CES/IOE. **A Studies Report on Efficiency Measurement of Biogas, Kerosene and LPG Stoves**. Biogas Support Programme, July 2001. 20p. BSP Lib Temp No. 71.

## Introduction

An agreement was signed between Biogas Support Programme (BSP) and Centre for Energy Studies, Institute of Engineering (CES/IOE) on $6^{th}$ July 2001 to evaluate the efficiency of biogas stove. For comparison, efficiency of Liquefied Petroleum Gas (LPG) and kerosene stove (pressure type and wick type) was also studied. The biogas stove under test was manufactured by Nepal Metal Cast of Butwal, Nepal.

## Literature Review

Cooking stoves operate with a variety of fuels, such as solid, liquid, gaseous and other fuels. Animal dung agricultural waste, wood, charcoal, sawdust, biomass briquette could be considered as solid fuels. Kerosene, alcohol, and other hydrocarbons are termed as liquid fuels. LPG, natural gas, biogas etc. could be considered as gaseous fuel.

Efficiency of a stove could be categorised as **burning efficiency** and **overall efficiency**. Burning efficiency of a stove accounts for the capacity of that stove in terms of combustion of fuel. In other words ability of the stove to change the energy from fuel to heat energy is related with burning efficiency. The ability of the stove to change the energy from fuel into the energy gained by the specimen such as water, rice, curry, milk, etc. is termed as overall efficiency of the stove. Generally efficiency of stove is indicated by overall efficiency.

Overall efficiency of stove depends upon different conditions such as temperature, pressure, wind speed, specific heat capacity of the vessel, bottom and overall shape of vessel, weight vessel, size of vessel and amount of specimen. Thus, different tests for efficiency could yield different results of the same stove. Calorific value (MJ/kg or kJ/Lit) of the fuel is the input energy for stove and should be accounted in course of efficiency measurement. Calorific values of fuels may vary from sample procured at different locations.

## Approach and Methodology

Efficiency of cook stoves could be calculated by several methods. In this study efficiency of cook stoves was determined by calculating the heat gained by the water subjected for heating and amount of fuel consumed during this process. In this study, heating process is classified as **Low Power Phase** and **High Power Phase**. Heating of water from initial water (subject to boiling) temperature $T_1$°C to boiling point is termed as High Power Phase (HPP). During this phase water in vessel gains energy from fuel with the help of burning stove and that value of energy is equivalent to energy required to raise the temperature weight of water at boiling point was subjected to boil for five minutes and energy gained by this water is calculated by multiplying latent heat of vaporisation ($L_{wboi}$) of water and mass of vaporised water. Fuel consumed during each process is the input energy for these phases. Overall efficiency is calculated by dividing output energy by input energy. In this process we have to include the head gained by vessel in which water was boiled.

Hence,

| | | | | |
|---|---|---|---|---|
| ***Heat gained by vessel*** | = | ***Mv * Sv **** | $(T_b - T_1)$ | ***Joule*** |
| ***Heat gained by water in HPP*** | = | ***Mw * Sw **** | $(T_b - T_1)$ | ***Joule*** |
| ***Heat gained by water in LPP*** | = | | $(M_{steam} * L_{wboil})$ | ***Joule*** |
| ***Energy of fuel*** | = | | $M_{fuel} * K_{fuel})$ | ***Jules*** |

Where,

$M_v$ = Mass of vessel
$S_v$ = Specific heat capacity of vessel
$(T_b - T_1)$ = Change in temperature (from T1 to boiling Point)
$M_w$ = Mass of water

$S_w$ = Specific heat capacity of water
$M_{steam}$ = Mass of evaporated water during LPP
$L_{wboil}$ = Latent heat of boiling of water
$M_{fuel}$ = Mass of consumed fuel
$K_{fuel}$ = Calorific values of fuel

***Efficiency*** (overall) = $\{M_w * S_w * (T_b - T_1) + M_{steam} * L_{wboil}) + M_v * S_v * (T_b - T_1)\}/ (M_{fuel} * K_{fuel})$
***Efficiency*** (overall) = ***{Heat gained by water in HPP + Heat gained water in LPP + Heat gained by vessle} /{Quantity of fuel consumed * unit calorific values of fuel}***

Hence, heat gained vessel (made from aluminium) is equal to heat gained from T1°C to $T_{boil}$°C and heat gained by water is equal to the summation of heat gained during High Power and Low Power Phase.

Fuels like Liquefied Petroleum Gas and Kerosene could be weighted by weighting machines. Mass of cylinder or stove before and after experiment gives the mass of fuel consumed. But for biogas, measurement of flow of gas is essential, which gives the amount of biogas consumed during experiments.

**Main Findings**
The efficiency of biogas stove calculated as per adopted methodology mentioned above is found to be 49.44 percent, 43.8 percent and 32.26 percent for perfectly controlled, semi-controlled and uncontrolled conditions respectively.

The efficiency of a given stove is not constant. It could vary on the basis of surrounding conditions and quality of fuel used. A high value of efficiency could be obtained under controlled conditions. But in practice this value is normally lower than the value found in the controlled laboratory condition. The efficiency of stove depends upon following conditions.

- Environmental conditions, such as wind, temperature, pressure.
- Shape, specific heat capacity and weight of vessel.
- Burner size of stove and size of bottom face of cooking vessel.
- Energy content of fuel and quality of fuel.

**Recommendations**
- Further study is essential for improvements of biogas stove and other types of stoves for different purpose of cooking and conditions.
- Actual efficiency measurement could be determined only when actual calorific value of fuel is known. For this, calorific values at laboratory should be measured where efficiency measurement of stoves is to be conducted.
- Efficiency of biogas stoves under operation in different locations of Nepal should carried out as soon as possible and after analysing the result necessary action should be taken so that energy from biogas plant is used as effectively as possible.
- The users of biogas plants have to be informed on optimum application of flame flaring.