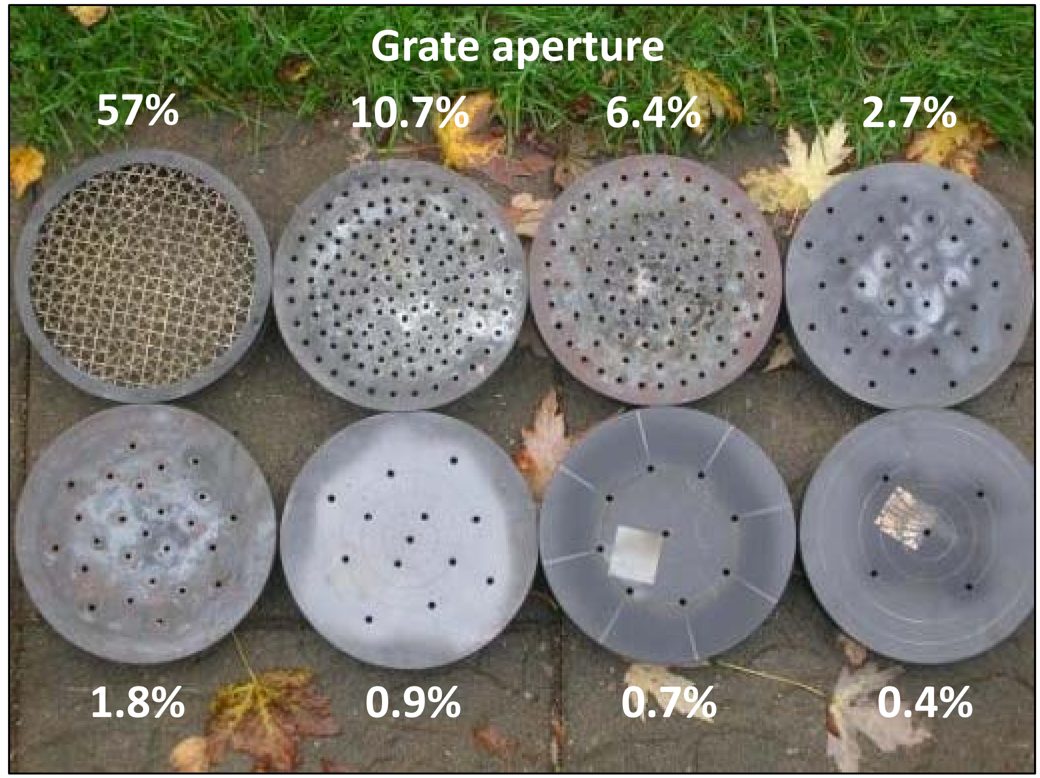


The burner had been proven reliable over a wide range of gasification rates. It was 1.3 times wider than the reactor to allow horizontal expansion of the flame. Twenty-four, 1.9 cm diameter secondary air holes had a total area equivalent to 27.6% of reactor cross-section. Area for secondary air would be in a 4:1 ratio with primary air holes if the grate aperture was 6.9% of reactor area. A deflector ring above the secondary air holes prevented vertical flamelets—which produce smoke—arising from the holes.

The ND-TLUD was fitted with a grate, then loaded with 2300 g of 6 mm diameter softwood pellets having 7% (ww) moisture. One hundred grams of pellets moistened with 6 g kerosene, then 6 g isopropyl alcohol, were placed on top and lit. The reaction was stopped at the end of pyrolysis, when the gas flame turned from yellow to blue, or extinguished. The remaining char was weighed.

Temperature was measured in the middle of the fuel bed using two K-type thermocouple probes, and a data logger reading every 5 seconds.

Two replications for each combination of grate and riser were necessary to get sufficient precision in temperature values, and verify all measurements.



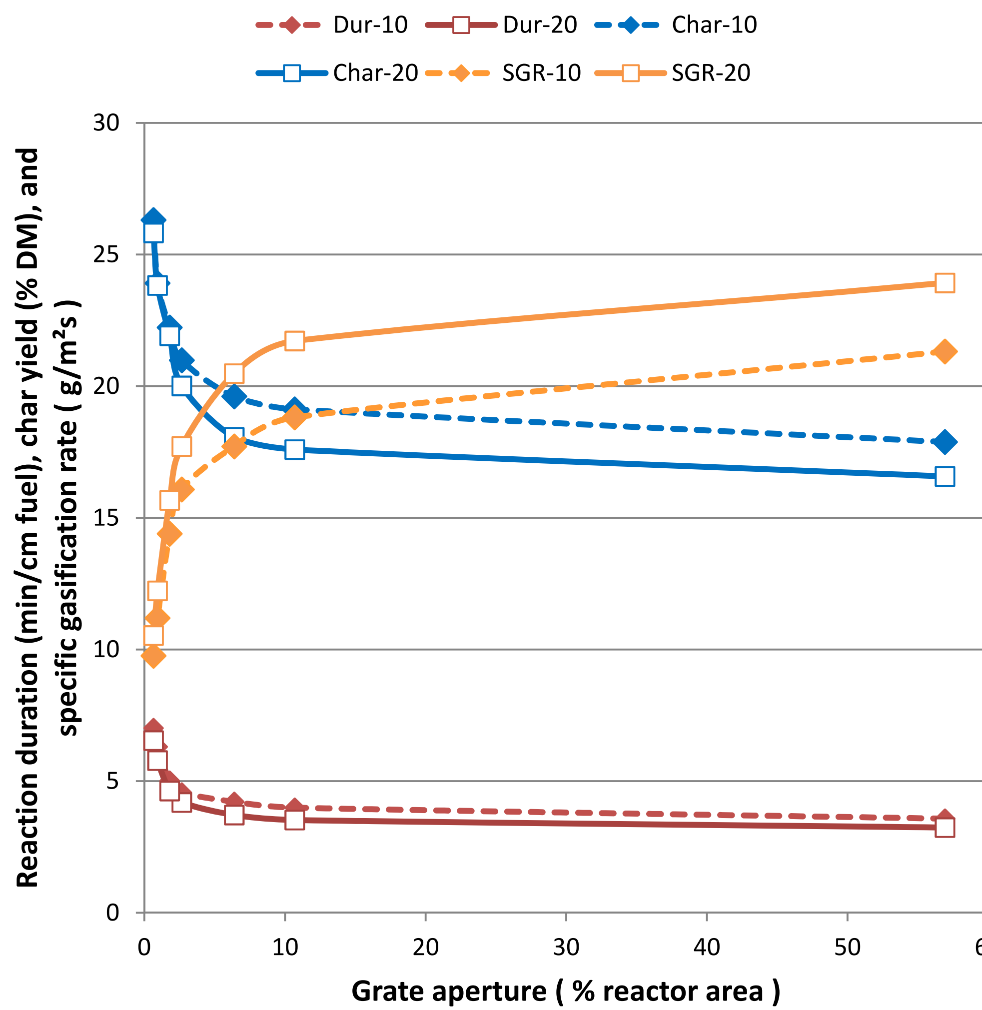
(NOTE: The arrangement and diameter (4.76 mm) of holes affects air flow and may yield slightly different power curves than other methods for air control. The “57%” was a wire mesh. This method has helped to reduce channelling of the pyrolytic front in wood chips, and was repeatable.)

RESULTS:
Doubling riser height increases gasification rate

Increasing the riser height from 10 to 20 cm increased specific gasification rate (SGR), resulting in a shorter duration of the reaction (Dur), and a smaller amount of residual char (Char).

The effect of increasing riser height was greatest at a grate aperture of 6.4%; that may not be the same for other types of gas burner.

Grate aperture (%)	SGR-20 vs. SGR-10 (%)
57.0	+12
10.7	+15
6.4	+16
2.7	+10
1.8	+9
0.9	+9
0.7	+8



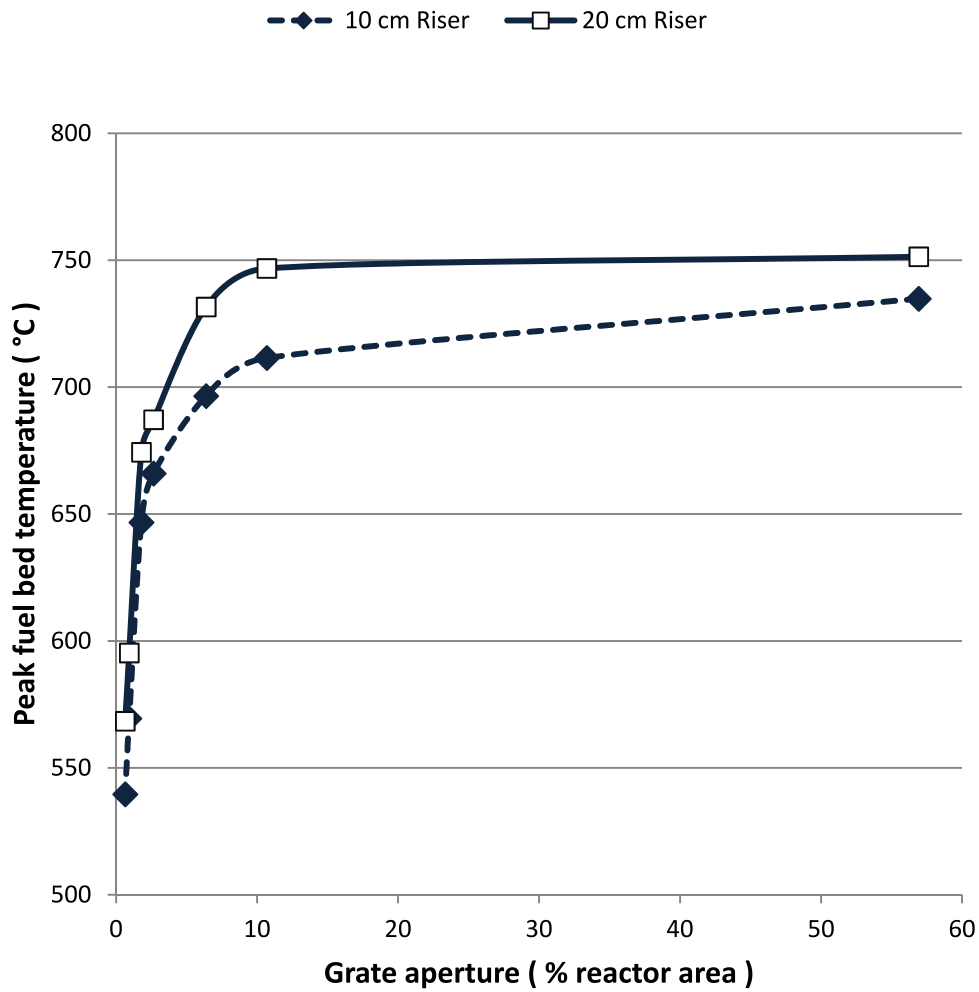
Increasing riser height significantly ($p < 0.001$) decreased Dur & Char, and increased SGR.

Doubling riser height increased maximum temperature of pyrolysis

As the grate aperture was increased from 0.7 to 57% of reactor area, the temperature at the pyrolytic front increased by 200°C.

Doubling riser height increased the peak fuel bed temperature by as much as +35°C.

Grate aperture (%)	Temp-20 vs. Temp-10 (°C)
57.0	+17
10.7	+35
6.4	+35
2.7	+21
1.8	+28
0.9	+26
0.7	+29



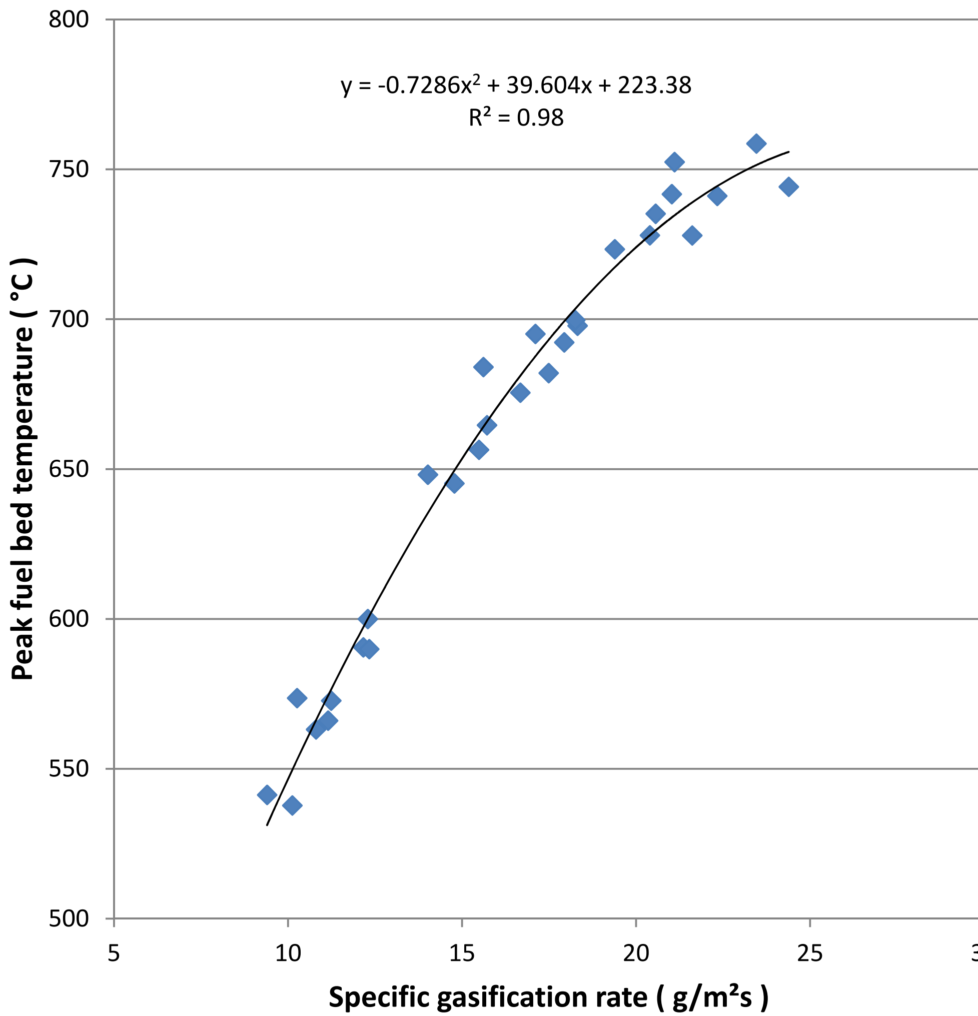
Increasing riser height significantly ($p < 0.001$) increased temperature.

Quadratic relation between gasification rate and fuel bed temperature

For this particular fuel—softwood pellets at 7% moisture—the relationship between bed temperature and gasification rate was broadly linear. However, there was a downward curve in the relation that increased at higher gasification rates.

Since temperature is greatly dependent on the rate of exothermic reactions, the linear trend was not surprising. Speculating, the curve may be related to limited space and oxygen for full flame expansion at the ignition front; full fame heat can't develop.

For the same fuel, we may expect to find a similar relationship using different TLUDs. However, the relationship is likely to vary between fuels, and moisture contents. The curved relation may not exist in fuel beds with large vertical spaces. Temperatures > 1000°C have been observed for vertical pieces of lumber.



The quadratic regression (R^2 = 0.98, AIC = 212) was a significant improvement ($p < 0.001$) over a linear regression (R^2 = 0.95, AIC = 240). Gaps in the distribution of points result from the choice of grate apertures.

DISCUSSION

- **Increasing the grate aperture** will increase the amount of primary air, increasing the rate of gasification and temperature at the flaming ignition front.
- The higher temperature will increase the buoyancy of gases in the fuel bed, resulting in a faster velocity of primary air moving through the grate.
- Changing from a small to wide grate aperture, and increasing the flux of primary air, resulted in a temperature change of 200°C.
- The combination of increasing grate aperture and faster velocity of primary air explain why, at the bottom of the power curve, small increases in grate aperture caused large increases in the rate of gasification.
- As grate aperture increased beyond 10% of reactor area, other factors, such as resistance to gas flow in the fuel/char bed, started to limit gasification rate.

- **Increasing the height of the riser** will increase buoyancy in the burner, and increase the velocity of secondary air moving through the air holes. If that was all that happened, then the gas flame would become leaner.
- However, increasing the height of the riser also caused an increase in gasification rate: we conclude, therefore, that *buoyancy in the burner affects the velocity of both primary and secondary air*.
- Therefore, the fuel/air ratio will not necessarily become leaner, as burner draft increases, but how the ratio changes along the power curve is uncertain, and needs to be studied.

- There will be a **feed-back mechanism** between burner draft and gasification rate. If burner draft increases, primary air velocity increases, leading to faster gasification and more pyrogas, causing a larger gas flame, and greater draft in the burner. As some point, something like resistance to primary air flow at the grate will become a limiting factor.

CONCLUSIONS

Increasing the riser height of the gas burner will increase the draft generated in the gas burner and the velocity of secondary air entering from the sides.

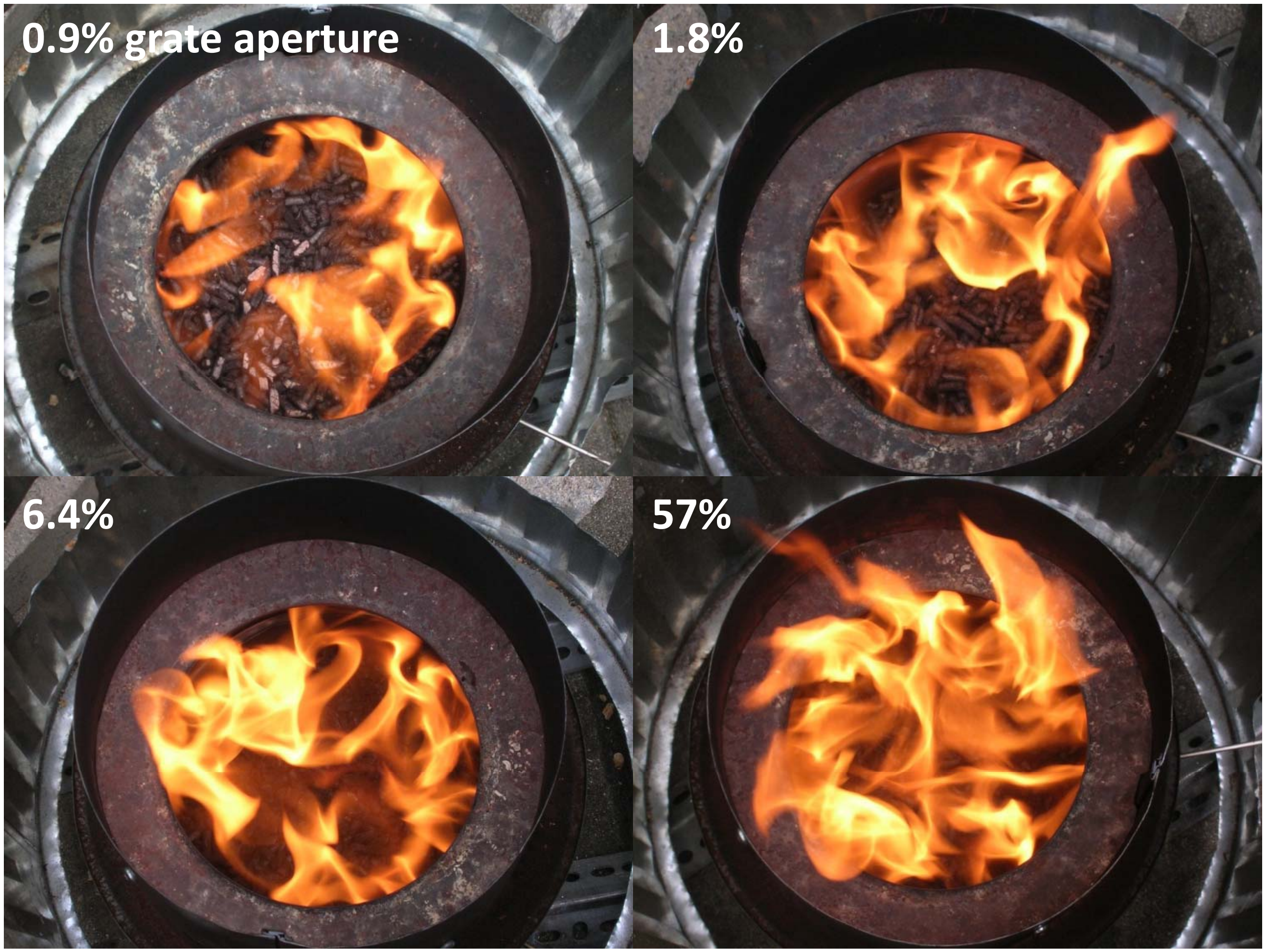
The present experiment showed that a taller riser resulted faster gasification. Therefore the flow of primary air must also be affected by buoyancy in the burner.

For softwood pellets, a 100% increase in riser height resulted in a modest 16% increase in gasification rates. Riser height may have a stronger effect with a more open fuel bed of wood pieces, because it has less resistance to gas flow than a fuel bed of 6-mm pellets.

Experimenting with the grate aperture and riser height revealed that that the regression of fuel bed temperature on gasification rate has a positive slope with a shallow convex curve. The linear trend is easily explained by the heat produced by gasification, but the curve will need corroborating in other fuels where we may find that it doesn't exist.

Acknowledgements

Thanks to Dr. Paul Anderson for urging me to saw my riser in twain.


0.9% grate aperture
1.8%
6.4%
57%