Solid-Fuel Stove Testing

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## Solid-Fuel Stove Testing

**Title and Subtitle**

**Performing Organization**

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Introduction

• Stove testing is important and necessary
• Lab tests provide valuable information, but are inadequate for predicting field performance
• Field tests are needed
  – Controlled Cooking Test protocol
  – Kitchen Performance Test protocol
Objectives of Our Testing

• Determine if stoves have improved fuel efficiency and lower pollutant emissions compared with traditional stoves
• Provide useful information to PCIA (Partnership for Clean Indoor Air) partners and others disseminating stove technology in the field
• Compare test results with a PCIA partner, Aprovecho Research Center, using a standard test protocol
Methodology

• Tested 14 stove/fuel combinations for performance and emissions
• Used WBT (Water Boiling Test) Protocol
  – Stove cold, 5L water heated to boil, high power
  – Stove hot, 5L water heated to boil, high power
  – Stove hot, 5L water maintained at simmer, low power
• Captured emissions with a hood and duct system
• Measured CO$_2$, CO, and THCs (total hydrocarbons) with CEMs (continuous emission monitors)
• Measured PM (particulate matter) with filter method and ELPI (Electrical Low-Pressure Impactor)
• Sampled PM for OC/EC (organic carbon/elemental carbon) analysis
Stove testing in emissions hood

Continuous emission monitors
Stoves tested: A Ecostove, B VITA stove, C UCODEA charcoal stove, D WFP rocket stove, E 3-stone fire, F Philips stove, G 6-brick rocket stove, H Lakech charcoal stove, I NLS stove, J UCODEA rocket stove
Results

Time to Boil
## Results

### Time to Boil

![Graph showing time to boil for different stoves and materials.]
## Performance

<table>
<thead>
<tr>
<th></th>
<th>Time to boil</th>
<th>Thermal efficiency</th>
<th>Specific fuel consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High power</td>
<td>Low power</td>
<td>High Power</td>
</tr>
<tr>
<td></td>
<td>Cold start</td>
<td>Hot start</td>
<td>Cold start</td>
</tr>
<tr>
<td>3-Stone, fir</td>
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<tr>
<td>3-Stone, oak</td>
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<tr>
<td>VITA, fir</td>
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<tr>
<td>VITA, oak</td>
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<tr>
<td>WFP Rocket, fir</td>
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<tr>
<td>WFP Rocket, oak</td>
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<tr>
<td>Philips, fir</td>
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<tr>
<td>Philips, oak</td>
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<tr>
<td>6-Brick, oak</td>
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<tr>
<td>Ecostove, oak</td>
<td>☐</td>
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<tr>
<td>UCODEA-R, oak</td>
<td>☐</td>
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</tr>
<tr>
<td>UCODEA, charcoal</td>
<td>☐</td>
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</tr>
<tr>
<td>Lakech, charcoal</td>
<td>☐</td>
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<tr>
<td>NLS, garment waste</td>
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</tr>
</tbody>
</table>
CO/CO2 Ratio, High Power

CO/CO2 Ratio, Low Power
PM2.5 Emissions, High Power

PM2.5 Emissions, Low Power
WFP (World Food Program) Rocket Stove
+ Excellent overall performance
+ Low emissions
+ Low cost
- Short lifetime
Philips Stove
+ Best overall performance
+ Lowest emissions
- More expensive than other stoves
- Shorter pieces of fuel required
Ecostove
+ Chimney reduces indoor air pollution
+ Griddle top designed for making tortillas or frying foods
- Not well suited for boiling water or cooking in a pot
* Could be improved for cooking with a pot by providing a removable disk on top to directly expose bottom of pot to hot combustion gases
Conclusions

• Stoves with smaller heated mass tend to have:
  – Faster time to boil
  – Better fuel efficiency
  – Lower pollutant emissions
Conclusions

• Comparison of results between labs showed that results can be replicated when the same stove and fuel are tested using the WBT protocol.

• Ability to replicate results could be improved by:
  – Detailed documentation of stove operation technique
  – Consistent training of stove operators
  – Specifications for the fuel
  – Improved specifications and quality control for stove dimensions and materials
Further details and information:


- [www.pciaonline.org/research](http://www.pciaonline.org/research)
Acknowledgements

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• Michael Hays and Pamela Barfield of EPA/ORD
Our next stove tests

• Will include latest mass-produced stoves
• Will compare performance and emissions with varying moisture content of fuel
• Will include measurements of CO, CO$_2$, CH$_4$, NMHC, PM, BC/EC/OC
• Will begin January 2010
• Comments and advice welcome!