An Improved Gasifier Stove for Institutional Cooking

S.C. Bhattacharya*, San Shwe Hla, M. Augustus Leon and Kapila Weeratunga

Energy Program, School of Environment, Resources and Development
Asian Institute of Technology
P.O.Box 4, Klong Luang, Pathumthani 12120, Thailand

Abstract

A natural cross-draft gasifier stove has been developed at the Asian Institute of Technology for institutional kitchens. This paper presents the design and experimental results of this stove using wood and rice husk briquette as fuels.

The gasifier stove consists of five main parts i.e., fuel storage hopper, reaction chamber, primary air inlet, combustion chamber and pot support. The biomass fuel is loaded into the metallic hopper from the top. The cover of the hopper is next placed in position. For ignition, a flame torch is held below the grate by opening the ash pit door. During the start-up, a considerable amount of smoke is generated from the stove; in about fifteen minutes, the reactor starts producing a combustible gas after which a flame appears inside the combustion chamber. Once the flame appears inside the combustion chamber, the stove operates with practically no smoke. Also, the stove could be operated continuously by refilling the fuel into the fuel hopper at 1-2 hour intervals.

Efficiency and wattage of the gasifier stove were determined by means of the water boiling test for a number of combinations fuel, pot size and pot support. Highest efficiency of the stove has been found to be about 27 % for wood using a two-pot configuration. The gasifier can be operated continuously by simply refilling the fuel into the hopper.

Keywords: Improved stove; Gasifier stove; Biomass stove; Briquette; Stove efficiency

1. Introduction

Biomass combustion provides basic energy requirements for cooking and heating of rural households and for process in a variety of traditional industries in the developing countries. In general, biomass energy use in such cases is characterized by low energy efficiency and emission of air pollutants.

Biomass fuels currently used in traditional energy systems could potentially provide a much more extensive energy service than at present if these were used efficiently. For example, new stove designs can improve the efficiency of biomass use for cooking by a factor of 2 to 3. Thus, the energy service provided by biomass in this case could be potentially provided by one third to half of the amount of biomass used currently; the amount of biomass saved through efficiency improvement can be used to provide further energy services. According to a recent study, the total potential of saving biomass used for domestic cooking through substitution of the traditional stoves by improved ones in six Asian countries (China, India, Nepal, Pakistan, Philippines and Sri Lanka) is about 277 million tons/year (**Bhattacharya et. al, 1999**); the saving amounts to about 36% of the biomass consumption for cooking in these countries at present.

Exposure to smoke from indoor biomass burning is known to cause acute respiratory infection and chronic lung disease. As pointed out by **Kammen** (1999), some studies have also linked wood-smoke to an increased incidence of eye infections, low birth weight and cancer. Considering the severity of indoor air problem, **Reddy et al.** (1997) cautions, "because a large portion of the population is exposed, the total indoor air pollution exposure (from domestic biomass combustion) is likely to be greater for most pollutants than from outdoor urban pollution in all the world's cities combined."

A large number of improved wood fired cooking stoves have been developed in different countries, most of these basically aim to overcome the two major drawbacks of traditional stoves, namely low efficiency and indoor air pollution. Gasification of biomass (and use of the product gas) appears to be an interesting option for its clean and efficient use for cooking. Networks of producer gas supply have been reported to exist in Shandong and Hubei provinces of China (**Keyun, 1993**). The gasifiers use agricultural and forest residues and one gasifier set can supply about 100 households with gas for heating and cooking. A gasifier stove is essentially a small gasifier-gas burner system.

The main advantage of a gasifier stove is that almost total elimination of smoke is possible with this design. A forced downdraft gasifier domestic cooking stove producing about 12 m3/hr of gas is commercially manufactured in China. Considering that it is normally not possible to operate a blower in rural areas of most of developing countries due to lack of electricity supply, a natural draft gasifier stove appears to be a particularly interesting concept. A natural crossdraft gasifier stove has been developed at the Asian Institute of Technology (AIT) for institutional kitchens. This paper presents the design and experimental results of this stove using wood and rice husk briquette as fuels.

2. Gasifier stove and Fuels

2.1 Gasifier Stove

The gasifier stove consisted of five main parts i.e., fuel storage hopper, reaction chamber, primary air inlet, combustion chamber and pot support. Each part of the stove was independent and could be attached together by bolts and nuts. The details of the gasifier stove are shown in Figure 1.

Fuel hopper:

It was made of mild steel sheet and was located above the reaction chamber. The fuel storage hopper had a height of 70 cm and a square cross-section (17 x 17 cm). The upper end of the hopper was covered by a lid which was designed for ease of loading of the fuel and preventing gas leakage by filling water into a water rail fixed on the upper side of the hopper.

Reactor:

The reactor is the heart of the stove where producer gas is produced. The outside wall of the reactor was made of mild steel sheet and outside dimension of the reactor was 36 x 36 x 44 cm. The inside wall was made of bricks cemented together by Castable-13 refractory. The dimension of the reaction chamber was 17 x17 x 22 cm and it had a grate installed at its bottom. Above the reactor was the fuel chamber from where fuel flowed down by its gravity to the reaction chamber. The grate was made parallel steel bars of diameter 5 mm with 2 cm spacing in between. Ash from reactor could fall down freely through the grate and accumulated in an ash collector. A mild steel door (22 x 22 cm) was provided at the front of the ash pit for removing the accumulated ash.

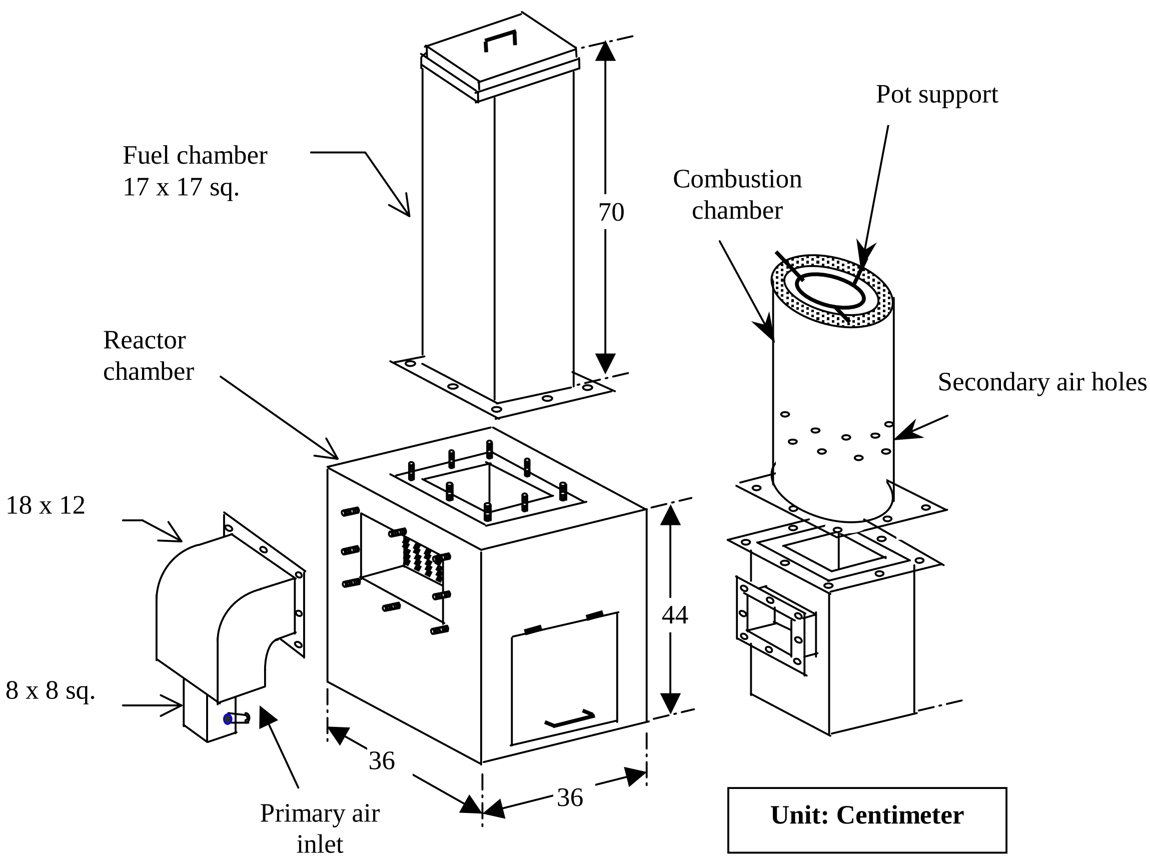


Figure 1. Configuration of the improved gasifier stove

One side of the reaction chamber was a primary air inlet, though which primary air entered; producer gas from the reaction chamber passed to a cylindrical combustion chamber at the opposite side.

Primary air inlet:

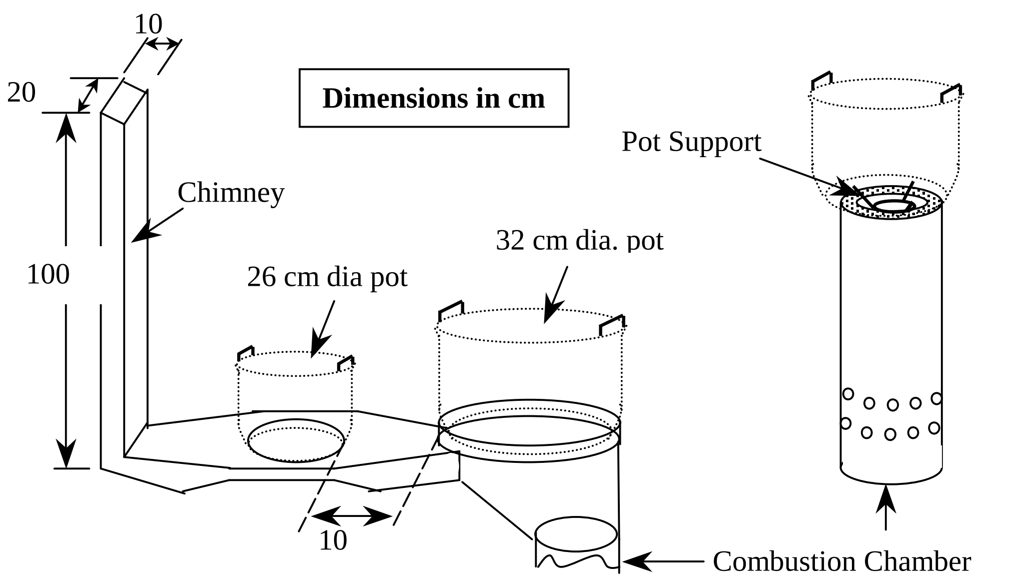
The primary air inlet was made of 2 mm thick mild steel sheet and attached on one side of the reactor. A sliding piece of mild steel sheet was provided to control the amount of primary air supply to the reaction chamber for regulating the heat output of the stove.

Combustion chamber:

Inside this part, the gas produced in the reaction chamber burned on coming in contact with secondary air. The secondary air entered the combustion chamber through a series of holes in its wall.

***Pot support*:**

Two options were tried as shown in Figure 2. In one, the pot was simply put above the combustion chamber with three small supports. In the other option, two pots were used in order to utilize heat more effectively. Two two-pot configurations were tested. The first one was designed to use two different sizes of pots having diameter of 32 cm and 26 cm. The second one was fabricated to operate with two pots having same size (32 cm diameter). Figure 3 presents the detailed dimensions of the pot supports.

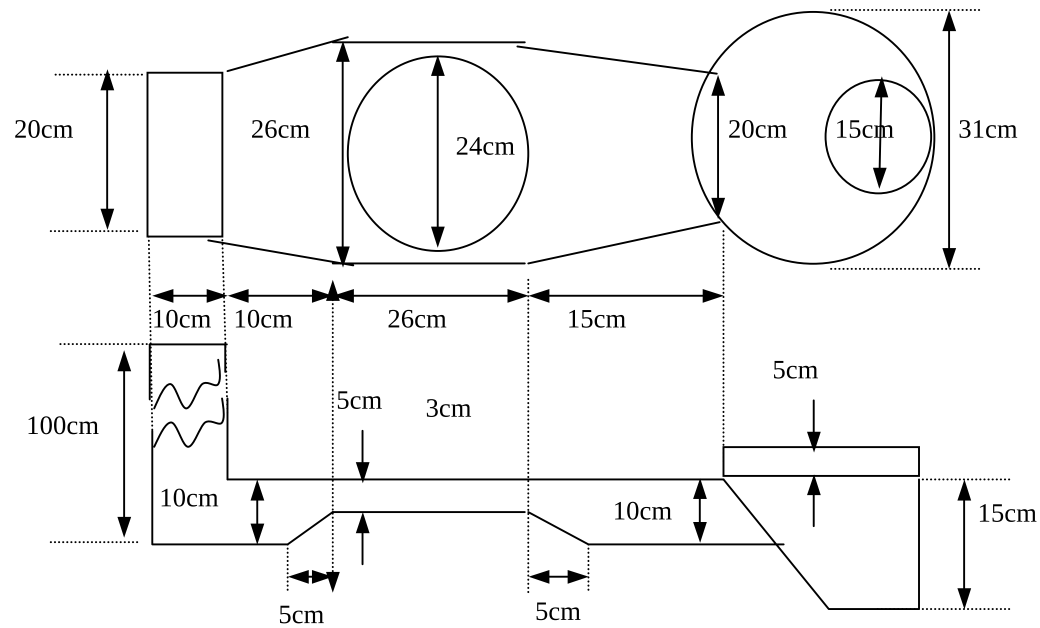


(i) Two-pot configuration (ii) Single-pot configuration

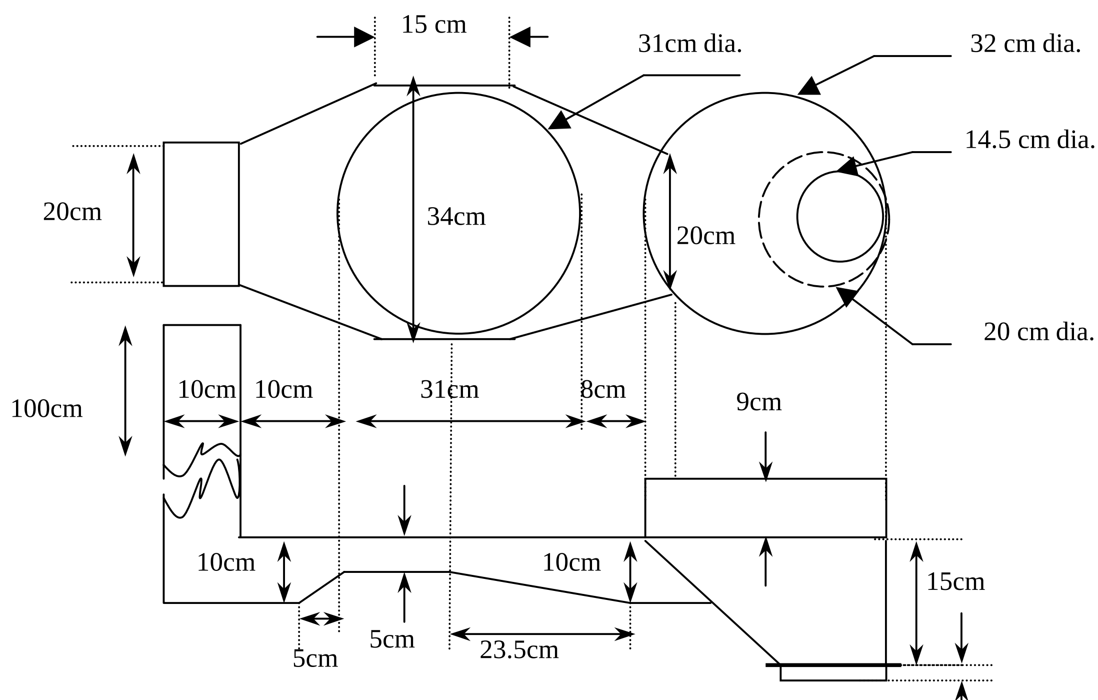
Figure 2: Two different configurations of pot setting

2.2 Biomass Fuels

The stove was tested with two biomass fuels, wood chips and ricehusk briquettes.



(a)



(b)

Material: 1.5 mm thick mild steel sheet

Figure 3: Detailed dimensions of two different two-pot supports

Wood:

Wood chips were cut from eucalyptus logs and sun-dried for a week. Fuel properties of the wood chips are given in Table 1.

Rice-husk briquette:

Rice-husk briquettes produced by a heated-die screw-press machine were used as fuel after splitting into small pieces. The properties of the briquette-pieces are presented in Table 2.

Table 1. Average properties of wood chip

Apparent density[1], (kg/m^3)	784
Bulk density[1], (kg/m^3)	350
Higher heating value[2] (dry basis) (MJ/kg)	18.99
Lower heating value (dry basis) (MJ/kg)	17.50
Lower heating value (wet basis) (MJ/kg)	16.22
Proximate analysis[3] (wet basis)	
Moisture content, (%)	7.31
Volatile matter, (%)	75.07
Fixed carbon, (%)	17.09
Ash, (%)	0.53

Table 2 Average properties of rice husk briquette

Apparent density[1], (kg/m^3)	1006
Bulk density[1], (kg/m^3)	620
Higher heating value[2] (dry basis) (MJ/kg)	16.04
Lower heating value (dry basis) (MJ/kg)	14.63
Lower heating value (wet basis) (MJ/kg)	13.76
Proximate analysis[3]	
Moisture content, (%)	5.93
Volatile matter, (%)	61.02
Fixed carbon, (%)	16.59
Ash, (%)	16.46

3 Experimental procedures and variables

The biomass fuel was loaded into the metallic hopper from the top. The cover of the hopper was next placed in position and some water was filled into the small pool of the cover to prevent air leakage from the top. For ignition, a flame torch was held below the grate by opening the ash pit door. During the start-up, considerable amount of smoke was generated from the stove; in about fifteen minutes, the reactor started producing a combustible and a flame appeared inside the combustion chamber. Once the flame appeared inside the combustion chamber, the stove operated with practically no smoke. The gas mixed with secondary air entering from the sides of the combustion chamber and gave a forceful flame. Also, the stove could be operated continuously by refilling the fuel into the fuel hopper at 1-2 hour intervals. The stove during operation is shown in figure 4.

Efficiency and wattage of the gasifier stove were determined by means of the water boiling test for a number of combinations fuel, pot size and pot support.

4 Results and discussions

The effects of type of fuel, pot size and pot support on thermal efficiency of the gasifier stove are shown in Table 3.

4.1 Effect of pot size

As indicated in Table 3, the stove efficiency was higher for bigger pot size; this is due to the fact that the contact area between the flue gas and the pot was higher in case of the bigger pot so that heat transfer to the pot was also higher. For the one-pot configuration, for a 32 cm diameter pot, efficiency of the stove was higher by about 3% compared with a 26 cm diameter pot.

Figure 4: Gasifier stove under testing

4.2 Effect of type of fuel

It was found that efficiency of the stove using rice-husk briquette as fuel was less compared with that in case of wood. While using the rice-husk briquette as fuel, ash-accumulation rate at the reactor chamber was far higher due to high ash content of rice-husk. Accumulated ash was taken out through the grate by means of an ash scrapper. With the falling ash, some small burning char particles also fell to ash pit; the lower efficiency of the stove with rice-husk as fuel was due to higher combustible loss with ash.

4.3 Effect of height of combustion chamber

The height of the combustion chamber is an important parameter of stove design. For one-pot configuration, it was observed that the gas from the reactor could not burned efficiently and some smoke emerged from the combustion chamber if the height was too low. Using a too long combustion chamber with one pot-configuration resulted in clean combustion but lowered the efficiency of the stove due to increased distance of the pot bottom from the flame. By trial and error, the optimum height of the combustion chamber for one-pot configuration was estimated to be 42 cm.

Table 3. Performance of the modified gasifier stove with different configurations

Options							Based on LHV_d		Based on LHV_w	
Fuel	Pot dia. (cm)	Pot support	C.C* height (cm)	Exp. No.	Fuel consmd (kg/hr)	Output wattage (kW)	η (%)	Input wattage (kW)	η (%)	Input wattage (kW)
Wood	26	One pot setting	42	1	2.42	1.11	9.79	11.30	10.57	10.48
				2	2.28	1.05	9.89	10.66	10.67	9.88
				3	2.37	1.15	10.42	11.08	11.24	10.27
Wood	32	One pot setting	42	1	2.33	1.53	13.50	11.31	14.58	10.48
				2	2.12	1.33	12.87	10.29	13.89	9.54
				3	2.35	1.58	13.85	11.40	14.94	10.57
Briquette	32	One pot setting	42	1	3.03	1.24	10.12	12.30	10.76	11.57
				2	3.45	1.48	10.56	14.01	11.23	13.18
				3	3.48	1.46	10.31	14.14	10.97	13.29
Wood	26, 32	Two pot setting	42	1	5.00	3.94	16.22	24.31	17.51	22.53
				2	5.14	4.28	17.16	24.96	18.51	23.14
				3	4.67	3.72	16.38	22.71	17.68	21.05
Briquette	26, 32	Two pot setting	42	1	6.05	3.14	12.78	24.59	13.59	23.13
				2	5.90	2.93	12.21	23.98	12.98	22.56
				3	5.85	3.22	13.52	23.79	14.37	22.37
Wood	32, 32	Two pot setting	32	1	4.25	5.24	25.35	20.68	27.35	19.17
				2	4.19	5.06	24.82	20.37	26.78	18.88
				3	4.45	5.80	26.77	21.65	28.88	20.06
Briquette	32, 32	Two pot setting	32	1	4.62	3.20	17.07	18.76	18.15	17.64
				2	4.83	3.40	17.29	19.64	18.38	18.47
				3	4.56	3.32	17.95	18.52	19.08	17.42
Wood[1]	32, 32	Two-pot	32	1	3.06	3.64	24.47	14.87	26.40	13.78
Briquette[1]	32, 32	Two-pot	32	1	4.28	2.92	16.80	17.41	17.86	16.37

*Combustion Chamber
[1]Tests were done by refilling the fuel for long time operation.
The rests were tested with one batch fuel loading.

For the two-pot configuration, it was observed that a short combustion chamber (32 cm) worked better due to the attached chimney. The highest efficiency of the stove was achieved by using a two-pot configuration and a combustion chamber height of 32 cm.

4.4 Effect of chimney

Attaching a chimney (1m height) to the stove creates additional draft and increases flow of air into to the reaction chamber; this causes an increase in fuel consumption rate.

For a two-pot stove configuration with a chimney of height 1 m, as shown in Figure 3, the fuel consumption was found to be two times the consumption without any chimney. It was observed that thermal efficiency of the stove was increased and cleaner combustion was achieved on attaching the chimney. Also, the ignition time was about 5 minutes less than that required without any chimney.

5. Concluding remarks

A cross-draft gasifier stove that can operate continuously and practically without any smoke has been developed. The highest efficiency of the stove is about 27% with a two-pot configuration using wood chips as fuel.

One common problem of biomass fired stoves is the need to attend to the fire and feed fuel at frequent intervals; the gasifier stove developed at AIT is practically free of this problem. The stove can be left largely unattended and needs refilling of the fuel into the hopper at about two-hour intervals.

Acknowledgement

The financial support by the Swedish International Development Co-operation Agency (Sida) for this study in the framework of the project "Renewable Energy Technologies in Asia - A Regional Research and Dissemination Programme" is gratefully acknowledged.

References

1. Bhattacharya, S.C., R.A. Attalage, M. Augustus Leon, G.Q. Amur, P.A. Salam and C. Thanawat, 1999, Potential of biomass fuel conservation in selected Asian countries. Energy Conversion & Management, Vol. 40, pp. 1141-1162.
2. Kammen, D.M., 1999., http://www.undp.org/seed/energy/policy/ch_5.htm, 12 December, 1999.
3. Keyun, Deng, 1993, State of the art of the utilization of agricultural residues and other biomass and identification of priority projects in China in Agricultural Biomass for Sustainable Rural Development, ESCAP, Bangkok.
4. Reddy Amulya K.N., 1997, Robert H. Williams, and Thomas B. Johansson, Energy After Rio: Prospects and Challenges, UNDP.