Test of Gas Burners on a Natural-Draft, Top-Lit Updraft Gasifier

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Problem: Poor mixing of secondary air with syngas coming off a natural-draft, top-lit updraft gasifier (ND-TLUD) leads to incomplete combustion of the syngas and the production of soot that blackens the bottom of pots, and is a potential source of indoor air pollution.

Objective: Observe flame characteristics from four different prototypes of syngas gas burner.

Observe soot deposition on the bottom of a cooking pot from the same burners.

Test System

Figure 1. Bottom and top of the ND-TLUD

Tests used a ND-TLUD with an internal height of 11.3 cm, and diameter of 8.3 cm, giving a reactor area (RA) of 54.1 cm^2. There were fifty-seven holes in the bottom for primary air having of 8.3% RA. Increasing the primary air holes to 20.7% RA didn't increase the rate of gasification for pellet fuel.

The ND-TLUD had double-walls with an air space to reduce the loss of heat through sides.

Hardwood pellets (300 g air dry), sieved of fines, were used as fuel. The fire was stated by coating the top layer of pellets in fire started fluid, and ca. 10 mL of 99% isopropyl alcohol.

One of four different gas burners (Table 1) were placed on top of the TLUD before lighting.

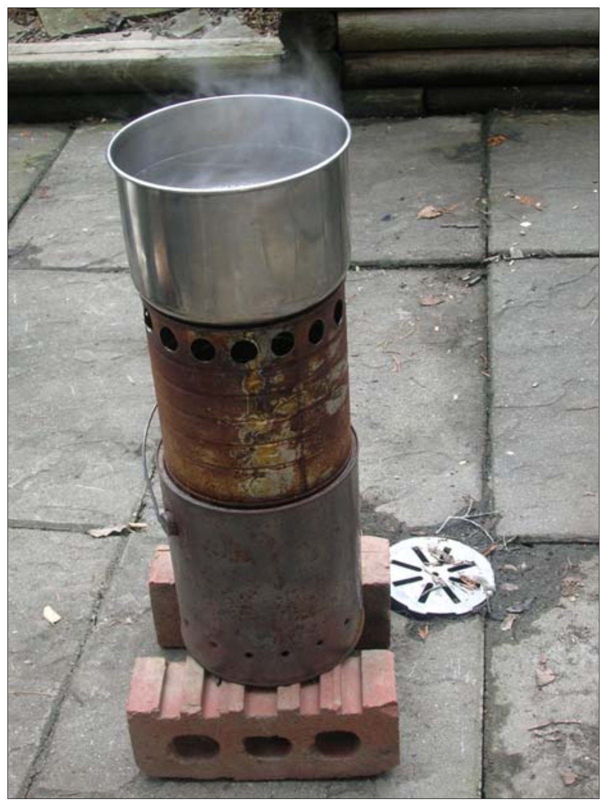
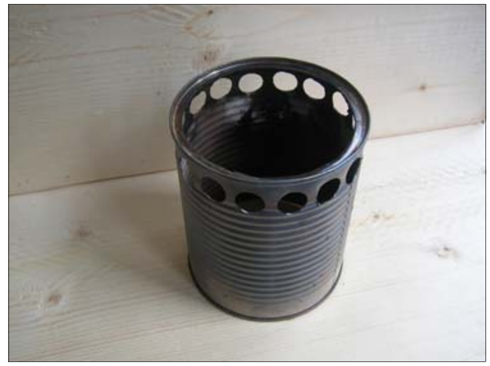
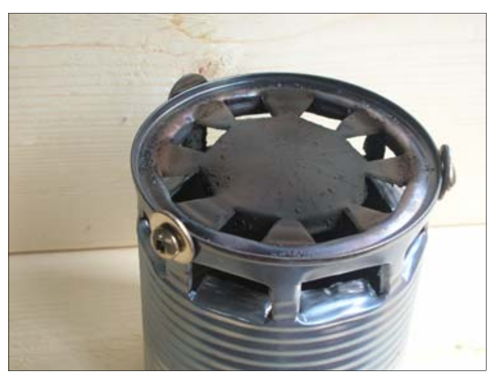


Figure 2. Assembled test system with pot.

The ND-TLUD plus gas burner was enclosed in an open-bottomed shield to protect from wind and support the pot. Ten minutes after lighting the TLUD (allowing gasification to establish), a pot filled with 1.5 L of cold water was placed on the stand.   The pot didn't affect gasification rate.

Table 1. Four different prototype syngas burners that were placed on top of the ND-TLUD

Gas Burners	Characteristics	Bottom View of Burners
OpenChim	An open chimney with no obstruction above the TLUD fuel bed. The cylindrical chimney was 10.1 cm diameter, 12 cm tall and had 16 circular holes around its circumference for secondary air. These holes were 1.45 cm diameter and summed to 49% RA.	
ConcBelow	A gas concentrator disk was paced below the secondary air holes in an OpenChim burner. The orifice of the concentrator disk was 5.5 cm diameter, or 44% RA. The aperture was expected to be large enough to cause a minimum reduction in gasification rate and gas flow through the TLUD (Birzer et al., 2013).	
ConcAbove	A gas concentrator disk was paced above the secondary air holes in an OpenChim burner.	
Rectangular	A cylindrical chimney had a solid base with eight square holes (1.4 x 1.4 cm, 29% RA) to allow the passage of syngas from below. In the side wall of the chimney, eight rectangular holes (2.9 x 1.3 cm, 56% RA) direct secondary air across the syngas holes in the base. The secondary air holes are twice the width of the syngas air holes. After lighting the TLUD, ConcBelow was used for 10 min, then switched to Rectangular.	

Results

Burner geometry and chimney height can affect the rate gasification in a ND-TLUD (Birzer et al., 2013), so the duration of flaming pyrolysis was recorded for all four gas burners, from lighting the fuel to the extinction of the gas fire. The OpenChim, ConcBelow, and Rectangular burners had similar durations (44.8 ± 2.0, 44.4 ± 1.2, 46.6 ± 1.3 min ± se, respectively), but the ConcAbove (53.0 ± 2.6 min ± se) was significantly longer ($p < 0.01$; five replicates). In general, the velocity of the ignition front in the TLUD was roughly 11 cm / 45 min = 0.25 cm / min, gasifying 6.7 g-pellets / min.

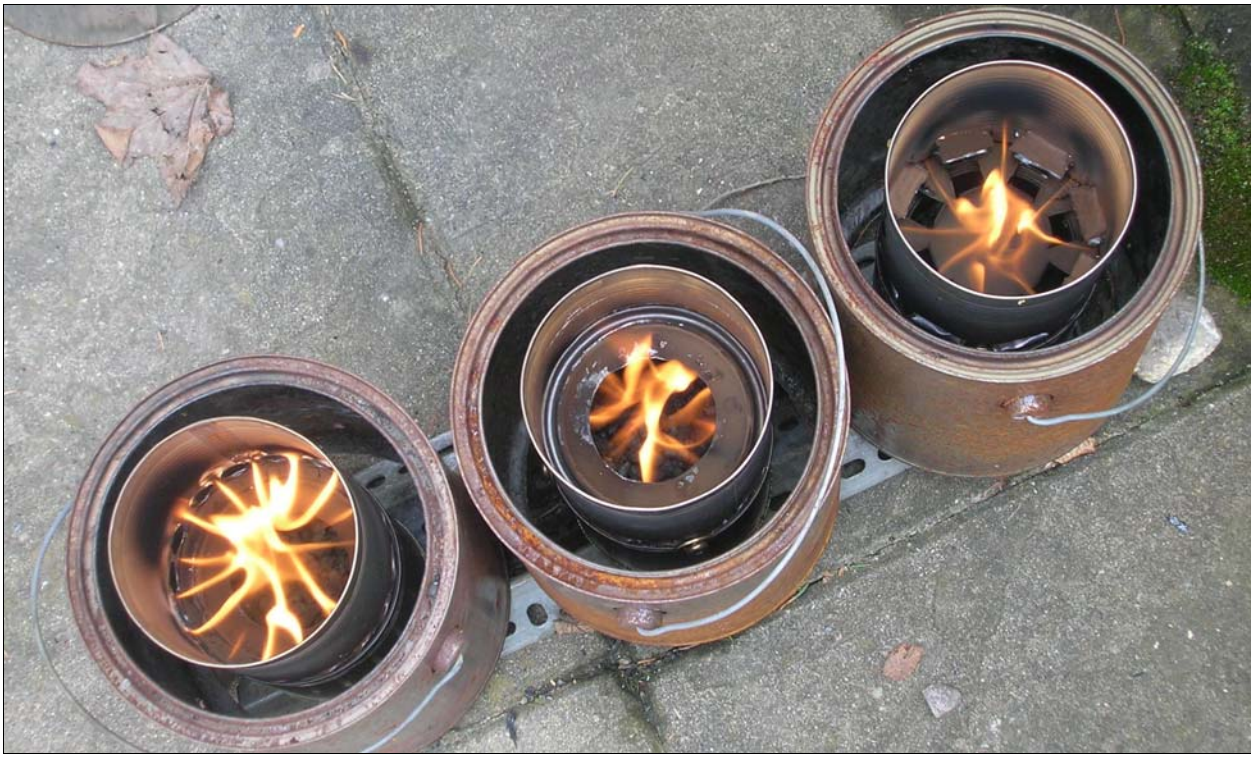


Figure 3. Flame structure for ConcBelow, ConcAbove, and Rectangular syngas burners.

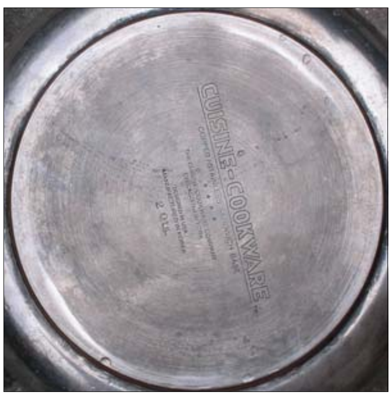
(Youtube videos: http://youtu.be/t1xABAVtasQ ; night time blue flames: http://youtu.be/T6RB9wIPirE)

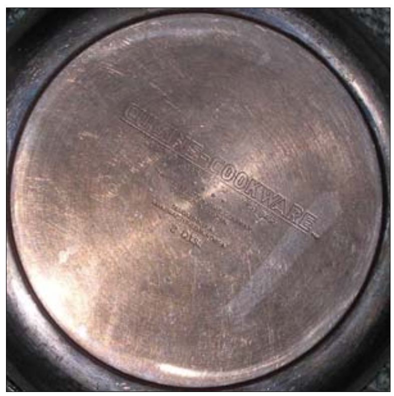
When secondary air is fed from the circumference, the typical gas flame above a ND-TLUD is tall cone with a barely visible blue base, and a yellow-orange center. In a previous trial with an OpenChim style burner, but with small secondary air holes (fuel rich conditions), the syngas formed a torus-like ring of smoke above the fuel bed, but below the secondary air holes. This may be explained by gases expanding at center base of the flame forced the syngas out to the sides. If so, more secondary air and syngas were mixing at the circumference of the burner than would be expected if syngas simply moved vertically in the chimney. The ConcBelow burner corroborated this hypothesis. Instead of concentrator disk creating a poorly mixed diffusion flame in the centre of the chimney, syngas moved through the aperture of the concentrator, and then radially outward towards the secondary air holes where it supported a faint blue flame around the air holes (Figure. 3; best seen in the night time Youtube video).

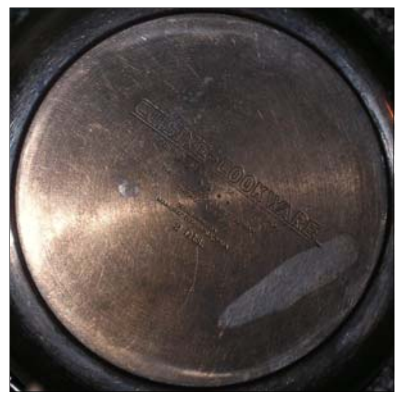
The ConcAbove placed the concentrator disk above the secondary air holes forcing both syngas and secondary air to move through the aperture of the disk. This may have created an increased resistance to air flow compared to other burners that caused the ND-TLUD with the ConcAbove to have a slower gasification rate. It may have also reduced secondary air intake resulting in a richer fuel/air mixture and less complete combustion (see below). The flame from the ConcAbove was taller and contained more orange color than the other three burners.

The Rectangular burner was intended to force mixing of syngas and secondary air prior to ignition by placing secondary air hole directly over the entry point of syngas. The flame produced was clear blue at the circumference, but still formed a yellow cone in the center (Figure. 3; best seen in the night time Youtube video). The flame height was lower with the Rectangular burner than the other three burners. Although the ConcBelow burner was used for the first 10 minutes in the present trial, it was possible to ignite the TLUD with the Rectangular burner on top.

The main objective of this trial was to improve syngas combustion efficiency and reduce soot accumulation on the bottom of pots. To test the burners for soot production, a pot with 1.5 L of cold water was placed on top of the shield containing the TLUD+burner. Soot deposition was visually assessed. Only trace amounts of soot were produced for the OpenChim, ConcAbove and Rectangular burners (Figure 4). However, the ConcBelow burner produced blackened pot bottoms indicative of a richer fuel/air mixture, poorer mixing of secondary air and syngas, and/or a taller flame than the other burners.


Clean pot bottom


OpenChim


ConcBelow


ConcAbove

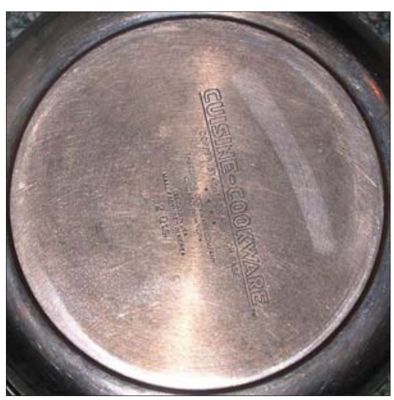

Rectangular

Figure 4. Soot deposition on the bottom of a pot after ca. 35 minutes using four types of syngas burners.

In conclusion, the OpenChim, ConcAbove and Rectangular burners perform equally well for these prototype conditions: the rate of gasification was similar, and soot deposition was low. By contrast, the ConcAbove burner slowed down the rate of gasification and produced sooty-bottomed pots. The Rectangular burner was promising because it had a lower flame height. Future testing will involve larger diameter TLUDs using rough fuel. It may be that the Rectangular burner is not suited to more varied operational conditions.

Reference

Birzer, C; Medwell, P; Wilkey, J; West, T; Higgins, M; MacFarlane, G; Read, M. 2013. An analysis of combustion from a top-lit up-draft (TLUD) cookstove. Journal of Humanitarian Engineering, 2(1). http://www.ewb.org.au/jhe/index.php/jhe/article/view/11