



## CHAPTER III

### THE EXPERIMENTAL INVESTIGATION

A number of air gasification runs were performed on a batch open-top gasifier with biomass schredds as fuel.

#### 3.1 Description of the equipment

The gasifier apparatus built for this study consists of a gas producer, a water scrubber/cooler, a coarse charcoal filter, a centrifugal air blower, and a gas burner equipped with an LPG torch ignition flame. A picture of this apparatus is shown in figure 3.1. A schematic diagram of the apparatus is presented in figure 3.2.

The gas producer consists of a 150 cm. long, 6 inches internal diameter stainless steel pipe, equipped with a removable iron grate perforated with 1 cm diameter openings situated exactly at the bottom of the pipe. A larger and longer ordinary steel pipe 170 cm long 20 cm in diameter is fitted over the smaller pipe and the flanges of both concentric pipes are bolted together at the top leaving the opening of the smaller pipe open. The bottom of the assembly consists of the shorter inner pipe equipped with the grate, and the longer and larger pipe which is dipped 5 cm. into water which provides a water seal. The annular space between both tubes is filled with mineral wool insulator to prevent temperature drop from the central core gasifier chamber. A 1.5 in. pipe is fitted to the outer pipe at 15 cm. from the water surface to serve as gas outlet from the gas producer.

The water scrubber/cooler consists of a 100 cm. high, 4 in.

inside diameter steel pipe filled with 1 cm. long, 1 cm. diameter PVC piping pieces and equipped with a 5 cm. diameter shower cap to spray water onto the packing.

The coarse charcoal filter consists of a 35 cm. high 6 in. inside diameter steel box filled with rice hulls. This filter serves as a final particulates filter.

The centrifugal air blower is situated after the final filter and immediately after the flowmeter and send the gases to the gas burner.

The gas burner is made up of a 6 in. diameter, 15 cm. long steel pipe placed vertically and opened at both ends. The producer gas to be burned is introduced perpendicular to the burner at 3 cm. from the bottom but is off centered to allow for the gas to rotate in the burner. An LPG torch is introduced perpendicular to the axis of the burner and is kept turned on throughout each experiment.

The temperature measurement apparatus : The temperature measurements inside the gasifier were made with thermocouples of type K (chromel-alumel) of 1 mm. diameter connected to a numerical display with 16 temperature measurement points selected as follows : 5 cm below the grate, 1 cm above the grate, then 5 cm from that point, 5 cm from the third point, 5 cm from the fourth point, and the remaining points at 10 cm from one another. A thermocouple was also placed at the inlet and outlet of the water scrubber and a last thermocouple was placed near the flowmeter. The temperature measurement points inside the gas producer were introduced through holes on the gas producer walls and penetrating 3 cm in the bed. Each thermocouple was connected to a digital display equipped with a switch allowing for each temperature to be read one at a time.

### 3.2 Experimental Procedure

The procedure followed for each experiment is to ignite the gas producer column then start the batch gasification process. After the gas is cooled and scrubbed to protect the centrifugal blower it is burned away. The object of each experiment is to determine whether it is possible to gasify a given fuel and given a fuel determine the best operating conditions. The actual measurements needed for each experiment are fuel properties, air moisture, air flow rate temperatures, gas compositions. The experimental procedure is detailed as follows.

Gas producer ignition procedure: As the gas producer under consideration was designed to be a batch unit for rural applications it was decided to eliminate the ordinary inclined ignition port from the side of the gasifier into the center of the gasifier. Based on the recommendation of Dr. Albert Kaupp it was decided to ignite the gasifier using the following sequence

(i) turn on the centrifugal suction blower and regulate the speed to obtain the measured flow rate reading at the flowmeter level. Do this while the gas producer is fully empty and the water seal tight.

(ii) turn on the water feed into the water scrubber

(iii) throw a few handfuls of biomass material into the gasifier through the open top in such a way as to have about 5 cm of fuel above the grate.

(iv) Ignite a torch using anything that can burn away easily such as a piece of paper, then throw the torch into the gasifier. With the suction effect of the fan helping, the biomass material at

the bottom of the gasifier will start to burn.

(v) Once the entire cross sectional area of the gasifier is red hot which indicates a high temperature over the entire cross section, then the entire biomass fuel load is emptied into the gasifier up to the desired level inside the open column.

(vi) At this point the LPG torch is turned on and ignited. The gas coming out of the gas producer will all combust in the burner. Eventually as the producer gas quality improves the combustion will produce a clean and smokeless exhaust.

Experimental procedure during a run: After the biomass has been loaded into the gas producer temperatures are read and recorded manually for each thermocouple position every minute. Every five minutes a sample of gas is taken using 60 cc plastic syringes at the gas sampling port. The gas sampling port is situated after the condenser/cooler and is equipped with a silica gel dehydrator tube to reduce water content of the gas sample. The gas sampled is eventually analysed for  $\text{CO}$ ,  $\text{H}_2$ ,  $\text{CH}_4$ ,  $\text{N}_2$  in the gas chromatograph and analysed for  $\text{CO}_2$  in the orsat apparatus.

During many runs as it had been found that fuel cavitation was a problem, it was necessary during all runs to continuously poke into the bed from the open top with a stick to help the biomass fuel fall into the gasifier as fuel was being consumed.

Other experimental procedures included for each run a measurement of weight and water content of the biomass fuel, proximate analysis of fuel and the remaining char-ash mixture, weight of remaining char-ash mixture. Measurements of air temperature and ambient humidity were also made.

Finally the flowmeter reading was recorded, including the

temperature at the flowmeter position.

The equipment however was not designed to measure tar and moisture contents of the gas.

Parameters used in the study : Five different biomass materials were tested in this study : rice husk, corn cob, wood shavings, water hyacinth stems, and bagasse.

The rice hull tested included both ordinary rice hulls untouched from milling plants, and shredded rice hull used as duck food additive. The corn cobs tested included whole cobs as purchased, hammermilled cobs of three different sizes. The wood shavings used were untouched shavings from furniture manufacturers. Some tests were equally conducted on sawdust from similar sources but sawdust was found to be ungasifiable in our apparatus. The water hyacinth stems used were cut into 1 cm. shreds by hand after oven drying.

Finally bagasse obtained from a sugar mill was tested both as untouched bagasse from the sugar mill and as bagasse with fines removed. More details of each specific fuel eventually used will be given in subsequent sections. A fuel which was tested unsuccessfully in the gasifier was carbonized tapioca starch mixed rice hull pellets of the size of ping pong balls which were a by product of an experimental rice hull pyrolysis unit.

The design of the gasifier allowed batches of biomass fuel to be used for each run to vary somewhere between 2 to 4 kgs depending on bulk density of the fuel. For a dense material such as sawdust a fuel charge would be about 15 kg, however sawdust could not be gasified with our equipment.

The gas flow rates used in this study varied between 15 to 35

normal cubic meters per hour, although this entire range was not used on all fuels. The lower limit of air flow rate was set by experimental findings that below such an air flow rate the gasification did not proceed well, the combustion zone temperature was abnormally low, and excessive tar was produced. The upper limit of air flow was set by the initial experimental evidence that 35 Ncu.m./h was beyond the optimal air flow rate for the ambient air humidity which varied unpredictably was recorded.

The gas analysis was performed using a Variant gas chromatograph (model 3400) and an orsat apparatus as presented in the annex. The proximate and ultimate analysis were performed as mentioned in the annex .



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