Natural draft gasifier water heater for rural households

In developing countries, biomass is used as a primary source of energy for cooking and water heating. Use of the biomass in traditional cook stoves creates serious health problems to rural women and children. Biomass gasification appears to have a significant potential for domestic cooking applications. However, due to some cultural and design barriers, the gasifier cook stoves are not widely accepted by the rural households.

Households in rural areas of developing countries are heavily dependent on wood and other biomass fuels for domestic thermal energy requirements such as cooking, room heating, heating water for bathing and boiling water for drinking. Although gasifier stoves are in general efficient and clean burning, issues like the need for fuel processing and behavioural changes in cooking practices have limited the widespread use of general purpose gasifier cook stoves. However, there is scope for introducing gasifier based thermal devices for specific applications. We have developed a water heater (for bathing water) based on the T-LUD (top lit updraft) micro-gasification principle (Anderson et al 2007), and have got encouraging results at the laboratory level as well as in field level testing.

Water heating stoves for bathing

In the rural areas of Maharashtra State, in Western India, households generally use two cook stoves, one for cooking and the other for heating water for bathing. The water heating stove is kept just outside the house. The choice of these two biomass stoves depends upon the economic condition of the family. Generally poor families purchase the cooking stove from the local manufacturer (potter) and for water heating use a three stone fire. Middle class and lower middle class families may purchase two stoves – one for cooking and one for water heating. The middle and upper middle class families in rural areas use LPG or kerosene stoves for cooking and a locally manufactured fire wood fuelled metallic water heater called a ‘bomb’ (due to its capsule like shape), as shown in Figure 1. However, these stoves are costly, inefficient and polluting.

The general practice followed in rural families is that the eldest woman (generally the grandmother) sits in front of the water heating stove and continuously feeds the fuel in the stove. Generally she sits in front of the stove daily for about 2-3 hours in the morning. The young children in the house sit or play around the grandmother, as the younger women (the mothers) remain busy in other house work. During the winter season the elderly men sit near the water heating stove for warmth. Even though the water heater is not inside the house, it does contribute to smoke exposure for the elderly and the children in the household.

Natural draft gasifier water heater

A design of the natural draft gasifier stove requiring batch feeding was developed to address this issue. The design is shown in Figure 2. The stove is fitted in a supporting metallic frame. The primary air flow through the stove body for pyrolytic gasification is controlled by a manual adjustment, provided at the lower end of the stove. The fuel gets hot secondary air for combustion by passing through an air gap between the fuel holder and the metallic frame. Sufficient combustion volume is provided between the fuel holder and the bottom of the pot, which allows the combustible gas to burn totally and cleanly. The circular metal plate with a central hole above the fuel holder, creates turbulence, and provides better mixing of secondary air with the combustible gas. A skirt is provided around the water heating pot, to increase the contact area between the pot and flame.

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Figure 1: Water heater bomb

Figure 2: Natural draft gasifier water heater design
Laboratory performance of the stove

The stove was tested for emissions and efficiency under laboratory conditions. The CO was measured in PPM by the CO level meter (TESTO 315-2). Readings were recorded every minute throughout the stove operation period. The CO level meter was kept 1 meter away and 1.6 meters above the mouth of the stove. The flame temperature was recorded with the help of a thermocouple with a digital read out unit. Efficiency was measured using the standard procedure of a water boiling test.

The general observations are summarized below:
- Time for boiling 5 litres of water = 22 minutes
- Thermal Efficiency = 31.5%
- The natural draft stove has a tall chimney between the fuel holder and the bottom of the cooking pot (i.e., between the gasification zone and the gas combustion zone). This provides better mixing of secondary air with the combustible gas and reduces the CO emission
- The CO emission is high only for a few minutes at the end during the char burning
- Fuel charge ~ 1 kg of fuel wood

The performance of the stove was also compared with that of a traditional ‘bomb’ water heater. The gasifier heater was observed to be superior in terms of efficiency as well as reduction in emissions (Table 1). It was also observed that the hot gas temperature remains high and stable over a longer time period in the case of the gasifier water heater as compared to the ‘bomb’ water heater. The variation of hot gas temperature and carbon monoxide concentration is shown in Figure 4.
Performance of the stove in the user’s home

As the laboratory performance of the stove appeared satisfactory, the water heater was given to a user for testing. As the stove is for heating water for bathing, it is not necessary to bring the water to a boil. It is just required to heat the water up to 70-75 °C. Based on the user’s demand, the water holding capacity of the stove was increased to 30 litres.

The stove continuously operates for 45 minutes for one batch of fuel (1 kg). During this period, the temperature of 30 litres of water reaches to about 72°C from room temperature. The stove has been used by the user for more than one year.

The test household is located in the western region of Maharashtra state of India. This is a low rainfall area and there is an existing tradition of using a traditional ‘bomb’ for water heating. In this region the majority of the rural people use the locally abundant prosopis or mesquite as a source of fuel wood, since it is easily available and in large quantity. Along with this fuel sometimes people use wood from trees like Neem and Mango. The water heater has been used with a mix of all the common fuel wood types used in the region and has been found to give satisfactory performance.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Gasifier Water Heater</th>
<th>‘Bomb’ Water Heater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Efficiency</td>
<td>31.5%</td>
<td>19.07%</td>
</tr>
<tr>
<td>Average CO emission</td>
<td>2 ppm</td>
<td>52 ppm</td>
</tr>
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Table 1: Comparison of gasifier water heater and traditional ‘bomb’ heater

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References


Profiles of the authors

Sanjay K. Babar M.Sc. (Physics) is currently engaged in research on gasifier cook stove designs working on two funded projects in this area. Sanjay is doing doctoral research in the Department of Physics, University of Pune, India and is a lecturer in Physics at D.Y. Patil College of Engineering, Pune, India.

Dr Priyadarshini Karve has been working on improving stove designs, experimenting with upgrading of biomass fuels, and dissemination of biomass energy technologies in rural areas since 1991. Currently, Dr Karve is working full time as Project Co-ordinator, ‘Commercialisation of Improved Biomass Fuels and Cooking Devices in India – Scale Up project’, at Appropriate Rural Technology Institute (ARTI) and also as Director, Samuchit Enviro-Tech (SET) Pvt. Ltd.

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