Lighting Cone for Haitian Stoves

GADGIL LAB for Energy and Water Research

Kathleen Lask

AS&T Applied Science & Technology

BERKELEY LAB Lawrence Berkeley National Laboratory

Background

Traditional Haitian stove

About 85% of Haitians use charcoal for cooking,[1] totaling 75% of Haitian energy consumption.[2]

Combustion chamber of the traditional Haitian cookstove is shallow and exposed, making it susceptible to wind and large heat losses.

Problem

Charcoal cookstoves take a long time to light and expose cooks to smoke during ignition.

Approach

Use a lighting cone!

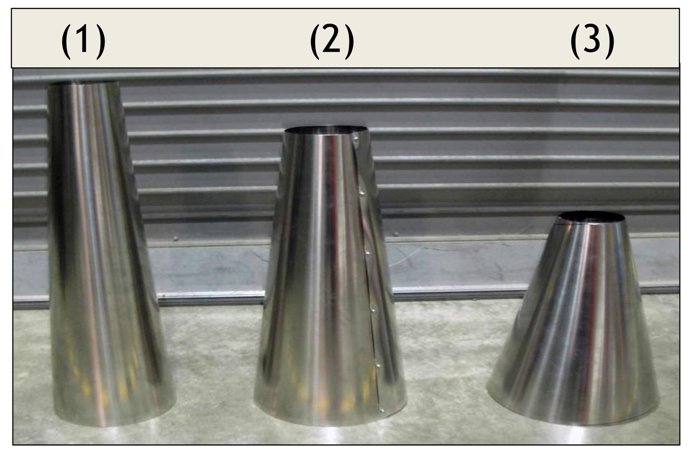
Acts as a removable chimney to:

- Increase natural draft
- Reduce ignition time
- Protect cooks from smoke inhalation

However theoretical understanding of the flow rate and design parameters is needed.

Prototyping

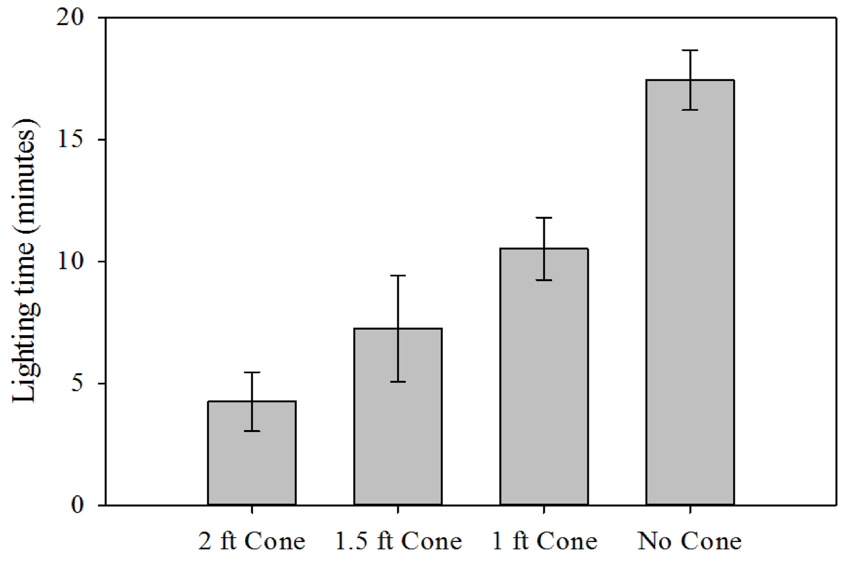
As proof of concept, the ignition time for three cone prototypes was found:



(1) 2 ft x 8 in x 4 in

(2) 1.5 ft x 9 in x 4.5 in

(3) 1 ft x 10 in x 4.5 in



The tallest, narrowest cone reduced lighting time the most.

All graphs show 95% confidence intervals for error bars.

Modeling and Theory

A simplified model was developed for cone design.

- Boussinesq approximation applied to approximate flow behavior.
- A hydrostatic equation was combined with Bernoulli's equation for incompressible flow to calculate velocity.

It is similar to the commonly used Chimney Effect Equation.

$$\vec{v}_{avg} = \sqrt{\frac{2gh\beta}{\alpha}\left(T_{avg} - T_{\infty}\right)}$$

Where:

a is the loss coefficient

T_{avg} is average interior cone temperature

T_{∞} is the ambient room temperature

B is the thermal expansion coefficient

Average calculated velocity $\vec{v}_{avg} = 1.25\ \mathrm{m/s}$

Field Observations

From informal observations and cone demonstrations in Haiti:

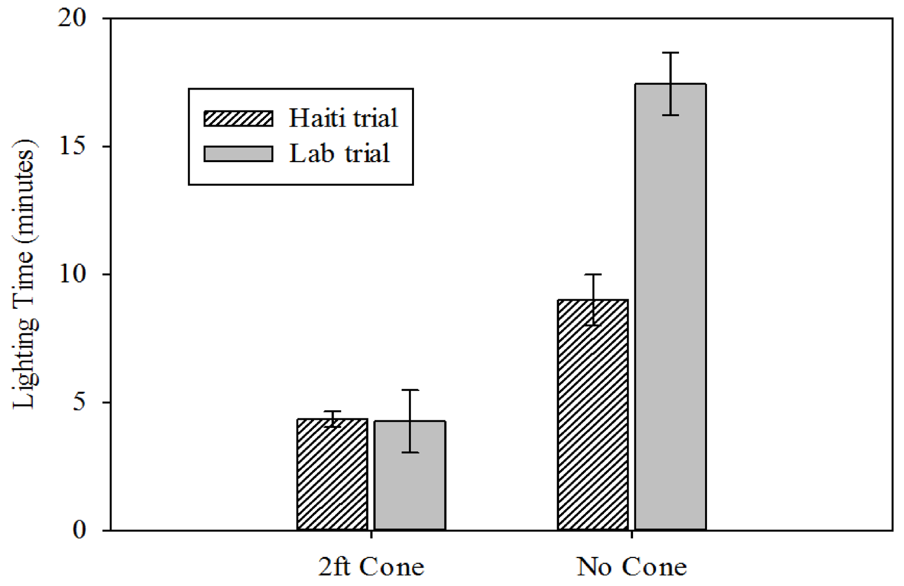
- The cone performed very well in the field, similar to performance in the lab.

Haitian cooks did not notice:

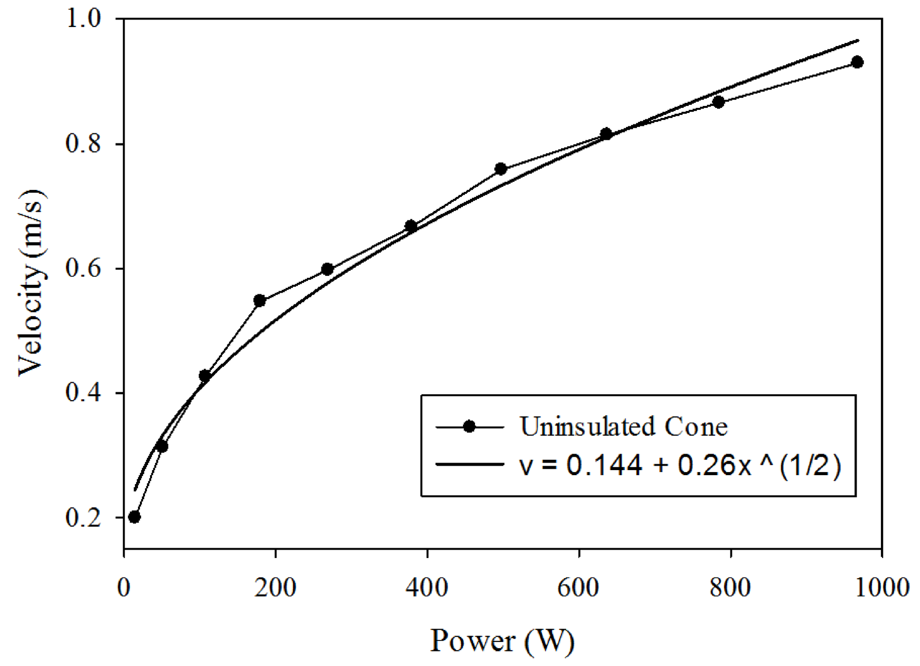
- Time-savings - even though time was reduced by at least 50%

Haitian cooks did notice:

- The cone protected the fire and blocked the wind.
- The cone directed the smoke away from people near the stove.



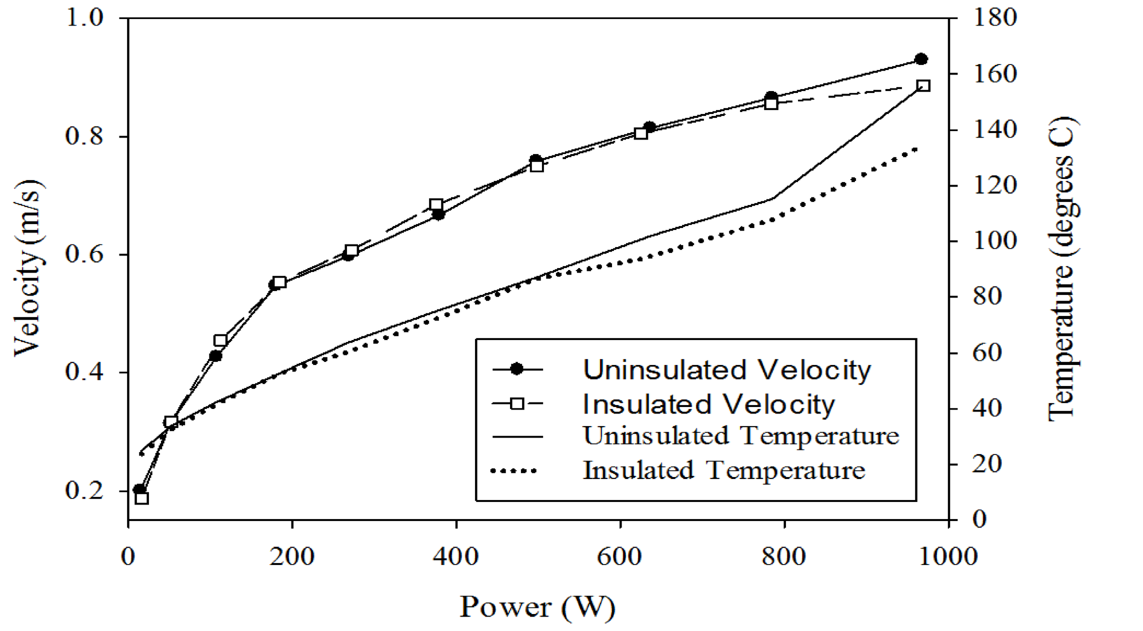
Flow Experiments



The velocity through the cone was derived using CO_2 trace gas experiments, so an electronic "charcoal" bed (e-bed) was used.

Experimental flow equation:

- *A square root curve, as found in the model, was force fit to the data.*
- *Less than 20% error occurs in the comparison, so the model provides an acceptable estimation of the necessary cone dimensions.*



Testing of thermal loss through walls:

- *Cone was thickly insulated*
- *Velocity stayed the same*
- *Temperature was relatively consistent except at higher power inputs*

Temperature Tests

Temperatures of the charcoal stove were measured:

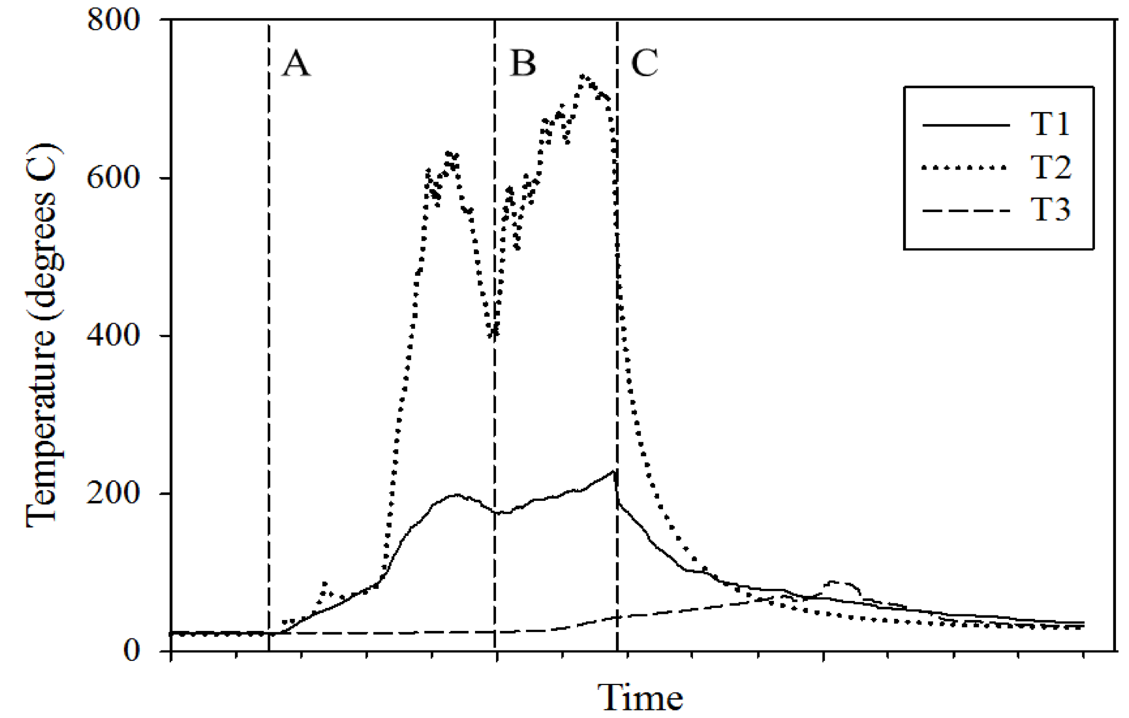
- *At the top of the cone (T1)*
- *At the bottom of the cone (T2)*
- *Underneath the charcoal bed (T3)*

Temperature curves show when:

(A) Fatwood ignites

(B) Fatwood extinguishes

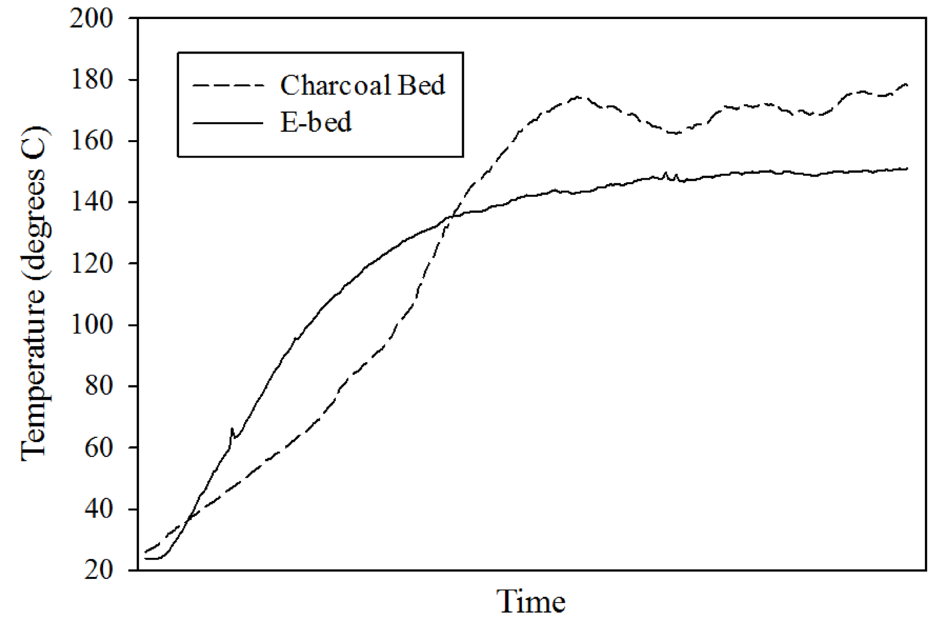
(C) Cone is removed - updraft decreases



The T2 temperatures were compared for the charcoal and e-bed.

The average temperatures between tests varied by 35% for the charcoal bed.

Discrepancies between the charcoal and e-bed were buried in the noise.



Conclusions

- Lighting cones perform well both in the lab and in the field to shorten lighting time.
- The simplified model presented here adequately estimates the influence of cone parameters on its performance.
- Lighting cones appear to be acceptable to the Haitian culture, based on exploratory observations.

[1] Centre de Formation et d'Encadrement Technique, 1997. Diagnostic des communaute vivant au sein et dans le voisinage de la Foret des Pins. Ministere de l'Environnement (MDE)/ (ATPPF), Port-au-Prince, Haiti.

[2] International Energy Agency (IEA), Energy and development. World Energy Outlook 2004. International Energy Agency Publications, Paris, 2004.

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