DEVELOPMENT OF A WOODSHAVING STOVE

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ABSTRACT

A 1.35 metre diamèter prototype woodshaving stove which employs natural draught for combustion control has been developed at the Pilot Plant Complex of the Food Research Institute (FRI) to service a 1.2 metre diameter multipurpose roasting vessel. The stove uses waste products such as woodshavings, combination of woodshavings with sawdust, rice husk, dried leaves, etc., as its fuel and can serve both domestic and industrial purposes. Its fuel consumption is 23 kg of woodshavings per hour when full loading method of operation is used and 18 kg of woodshavings per hour for gradual loading method of operation. The stove's size is dictated by the diameter of the serviced vessel and its output can be varied and controlled to give the needed heat energy. Even though the heat energy generated by the prototype stove is not distributed uniformly at the vessel base, it is capable of providing heat energy to roast 90 kg of cowpea, 110 kg of groundnut and 100 kg of maize per hour respectively. The cost of materials for the construction of the stove amounts to ¢25,000.00 and fuel cost of operating with gradual loading of the stove is ¢50.00 per hour.

1.0 INTRODUCTION

It is estimated that at least one and a half billion people in the developing world derive nearly all their energy requirements from wood, either as firewood or indirectly as charcoal. Whilst most of this is used for domestic cooking and heating, an estimated 20% of fuelwood used in the developing countries is burned for process heat in small - and medium - scale industries (Breag and others, 1986).

A document on Energy and Ghana's Socio-economic development (1990) indicates that woodfuels account for about 80% of Ghana's total energy consumption. Continuous use of woodfuel leads to worsening deforestation and desertification. Also the combustion of wood for both domestic and industrial applications in the developing countries are often carried out inefficiently, leading to atmospheric pollution, wastage of valuable resources and increased cost.

Knowing that woodfuel will continue to form the core supply source to meet Ghana's energy needs for the foreseeable future, one of the short term objectives of Ghana's Energy Sector is to improve the efficiency of production, conversion and use of woodfuels in all socio-economic sectors.

In this regard, efforts are being made by various organizations and institutions to educate the general public on the need to reduce the use of woodfuel. Among these institutions is the Ghana National Petroleum Corporation (GNPC) which started a nationwide campaign in 1990 on the need to use Liquified Petroleum Gas (LPG) in homes, educational institutions, traditional catering establishments, etc.

Anon (1990) reported that woodshavings have been used as fuel for operating a " country-style steamer " used for the sterilization of compost for mushroom production in some Asian countries. In Ghana woodshavings are often regarded as waste products from the timber and woodprocessing industries and as such they are rarely utilized. Utilization of woodshavings as fuel for stove is therefore one of the ways of effectively converting waste product from wood into useful and productive purposes. It helps not only in disposing waste products from the timber and woodprocessing industries, but also in reducing the sanitation problems and the threat posed by the waste products to the immediate environment of such industries.

The objective of this work is to develop an affordable woodshaving stove with high efficiency and low operational cost as a contribution to the improvement of the efficiency of conversion and use of woodfuels.

2.0 MATERIALS AND METHODS

2.1 PROTOTYPE DESIGN FEATURES

Sectional view, plan and pictorial view of the stove are shown in figures 1 and 2 of Annex I. The stove consists of three main parts : an air and fuel inlet chamber (1), combustion chamber (2) and an outlet duct (3). The 650 mm-high air and fuel chamber has a 300 mm x 300 mm opening at the top for fuel (woodshavings) passage and 360 mm x 460 mm opening at the front for air passage. Fixed in the inlet chamber is a removable grid (4) made from 6 mm - diameter steel rod and inclined at an angle of 45° and ends 60 mm from the floor at the entrance of the combustion chamber. The wall of the combustion chamber is 200 mm thick and consists of two parts: the lower part with an internal diameter of 1350 mm and an upper part with an internal diameter of just over 1200 mm corresponding to the external diameter of the roasting vessel. An opening (500 mm x 250 mm) at the right side of the wall permits the roasting vessel´s outlet gate to open and close and also makes it possible for the roaster´s inclined plate to guide the products away from the stove into a receptacle. The inside of the outlet duct is inclined at an angle of 60° and leads to a 150mm-diameter, 2500-long chimney (5) made from 1.6 mm galvanized steel sheet.

2.2 CONSTRUCTION OF STOVE

The woodshaving stove was constructed after the installation of the roaster. The roasting vessel was mounted 300 mm above the floor level on a 50 mm x 50 mm steel structures which had been embedded in the floor. Using the dimensions in figure 1, Annex I, the woodshaving stove was built around the roasting vessel using sandcrete blocks and cement for the main body. A grid made from thirty, 6 mm- diameter steel rods was positioned across the air inlet chamber at an angle of 45° to the horizontal by two horizontal rods (6) embedded in the wall of the air inlet chamber. The chimney was mounted 275 mm from the rear of the stove where it meets the 60° slope of the outlet duct.

2.3 OPERATION PROCEDURE

Two methods are used to operate the stove:

Method I - Full loading of fuel inlet chamber with woodshavings. Here, the fuel inlet chamber is at anytime of operation fully filled with the woodshavings.

Method II - Gradual loading of fuel inlet chamber with woodshavings. Here, the fuel inlet chamber is half-filled with woodshavings and the level is not allowed to go above the half mark during the operations.

Depending on the method, appropriate quantities of the woodshavings are fed into the opening of the fuel inlet chamber on the grid. The fuel is lit at the base of the grid using a match or a lighter and ensuring that the entire width at the base is burning. Combustion may be improved by fanning. Optimum fuel to air ratio which gives smokeless exhaust gas is achieved in the chamber by adjusting the fuel inflow to suit the prevailing air inflow. This optimum operational state is easily achieved when the operator has gained enough experience through frequent operation of the stove. As combustion takes place, the woodshavings is occasionally replenished when its level in the opening falls below the expected. The woodshavings are wetted or its rate of replenishment is reduced when optimum combustion is achieved and there is the need to conserve fuel and maintain the heat being generated. On windy occasions, wooden board is placed in front of the air inlet chamber at an appropriate angle to control the air flow rate. Ashes that collect at the floor of the combustion chamber are periodically removed to allow free flow of air through the system.

2.4 TESTING OF THE STOVE

The stove was tested by subjecting the roasting vessel to the two heating methods, first without load and then with cowpea, maize and groundnut.

During the test without load, five type K (Chromel-Alumel) thermocouples connected to the rear of a 5-channel recording thermometer (model KM 1242) were attached to the base of the roasting vessel at five positions uniformly distributed as shown in figure 3, Annex I to record temperatures. The experiment was done in four replications and the average values were used to plot graphs to represent the temperature profiles of the five positions at the vessel base. Average temperatures representing the entire vessel base for the two methods were also obtained.

The stove was then tested with only groundnut for Method I and with cowpea, maize and groundnut for Method II. During the tests the roasting vessel was preheated for 20 minutes before the materials were introduced into it.
Moisture contents before and after roasting were determined by oven drying method (AOAC, 1990). Weights of materials were also measured before and after roasting. Time taken for known quantities to be roasted were recorded as well as the weights of woodshavings used (see Annex II).

3.0 RESULTS AND DISCUSSIONS

Results obtained are shown in Annexes II and III. Figures 1 and 3, Annex III show that distribution of heat energy at the vessel base during the heating up periods in both Methods I & II was not uniform. Temperatures of positions closer to the fuel inlet chamber were found to be higher than positions farther away from the fuel inlet chamber contributing to the diversed temperature profiles obtained. This problem of non-uniformity of the vessel base temperatures could be attributed to the rather low height of the combustion chamber, i.e. from the floor to the vessel base, which is 300 mm as compared with the diameter of the roasting vessel which is 1200 mm. This problem could be minimized by increasing the height of the combustion chamber.

Positions 4 and 5 in figure 3, Annex I are equidistant from the fuel inlet chamber but the temperature profile for position 5 is lower than that of position 4. This is due to the absence of insulation of the vessel gate and also the opening in the wall near position 5 which prevents that part of the vessel side from being heated. Insulating the vessel gate will bring temperature profiles for positions 4 and 5 closer.

Figures 1 to 4 further show, that the heat generated by Method I cannot be controlled and as such the vessel base temperatures at the five positions rise throughout the heating up period whilst heat generated by Method II can be controlled to give the required vessel temperatures.

Figures 2 and 4 of Annex III show that average temperatures of 160°C and 131°C were attained at the vessel base after preheating period of 20 minutes for Methods I and II respectively.

Temperature differences between the exhaust part of the vessel (pos.3) and the vessel gate part (pos. 5) in figures 1 and 3 of Annex III indicate that Method II produces a more uniform heating compared with Method I.

Tests conducted with the roasting vessel containing groundnut,cowpea and maize established the following :

i) that roasting by Method I after preheating period of 20 minutes burns the products and therefore Method I is not suitable for groundnut roasting.

ii) that roasting by Method II after preheating period of 20 minutes successfully roasts the products and therefore Method II is suitable for groundnut, cowpea and maize roasting.

iii) that fuel consumption rates by Method I is about 23 kg of woodshavings per hour and by Method II is about 18 kg of woodshavings per hour.

iv) that the stove is capable of generating process heat to roast 110 kg groundnut of 6.3% moisture content (M.C.), 90 kg cowpea of 12.2% M.C. and 100 kg maize of 11.7% M.C. per hour respectively after heating up period of 20 minutes.

v) that material recovery of 88.2%, 88.0% and 90.6% were obtained for cowpea, groundnut and maize respectively.

4.0 CONCLUSIONS AND RECOMMENDATIONS

A woodshaving stove has successfully been designed, constructed, tested and found suitable to supply process heat to the multipurpose roaster. Based on the findings of the trial runs conducted, the following conclusions were made:

i) Gradual loading of fuel inlet chamber with woodshavings method of operating the stove (i.e. Method II) was found suitable for the multipurpose roaster.

ii) An average temperature of 131°C is attained at the vessel base after preheating period of 20 minutes.

iii) The stove's fuel consumption rate is 18kg of woodshavings per hour.

iv) The stove generates process heat for the multipurpose roaster to process 90 kg cowpea of 12.2% M.C., 110 kg groundnut of 6.3% M.C. and 100 kg maize of 11.7% M.C. per hour respectively.

It is recommended that the use of woodshaving stove should be encouraged for both domestic and industrial purposes because

i) the material cost of the stove is about five times cheaper than the cost of an alternative LPG industrial stove with accessories which is about ¢140.000.00.

ii) the fuel operating cost of ¢50.00 per hour is two times lower than that of LPG industrial stove and five times lower than firewood stove.

5.0 FUTURE WORK

1) The following important design features will be incorporated into the system:

   i) Lagging of the gate of the rosting vessel with appropriate insulating material to minimise heat loss and ensure more uniform heating.

   ii) Introduction of a chimney damper for a more effective control of draught to achieve a more efficient combustion.

2) A similar stove will be designed and constructed with an increased height of the combustion chamber as well as the above recommended design features.

3) Net Calorific Values (NCV) of different types of woodshavings available in the country will be determined and the thermal efficiencies of stove with these woodshavings will be assessed based on exhaust gas analysis.

6.0 REFERENCES

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2. Anon, A., 1983 "Growing Mushrooms" FAO Regional Office for Asia and the Pacific, Bangkok.

3. Min. of Fuel and Power, 1988 "Energy and Ghana's Socio-economic development." A Paper prepared for the Provisional National Defense Council (PNDC), Accra.

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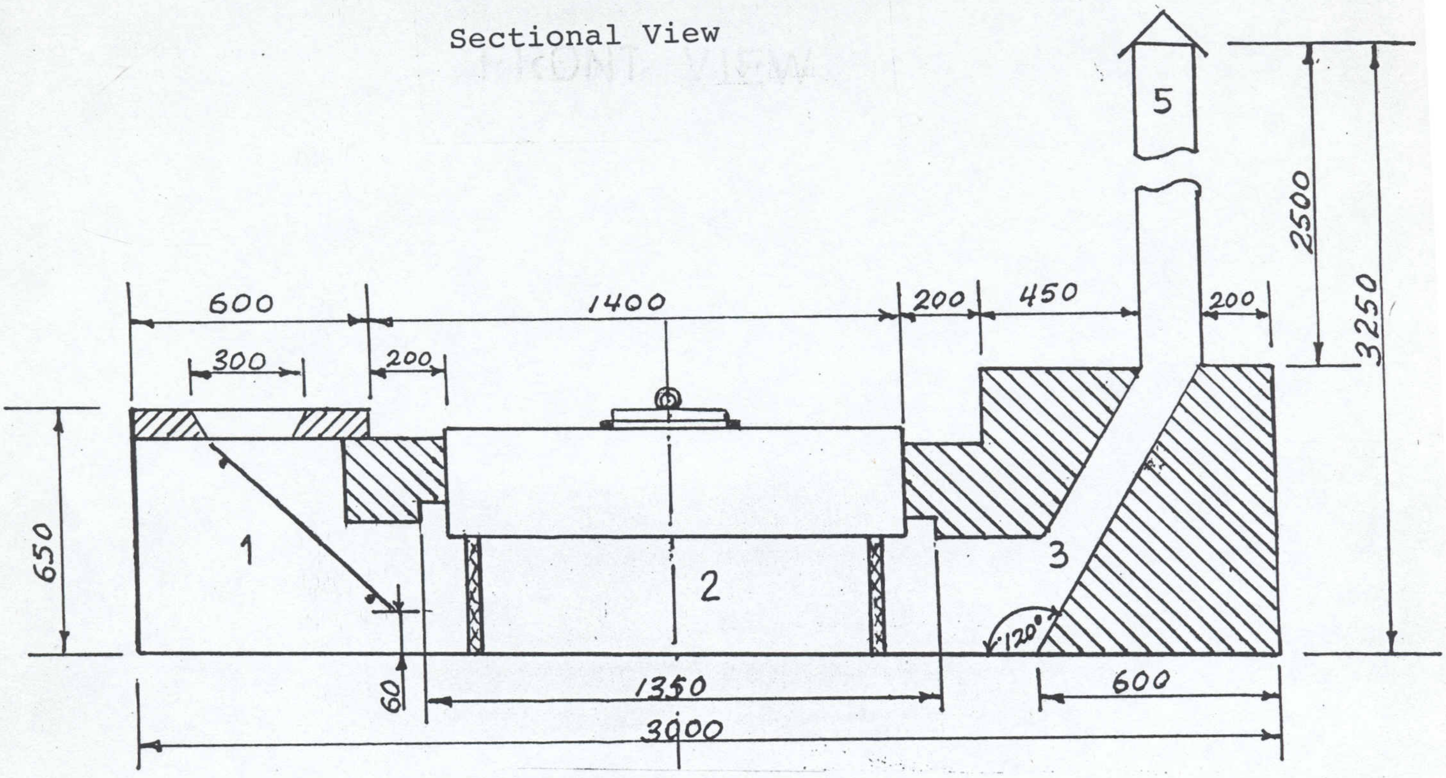
ANNEX I

FIGURE 1: Sectional view and Plan of stove with roaster

Sectional View



Plan

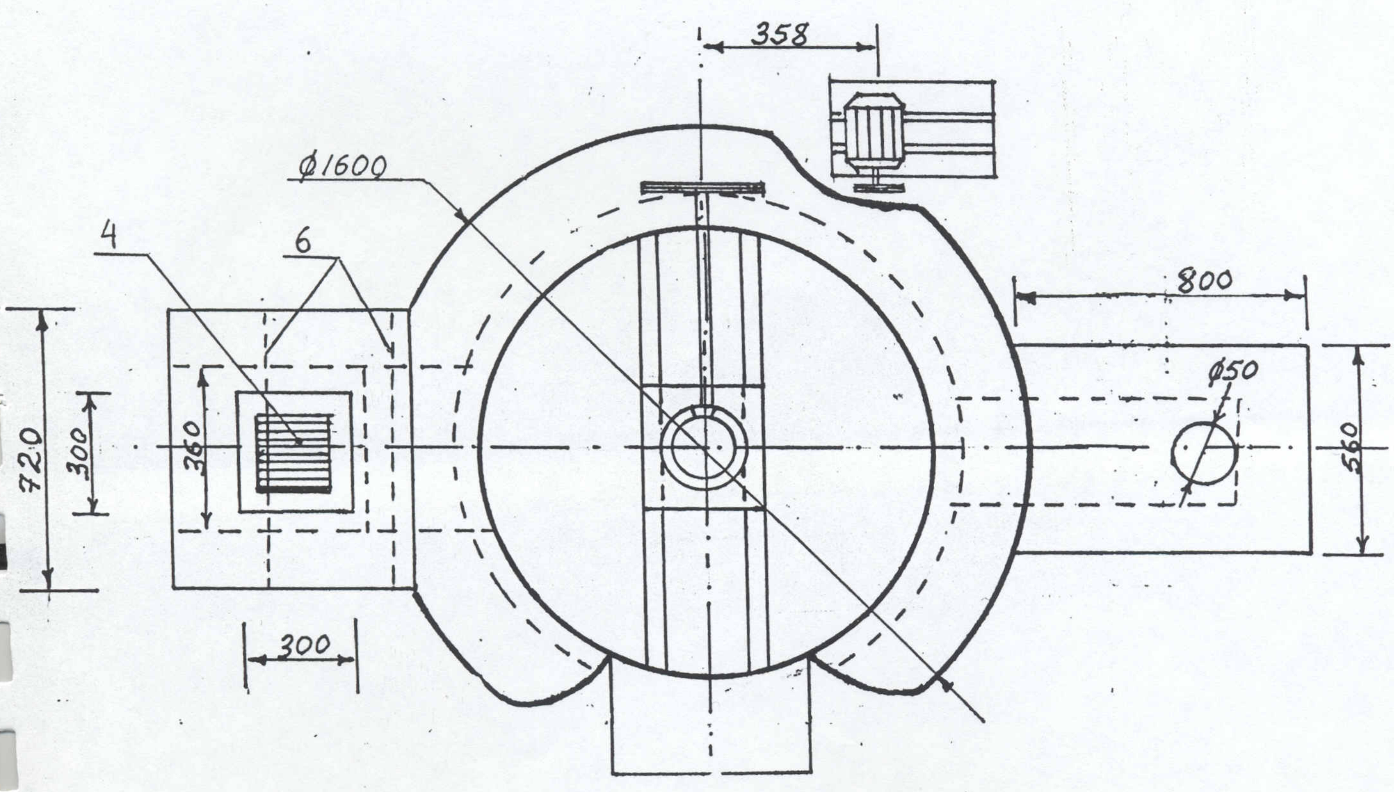


Figure 2: Pictorial view of stove

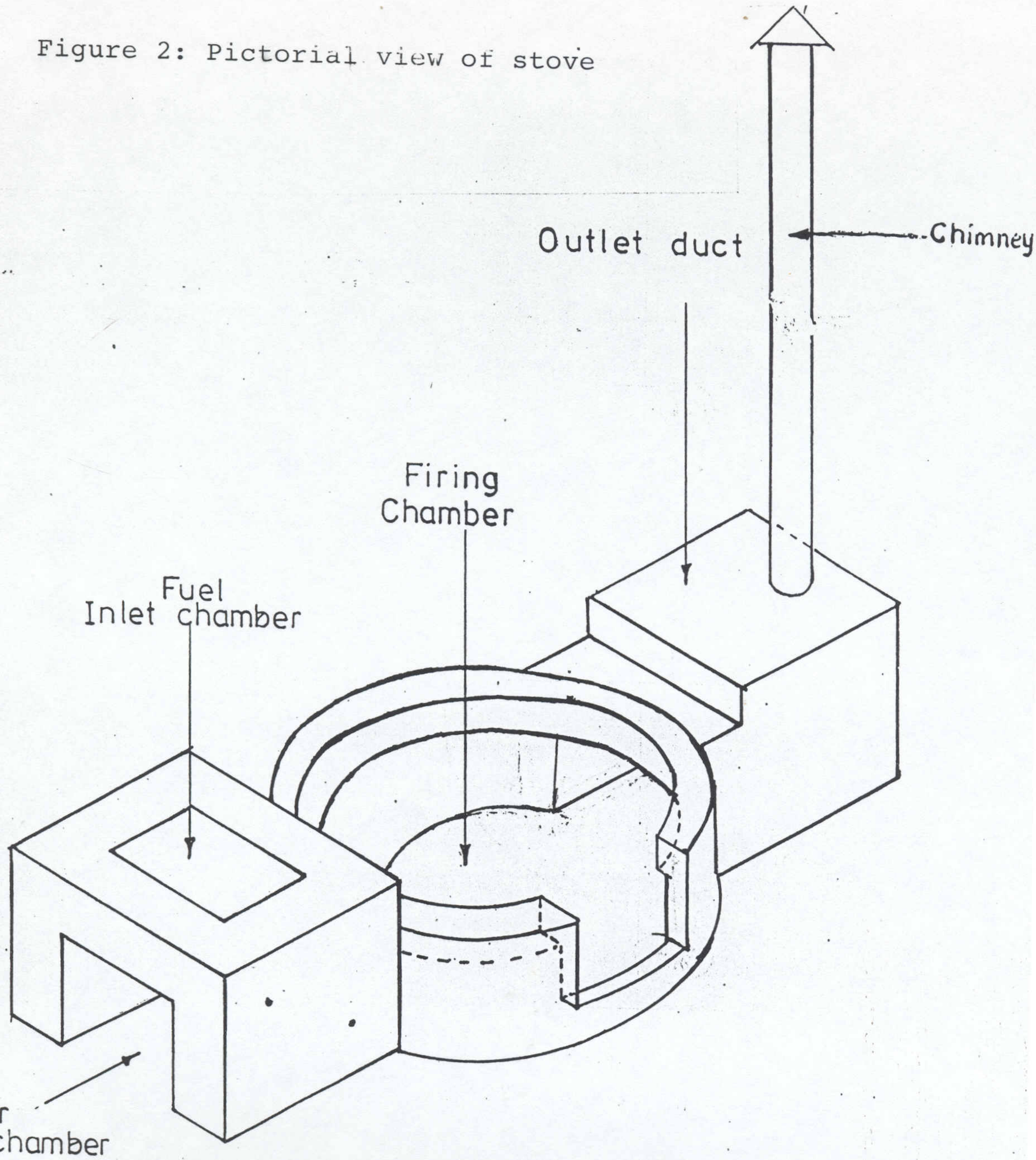
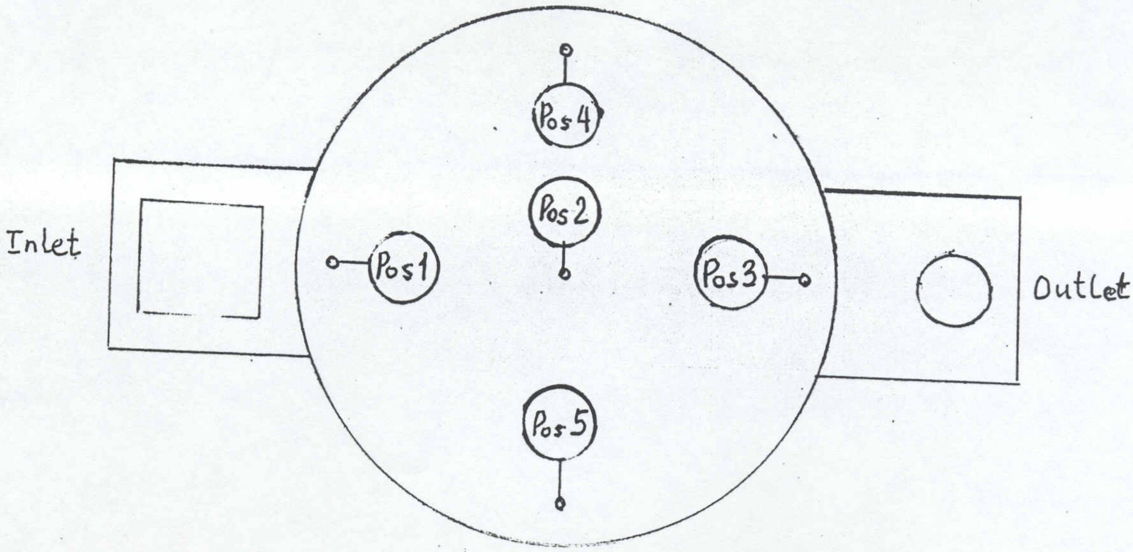


Figure 3: Positions of thermocouples at vessel base



ANNEX II: SUMMARY OF RESULTS

METHOD I

Material	Groundnut
Wt. before roasting, kg	85.0
Wt. after roasting, kg	77.0
Material recovery, %	90.6
Moisture before roasting, %	6.5
Moisture after roasting, %	2.1
Reduction in moisture, %	67.7
Weight of woodshavings, kg	11.5
Roasting time, min.	30.0
Fuel consumption, kg/hr	23.0

METHOD II

Material	Cowpea	Groundnut	Maize
Wt. before roasting, kg.	96.6	81.4	96.0
Wt. after roasting, kg.	85.2	71.6	87.0
Material recovery, %	88.2	88.0	90.6
Moisture before roasting, %	12.2	6.3	11.7
Moisture after roasting, %	3.7	1.8	5.5
Reduction in moisture, %	69.7	71.4	53.0
Weight of woodshavings, kg.	19.0	14.0	18.0
Time taken to roast, min.	66.0	45.0	58.0
Fuel consumption, kg/hr.	18.0	18.0	18.0

Figure 1: Temperature profile of vessel base
(Method I)

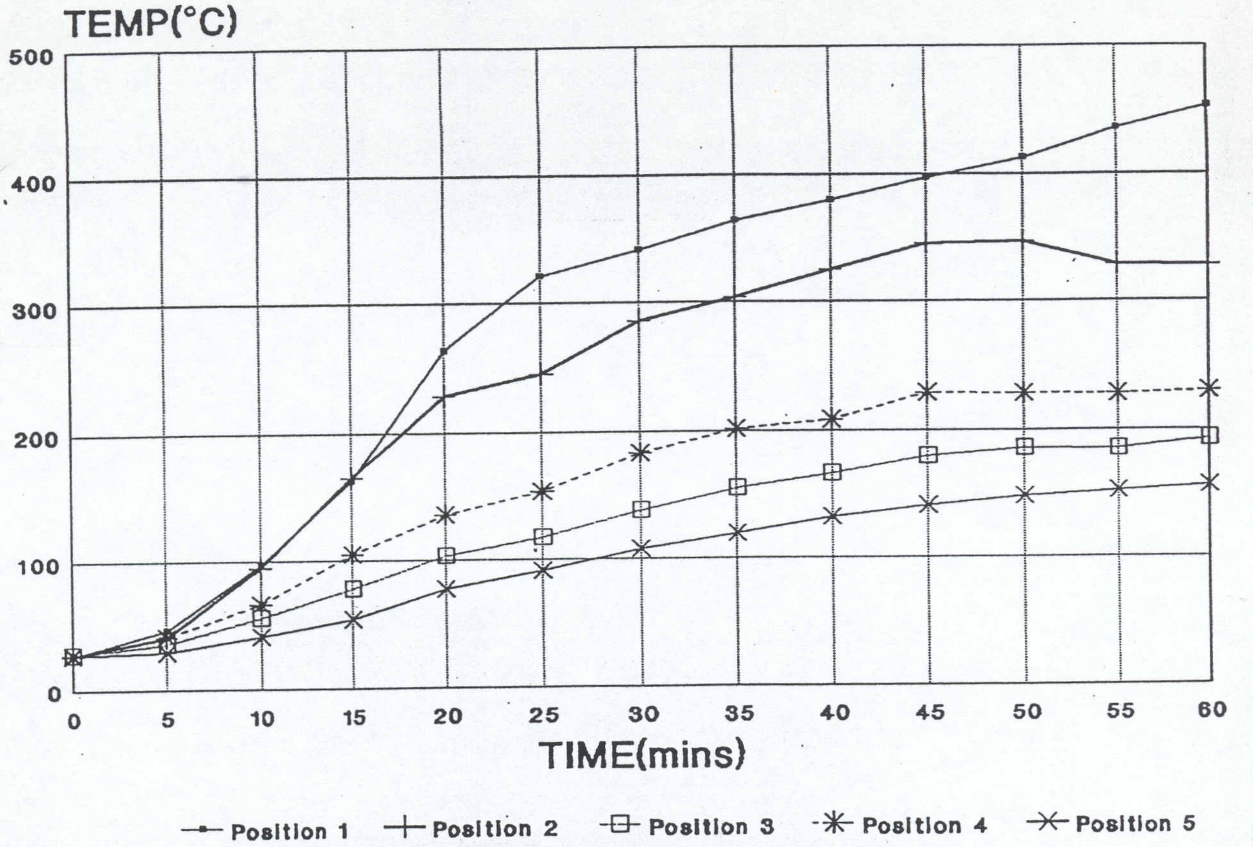


Figure 2: Average temperature profile of vessel base
(Method I)

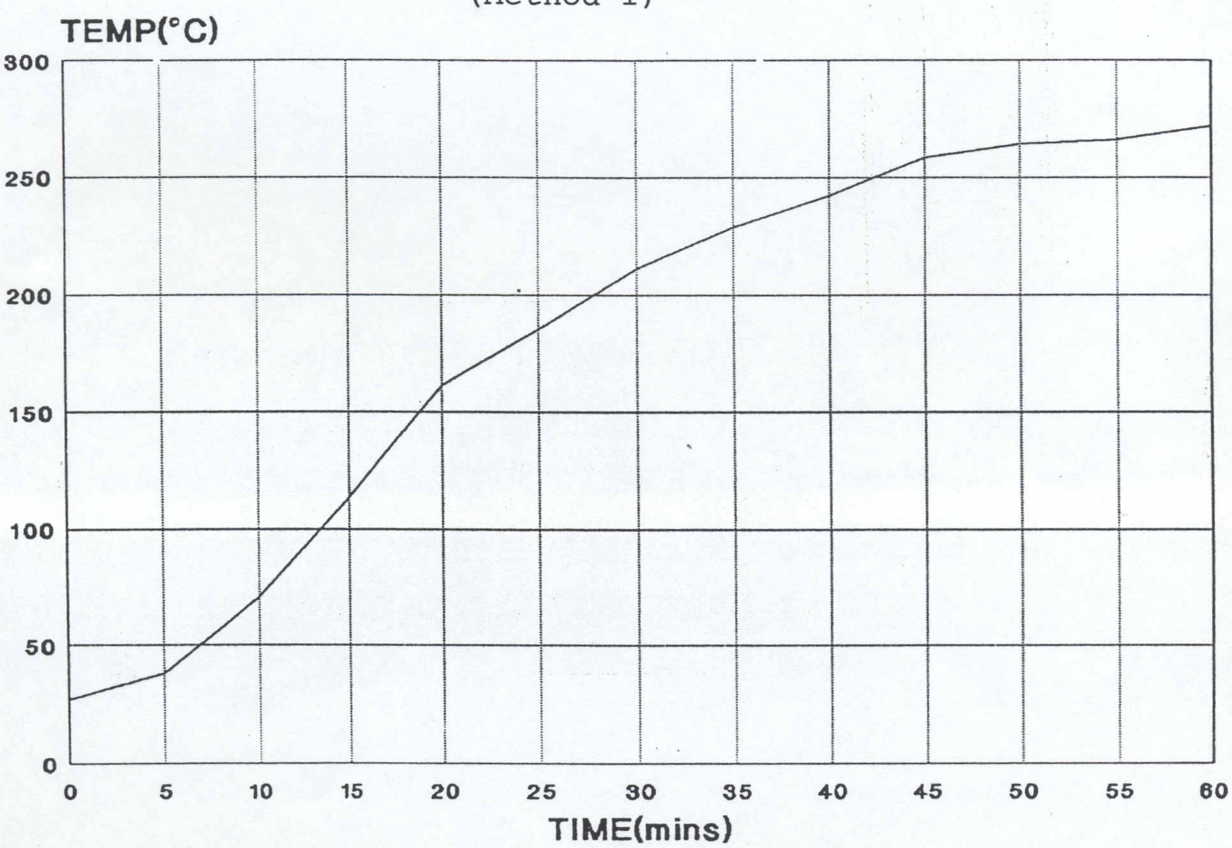


Figure 3: Temperature profile of vessel base

(Method II)

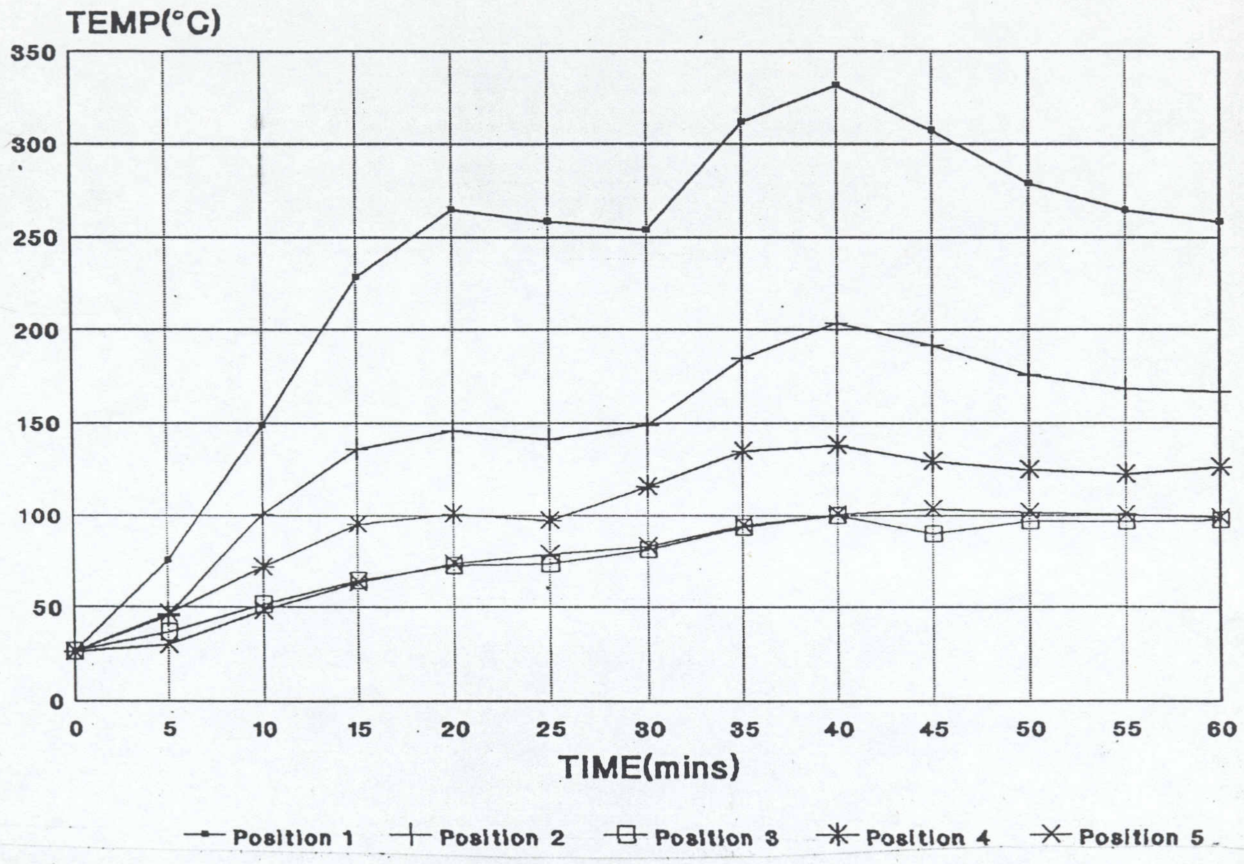


Figure 4: Average temperature profile of vessel base

(Method II)