THE DEVELOPMENT OF PRODUCER
GAS COOKING DEVICE

by

Dr. A.N.S. Kulasinghe

and H. Harischandra De Silva

Introduction

Fuel wood is extensively used as the major cooking fuel still in Sri Lanka. But, nowadays fire-wood fuel is replaced by LPG and electricity in urban areas, because of the convenience in their usage. A few years back, Kerosene oil was widely used as the cooking fuel in urban areas, but, because of its high price, Kerosene oil usage for cooking purposes has become much less.

Electricity and LPG prices are also increasing gradually and soon, their prices will become unaffordable for lower and middle classes. On the other hand, utilization of superior grade energy sources such as electricity and LPG for cooking purposes is not so advisable as far as energy conservation is concerned.


From 1944-1972 he was attached to the Colombo Port Commission progressively as Assistant Harbour Engineer, Chief Engineer and finally Port Commissioner. He was founder Chairman and General Manager of the State Engineering Corporation, Chairman of the Bureau of Ceylon Standards and Director of a number of Corporations. He has attended a number of conferences and seminars both local and overseas and has presented many papers. He has to his credit a number of developments and inventions, the most outstanding being the 'Kulasinghe-CPC' system of Prestressing.

He was the President of the Institution of Engineers, Sri Lanka in 1969 and President of the Sri Lanka Association for the Advancement of Science in 1970. He was also Chairman of the National Science Council from 1969 to 1972.

Mr. H. Harischandra De Silva, B.Sc.Eng.(Hons.), graduated from the University of Peradeniya in 1980. Corporate Member of the Sri Lanka Energy Manager's Association. He worked for 24 years as a Chemical Engineer/Assistant Shift Superintendent in S.F.M.C., Ambewela Plant. He then moved to NERD Centre of Sri Lanka and serves as a Chemical Engineer/Research Engineer in Dept. of Chemical Engineering. As part time basis he works with EMC staff, on industrial energy management.

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<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Heating Value kJ/Kg</th>
<th>Price Rs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Firewood</td>
<td>13,000</td>
<td>30/- per cwt.</td>
</tr>
<tr>
<td>Kerosene oil</td>
<td>46,431</td>
<td>6.60 per litre</td>
</tr>
<tr>
<td>LPG</td>
<td>46,100</td>
<td>160/- per 13 kg. cylinder Domestic</td>
</tr>
<tr>
<td>Electricity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>First 30 units</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.50/kwh</td>
<td></td>
</tr>
<tr>
<td></td>
<td>31-150 units</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.90/kwh</td>
<td></td>
</tr>
<tr>
<td>Wood Charcoal</td>
<td>30.100</td>
<td>10/- per 3 kg. bag</td>
</tr>
</tbody>
</table>

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TABLE 2
Cooking equipment used in Sri Lanka and their efficiencies

<table>
<thead>
<tr>
<th>Types of Cookers</th>
<th>Operation efficiencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Three stone stove</td>
<td>5 - 10%</td>
</tr>
<tr>
<td>Kerosene oil stove</td>
<td>30 - 55%</td>
</tr>
<tr>
<td>L.P.G. Cooker</td>
<td>50 - 55%</td>
</tr>
<tr>
<td>Electric Hot Plate</td>
<td>80 - 85%</td>
</tr>
<tr>
<td>Titan stove</td>
<td>15 - 20%</td>
</tr>
</tbody>
</table>

Following chemical reactions take place within a gasifier at the hearth temperature above 900°C.

\[
\begin{align*}
C + O_2 & \rightarrow CO_2 + 393,800 \text{ kJ/Kg mole} \\
C + H_2O & \rightarrow CO + H_2 + 131,400 \text{ kJ/Kg mole} \\
CO + H_2O & \rightarrow CO_2 + H_2 + 41,200 \text{ kJ/Kg mole} \\
C + CO_2 & \rightarrow 2CO + 17,260 \text{ kJ/Kg mole} \\
C + 2H_2 & \rightarrow CH_4 + 75,000 \text{ kJ/Kg mole} \\
CO_2 + H_2 & \rightarrow CO + H_2O + 41,200 \text{ kJ/Kg mole} \\
CO_2 + C & \rightarrow 2CO + 17,260 \text{ kJ/Kg mole}
\end{align*}
\]

Producer gas generated from wood by an air blown gasifier typically contains.

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide</td>
<td>CO</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H_2</td>
</tr>
<tr>
<td>Hydro-carbon gases such as Methane</td>
<td>CH_4</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>N_2</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>CO_2</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O_2</td>
</tr>
</tbody>
</table>

The uncleaned gas may contain some tarry matter, moisture, ash, dust and volatile substances.

However, in practice tarry liquid matter and ashes carried with producer gas, have to be removed before gas is to be used. The gas cleaning equipment solely depends on the application of the gas, i.e., whether it is shaft power or direct heat application. If the raw producer gas is not cleaned sufficiently well, the equipment where the gas is finally used for burning, will have clogging and malfunctioning problems, caused by accumulations of tar, moisture and ashes.

Heating value of the producer gas fuel is 4-6 MJ/Nm³.

The typical thermal efficiency of the gasification process ranges from 75 to 85% when using dry wood as the feed stock.

The quantity of the product fuel gas, i.e., mainly the calorific value and the tar content depends on the following factors:

1. Quantity of the feed stock, specially the moisture content, the fuel block size and variety of wood.
2. Design of the gasifier.
3. Operating temperature of the hearth zone.

Experiments and Results

A series of experiments were designed to study the following aspects.
1. Design and construction of a simple and efficient burner to burn producer gas as a cooking fuel.
2. Feasibility of producer gas cooking.
3. Overall efficiency of the operation.
5. Cost benefits.

Various types of burners, which are available in the market were tested under varying operating and design conditions. Since, producer gas flame has a very low flame propagation velocity and low heating value as compared to other gaseous fuels, special kind of burners had to be designed for the efficient and effective combustion of producer gas to generate cooking energy. A lot of important informations were collected from these tests. The following factors were found to be more critical for effective and efficient combustion of producer gas.

1. Producer gas quality and flow rate.
2. Gas cleaning equipment.
4. Profile of the burner.
5. Number of holes and the hole diameter of the burner's flame spreader.
6. Compatibility of the gasifier and the burners.
7. Distance between the burner surface and the heating surface.

Figure 2 shows the general layout of various equipment which were incorporated to complete the producer gas cooking device. Figures 3 & 4 show the isometric views of the successful burner design and air/producer gas mixing unit.

The following method was used to estimate the overall efficiency of the system. The gasifier was lit and a known weight of water (M) was placed on the cooker. After complete burning of the fuel, volume of water evaporated was found (m).

Overall efficiency $\eta = \frac{E_0}{E_1}$

energy output $E_0 = M \times \left(100 - \frac{T_a - T_w}{T_L - T_w}\right)$

- M S (100-T ) + mL
- W.G. + P.t

- power of the blower
- time of operation of fuel wood consumed.

35 - 40% overall efficiency was obtained with successfully completed burner design and four of these were fitted to the industrial type cooker, which is suitable for mass cooking, small scale steam generation, hot air generation etc. Two small burners were fitted to a domestic cooker. Figure 5 shows the effect of secondary air flow on flame temperature. The maximum flame temperature was around 900°C in most of the trials.

Gasifier Details

Gasifier should be designed properly to suit its application, usage or load. Otherwise maximum overall efficiency cannot be achieved. In other words, the gasifier which was connected to the four burner cooker, was not very efficient when it was connected with two burner system.

Design of a gasifier, to suit its application is an art rather than a science, since, design procedure solely depends on the experimentally collected data and empirical relationships. However, present gasifier designers have been guided and enlightened by experiences which were gathered from decades, modern analytical capabilities and current enthusiasm on the subject.

HEARTH

Arrangements were made to heat the incoming gasifying media; i.e. primary combustion air, using very hot effluent producer gas. A small fraction of the sensible heat of effluent producer gas was utilized to heat the incoming air, thereby thermal efficiency of the system was improved.

Ash removal, hearth ignition, air inlet and gas outlet facilities were provided at appropriate locations, where the experience and knowledge plays a significant role.

GAS CLEANING

A reasonable amount of water vapour can be produced because of following reasons.
1. Physically and chemically combined moisture which is in the fuel wood gets evaporated because of the high temperature of the hearth.

2. Moisture forms due to chemical reactions mainly from the following reaction.

\[ 2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O} \]

3. Moisture is brought into the system with incoming combustion air.

A distinct moisture trapping system was incorporated in the system. Figure 6 shows the details of the gasifier. The effectiveness of the condensation can be improved by attaching metallic fins to the condenser. This moisture trapping arrangement functioned very satisfactorily.

(Note - The selected location for the moisture trap is unique for air blown systems).

Dust, ash and carbon particles which were carried from the gasifier were arrested employing a cyclone separator.

Properly cleaned producer gas can create very successful operation of the cooker.

**GASIFIER FUEL**

The gasifier fuel was wood chips and wood blocks. The average moisture content should be low as far as possible, less than 20% is preferable.

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**TABLE 3**

<table>
<thead>
<tr>
<th>Gasifier</th>
<th>Average fuel size mm x mm</th>
<th>Fuel consumption rate kg/h</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which was coupled to domestic cooker</td>
<td>5x5x1 (flakes)</td>
<td>1.2</td>
<td>Carpentershop wastes</td>
</tr>
<tr>
<td>Which was coupled to industrial cooker</td>
<td>40 x 40 x 15</td>
<td>10.0</td>
<td>Prepared fuel wood</td>
</tr>
</tbody>
</table>

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**Cost Comparison**

- Energy required to evaporate 1 kg of water (E) = 2555.1 kJ
- Fire wood required to evaporate 1 kg of water viz a gasifier = 0.49 kg
- Cost of fire wood = Rs. 0.29
- Cost of electricity = Rs. 0.04
- Total cost of operation = Rs. 0.33
- LPG required to evaporate 1 kg of water = 0.12 kg.
- Cost of LPG = Rs. 1.48
- Cost of producer gas cooking = 1
- Cost of LPG cooker = 4.5

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**Other Implications**

Producer gas heat is very cheap, well controllable, relatively efficient, extremely effective. The approximate cost of generating 1kWh (thermal) is little less than 50 cents.

Therefore, producer gas heat can be utilized very effectively for some more thermal applications such as baking, process heat air generation, steam generation and drying operation. Experiments and pilot model trials are being carried out at NERD Centre to study the feasibility and other benefits. So far, the results obtained are very encouraging.

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**References**


Figure 1
GENERAL ARRANGEMENT OF A
DOWN DRAFT GASIFIER

Figure 2
SCHEMATIC DIAGRAM OF THE GAS PRODUCER INSTALLATION
FOR COOKING PURPOSE
Figure 3

Isometric View of the Producer Gas Burner

Figure 4

Isometric View of the Producer Gas Burner Mixing Unit

Figure 5

Effect of secondary air on flame temperature

Valve opening as a fraction of a full turn
SECTIONAL FRONT ELEVATION

SIDE ELEVATION

PLAN ON AA

DETAIL A

DETAIL B

DETAIL C

FIGURE 6

Air Inlet

Equally spaced 3/4mm Dia. holes

Nozzle A

Gas outlet

Thread B

Seal

Ash outlet

Confluous accumulator

3/8" x 1/4" Flat Iron

1/4" x 1/2" Flat Iron

(85)