# Development of Stove running on low ethanol concentration

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## INTRODUCTION

Most of the rural households in India and in other developing countries cook food on inefficient and smoky biomass cookstoves. Besides creating environmental pollution, these stoves create health problems for a housewife and are based on biomass, which is not easily accessible and tedious to collect.

Nevertheless every rural household aspires to have a cooking technology and fuel which gives a blue flame and is very user-friendly [1].

Liquid and gaseous fuels can fulfill this aspiration [1]. Homegrown ethanol and biogas can provide an environmentally sound renewable fuel, which can be produced from locally available biomass [1]. Biogas has been used for cooking purposes for a fairly long time. However it suffers from drawbacks such as; input of large amount of cowdung; low production of gas; bulky equipment of gas producer; inability to be transported and hence has to be used very close to the gas producer and holder.

Liquid fuels like ethanol on the other hand can be produced from any sugary biomass like sugarcane, sweet sorghum etc. [1]; has high energy density and is easily transportable. Our Institute, NARI has pioneered the production of ethanol from high yielding sweet sorghum varieties.

In rural areas of developing countries there is a substantial amount of illicit liquor production. Production and consumption of this liquor produces social tensions in the households and is the cause of innumerable marriage breakups in rural areas since mostly men drink and beat up their wives. The illicit alcohol production takes place in makeshift backyard and rudimentary distillation units which produce alcohol with 45-60% (w/w) ethanol/water concentration.

Hence it was thought prudent to develop an ethanol stove running on such a mixture so that it can solve the twin problems of drinking and cooking. Thus the woman of the house will get a very clean fuel for cooking and she will not have to go long distances for collecting firewood. This can also help solve the drinking problem of her husband. At the same time the production of such low concentration ethanol can easily be done in the rural setting through a simple distillation unit consisting of a flash evaporation system. This simple system can also save the energy for distillation of ethanol.

Besides these features another attraction of low concentration of ethanol is its inherent safety. Ethanol is very flammable with very low flash point (~$15^0$ C) and has been used in Brazil and South Africa as cooking fuel [2]. However generally it is used at 85% (v/v) and higher concentrations and is a dangerous fuel and many fire deaths have been reported in its use at these concentrations. However 50% (w/w) mixture is a very safe cooking fuel. This paper therefore presents the development of an ethanol stove which can run on a 50% (w/w) or higher concentrations of ethanol/water.

## STOVE DEVELOPMENT

The stove has the following components:

a) Fuel tank
b) Pressure regulating valve
c) Filter in fuel line
d) Flame controller
e) Burner assembly

Fig. 1 shows the schematic of the stove while fig. 2 shows the actual stove.

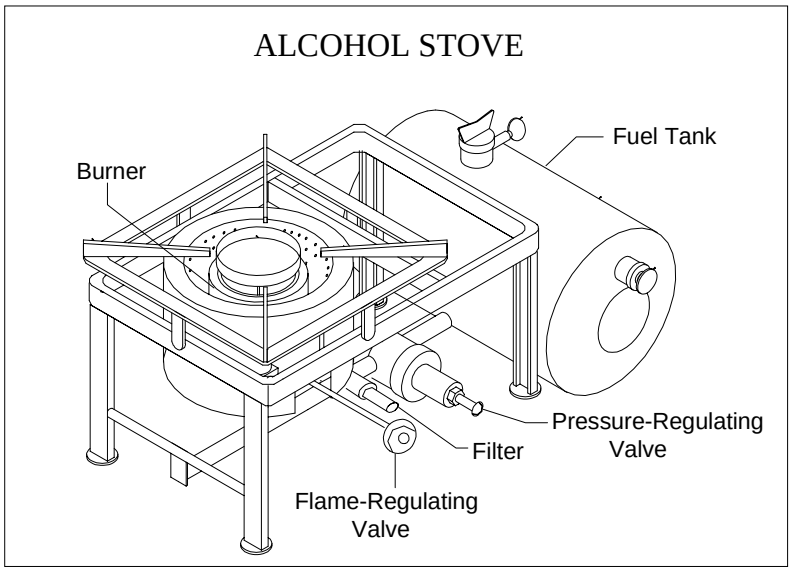


**Fig. 1. Schematic of Ethanol Stove**

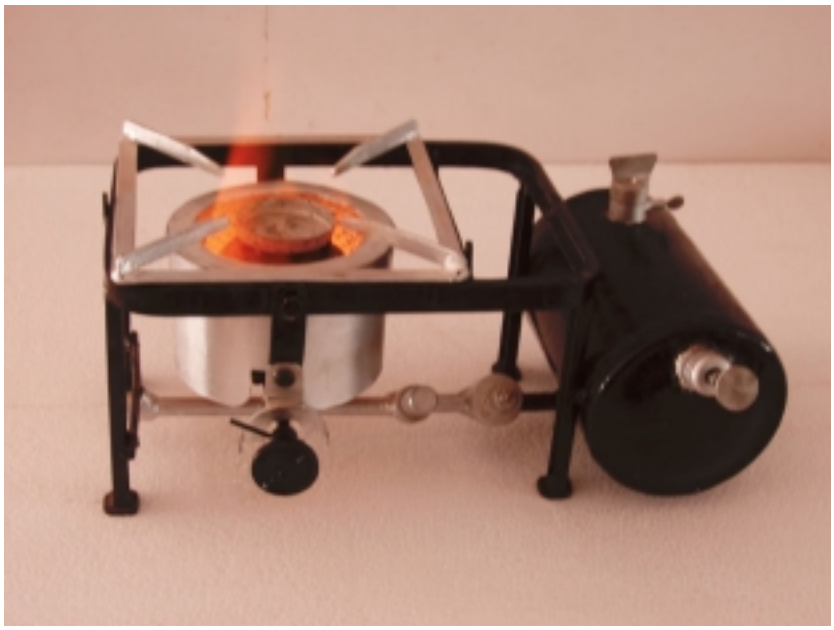

**Fig. 2. Ethanol Stove**

Pressure regulating valve was used so that the flame strength could be independent of the pressure in the tank. The regulator was specifically designed for the stove.

The flame controller has two control settings - high and simmer. This allowed the capacity of stove to be changed from a high of 2.45 kW to a low of 0.9 kW. Thus the stove is equivalent to a regular LPG stove with proper controls.

The heart of the system is the ethanol burner assembly, which allows the ethanol/water stream to evaporate, and ethanol to combust. The burner is designed so that the water in the ethanol converts into steam. The resulting flame is yellowish - red in color and has no smell. The CO emissions near the stove are well within the acceptable range.

All the components of the stove are made of stainless steel (SS) so that the corrosion by ethanol/water mixture could be minimized. The empty stove weight is 4.3 Kg and it has a 2.6 l S.S. tank. Table 1 gives the details of the stove and the salient results.

**Table 1. Test results of low concentration ethanol stove**

| | |
|---|---|
| 1. Dimensions of stove | 42.5 cm (L) X 20 cm (W) X 22.7 cm (H) |
| 2. Weight of stove | 4.3 Kg |
| 3. Fuel tank capacity | 2.6 l |
| 4. Material of stove | Stainless steel |
| 5. Capacity of stove (for 50% w/w mixture) | 2.45 kW for maximum capacity (max)<br>0.9 kW for minimum capacity (min) |
| 6. Fuel consumption (ethanol) | 0.33 Kg/hr (max)<br>0.125 Kg/hr (min) |
| 7. Efficiency of stove (50% w/w mixture) | ~ 45% (max)<br>~ 43% (min) |
| 8. Water boiling time (1 litter of water) (50% w/w mixture) | 5 minutes (max)<br>13.5 minutes (min) |
| 9. Carbon monoxide emissions | < 5 ppm |
| 10. Estimated cost (in mass production) | Rs. 800 - 1000/- |

The stove runs effectively on any ethanol/water concentration of 50% and above. Fig. 2 shows the effect of varying ethanol concentrations on burner capacity for the maximum setting.

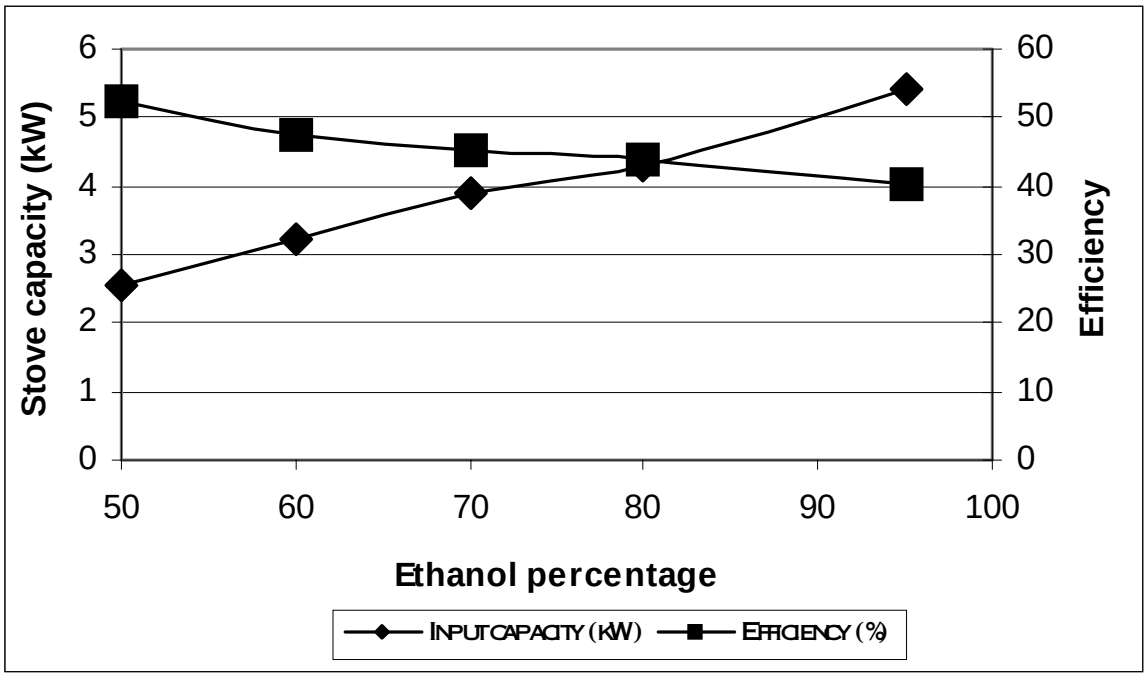


**Fig. 2. Stove capacity vs. ethanol concentration**

## FIELD TESTING OF STOVES

After the development and lab testing these stoves have been field-tested. Thus women farm laborers who do the cooking on wood stoves were asked to prepare their meals on this stove. They used their existing utensils and cooked their regular fare. The testing was done in a small room (4.5 m x 3.1 m and 3-m ceiling) which had one window and a door to simulate their actual dwellings. These women cooked regular food, which included rice, lentil soup, chapati (wheat flat bread) and vegetables. They liked the silent stove and specially the ability to control the flame.

On an average the stove consumed about 3.6 to 4.5 kWh (thermal) of energy in cooking this food. This is much less than 5-6 kWh normally used in wood cookstoves cooking the same amount of food. The CO levels, measured by hand held electronic CO meter, were between 3-10 ppm near the cook. Table 2, gives the details of testing and comparison of ethanol stove with kerosine and LPG stoves.

Some of the comments by the women were:

- It is very easy to light and run this stove.
- There is no smell and smoke and hence is much better than the woodstove. The eyes don't burn and it gives no headaches.
- Some women who cook on kerosene stove said that this is much better than the kerosene stove because it is completely silent and no kerosene smell comes out after extinguishing it. Some of them also felt that it is much safer than kerosene stove since it requires much less pumping.
- Some women thought that it is just like the LPG stove since it has flame control.
- Some said that they will buy it if it is priced less than Rs. 800.

**Table 2. Summary of cooking tests**

| No. | Item | LPG | Kerosene | Alcohol Stove |
|---|---|---|---|---|
| 1 | Total no of Field Tests | 2 | 6 | 67 |
| 2 | Total no of women | 2 | 4 | 16 |
| 3 | Dates of test | April, July 05 | April, July '05 | Feb, July, Nov, 05; Jan, Feb 06 |
| 4 | Average amount of fuel used per meal, kg | 0.21 | 0.27 | 0.48 |
| 5 | Avg. Food and water cooked, kg | 5.23 | 5.12 | 5.98 |
| 6 | Avg. Time required, minutes | 126 | 125 | 135 |
| 7 | Avg. Specific Energy required kW-hr/kg | 0.52 | 0.63 | 0.60 |
| 8 | CO values (near the cook), ppm | 0 to 2 | 8 to 10 | 6 to 8 |
| 9 | Cost of cooking , Rs/kg | 0.89 | 1.60 | 1.62 |

**Notes:**

- Meals were cooked for 4 to 5 people.
- The above data is for meals cooked without the use of pressure cooker. There is 20 to 30 % savings in the specific energy required per meal using a pressure cooker.
- Cost of cooking is estimated taking Ethanol cost at Rs 16/litre, Kerosene at Rs 25/litre and LPG at Rs 310 per cylinder (weight of 14.2 kg)

Ten stoves have been fabricated and are undergoing large scale testing for user performance evaluation. Fig. 3 shows a woman cooking on the ethanol stove during field-testing.

**Fig. 3. Ethanol stove in use**

## CONCLUSIONS

A very user-friendly stove running on ethanol/water concentrations of 50% (w/w) and above has been developed and field tested. The flame is controllable and the maximum capacity of stove is 2.45 kW with the turndown ratio of 1:2.7. The stove is very easy to light and use and can be an excellent alternative to existing smoky biomass stoves. Preliminary field-testing reveals that it is easily acceptable by rural poor. They consider this stove as convenient and efficient as the existing LPG stoves.

There is a need to change the government of India policies so that low-grade ethanol can be made available as a cooking and lighting fuel for household purposes. The production and use of ethanol for cooking and lighting in rural areas will improve the quality of life for its population and will help in creating wealth in these areas.

**Acknowledgements:** The authors would like to thank Ministry of Non-Conventional Energy Sources, Govt. of India for the financial support for this study and workshop technicians R.S.Bale, A.M.Pawar and D.B.Gadhwe for their help in fabrication of stoves.

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