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15582

March 1986
English

DEMONSTRATION PROGRAMME ON USE OF INDIGENOUS BIOMASS RESOURCES FOR MEETING ENERGY NEEDS

PHASE I

RP/RAF/85/627

ETHIOPIA

Technical Report*

Mission 11 November - 13 February 1986

Prepared for the Government of Ethiopia
by the United Nations Industrial Development Organization
acting as executing agency for the United Nations Development Programme

Based on the work of

Prem D. Grover

Expert in Design of Domestic Cooking Stoves
(for use with agricultural residue fuels)

United Nations Industrial Development Organization

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A. IMPORTANT NOTE

The present report should be read in conjunction with earlier report.

June 1984
Thermochemical Conversion of Biomass Materials For Energy Production.
UC/ETH/82/164

Based on the work of Prem D. Grover
Expert in thermochemical Conversion Technologies

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

VIENNA.

B. CONVERSION FACTORS FOR ENERGY

1 K.cal	$= 4.187 \times 10^3$ Joules
1 B.T.U.	$= 1.055 \times 10^3$ Joules
1 Therm	$= 1.055 \times 10^8$ Joules
1 C.H.U.	$= 1.9 \times 10^3$ Joules
1 K.W.H.	$= 3.6 \times 10^6$ Joules
1 ft lbf	= 1.356 Joules
1 ft lbf/lbm	= 3.0 Joules/kg.
1 BTU/lb	$= 2.326 \times 10^3$ Joules/kg
1 Kcal/kg	$= 4.187 \times 10^3$ Joules/kg

Latent Heat for water

(Ref. Rohsenow, W.M. and Hartnett, J.P. Hand book of Heat Transfer)

Temperatures		Pressure	Latent heat	
°F	°C	PSIA	BTU/lb	Kcal/kg
200	93.33	11.525	977.8	543.2
210	98.9	14.123	971.5	539.7
220	104.4	17.188	962.5	534.7

C. ABBREVIATIONS USED

ENEC	ETHIOPIAN NATIONAL ENERGY COMMITTEE
UNIDO	UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION
I.L.O.	INTERNATIONAL LABOUR ORGANISATION
BEDEC	BIOMASS ENERGY DEVELOPMENT CENTRE
MME	MINISTRY OF MINES AND ENERGY
'PARU'	NAME FOR STOVE OR FUEL SYNONYMOUS, IN SANSKRIT, WITH SUN AND FIRE

D. Acknowledgement.

The author would like to thank UNIDO to enable him to undertake this return mission. Dr. Myint Maung and Dr. R.O. Williams and their staff in Vienna and Dr. K. Vencatachellum and his staff in Addis Ababa are acknowledged for their active assistance during this mission.

Dr. Eng. Gebru Woldegiorgis,Executive Secretary, ENEC and his dedicated staff, not only provided facilities but actively assisted the consultant in carrying out tests on charring and briquetting unit and various stoves,under difficult conditions. Their generous cooperation is gratefully acknowledged.

Thanks are also due to Miss Abrehet Gebreselassie in Ethiopia and Mr. Bikram Chand and Mr. V.P. Gulati in Delhi for typing and compiling this report.

The consultant is thankful to Dr. Hubert, E.M. Stassen, UNIDO Consultant for having useful technical discussions and his coordination to this project during his mission to Ethiopia.

The consultant is indeed indebted to those personnel at ENEC who actively and sincerely assisted him in testing the equipment during this mission. Their number being large, only for brievity their names are presented in Annexure-K.

Acknowledgement is due for the active support and undiluted cooperation provided by Mr. Costantino Gliptis, proprietor of fabrication workshop 'Iron Industrial Installation' P.B. Box 40050 Addis Ababa for fabricating equipment in record time. Without his assistance it may not have been possible to develop so many units.

E. Recommendations

1. Firstly, in addition to husk stoves already made from empty tins, atleast 10 stoves should be got fabricated with three pan supports and tested with raw materials such as coffee husk, sawdust, eucalyptus leaves and different types of hay.

2. This simple husk stove should be popularised through mass media such as educational T.V. film and news-papers. Newspaper article should be supplemented with sketches showing different stages of its fabrication and combustion operation.

3. Immediate steps should be taken to acquire new space which should have the following facilities.

(a) Shed for Testing Stoves, charring and briquetting appliances. (Approximate area 8 m x 4 m x 4.5 m high).

(b) Open space away from residential and office areas for testing Kiln and drum charring units.

(c) The shed should be attached to testing Laboratory with approximate space area of 50 m^2.

(d) The shed should have space for workshop attached to the testing shed as recommended by other consultants.

(e) Covered space to store various biomass raw materials.

This activity should be given top priority as all other future activities in this project, comprising of gasification, stove testing, charcoaling and briquetting are directly dependent on availability of space. The present testing shed is absolutely inadequate and unsuitable. However, till such space is made available, the present work on testing of stoves, drum charring and Briquetting should continue.

4. The future work should be directed towards charring of such materials such as various types of hay and straw, eucalyptus twings with leaves and without leaves, leaves of various trees including eucalyptus, chopped twings of Acacia trees, mixture of coffee husk and chopped twings.

5. The activities mentioned under item (4) should follow the standard procedures such as finding the moisture and ash contents of raw materials and the product char with calculation of yields.

6. The above tests should be carried out in modified drum charring unit with tar collection system and the amount of tar recovered should be calculated. The drum should be painted with this tar just before firing/charcoaling operation.

7. These chars should be briquetted with different proportion of binders. The binders normally used are (a) cooked starch, (b) Lime, (c) molasses (d) Potter's clay (e) Black cotton soil free from silica and Bentonite. These binders should always be soaked in water for atleast 24 hours before being mixed with char. It is recommended that the total amount of inorganic solids (ash) in the dry briquettes should be between 15 to 25 per cent. The recommended proportion is 5 per cent bentonite and 5-7 per cent black cotton soil with and without 2 per cent lime. However, different proportions of various additives can be tried.

8. These briquettes should be tried for combustion in various stoves which have already been tested on charcoal, wood and biomass Ethio-briquettes as per procedure already adopted and listed in Annexure-V.

9. The 'PARU' stove with bottom opening system should be further tested on hay, coffee husk, sawdust as primary fuels and briquettes as secondary fuel. The bottom leakage

of tar can be stopped by providing asbestos rope of proper size.

10. The field testing of mobile Kiln should be carried out in the areas where materials such as corn cobs, cotton stalk and twigs are available in plenty. The tests should be carried out scientifically as mentioned for drum charring units. The present Kiln has been modified to have larger hopper and broader feeding chute to allow easy entry to chopped cotton stalk and twigs. Two such Kilns have been ordered and are being fabricated.

11. The Injera stove has been tested in the fabricator's workshop with Ethio-briquettes and wood blocks and gave satisfactory combustion performance. However, certain modifications such as having two openings for fuel injection instead of three at present, reducing the height of perforated circular sheet by 1 cm and increasing the diameter of smoke outlet pipe as specified in drawing should be carried out.

The stove should be tested with Ethio-briquettes, wood blocks and twigs both with individual fuel and in combination. The tests should be carried out both for water boiling in pan and cooking Injera and results compared with conventional three stone stoves.

12. Once the Laboratory equipment already ordered is received, the proximate analysis of various biomass and charred biomass as per standard procedure given in ASTM-D-1762 should be carried out. The heating values of such fuels

and briquettes should be found out by Bomb calorimeter by procedure given in ASTMD-2015.

13. A national training cum demonstration workshop should be organised in Nov., 1986. Two participants from each of the various training Institutes such as Forest Resources Institute Wendo Genet should be invited. The preparation for this workshop should be initiated by selecting the venue and identifying participating Institutes. In addition to giving general technical lectures by experts, each participant is required to operate equipment such as drum charring units, PARU stoves, briquetting unit and Sawdust stoves. At the conclusion of the workshop, every participating Institute should be given a set of Briquetting unit, drum charring unit and Paru stoves. The drawings of other stoves and Instructional manuals should also be provided to them. These institutes are then expected to demonstrate this units to their members/students and thereby these can be effectively disseminated. About 25 participants should be invited for this National Workshop.

14. Demonstrations for fabricating and combustion operation of simple sawdust tin stoves should be arranged for high school students either at ENEC or taking the units to schools by the ENEC staff. The activity shall motivate the students to make their own stoves and thus help in dissemination. For dissemination, manuals in simple language with pictorial illustrations should be prepared which has been elaborated under recommendation 16.

15. An International Regional demonstration cum training workshop should be organised in December, 1986 at Addis Ababa. The participants from Africa specially from East African region should be invited. This would be useful to share the ideas and also disseminate the appliances on biomass utilisation which have been developed by ENEC.

16. Before organising any workshop, it becomes imperative that detailed <u>operational manuals for units such as drum and kiln charring systems; briquetting of char and working of 'Pazu' and other stoves should be available.</u> These should be prepared in simple language and constructional features explained by simple illustrations. It should be of the type 'do it yourself' publication,first published in English and later translated into other languages including Amharic.

1.0 SUMMARY - INTRODUCTION

1.1 Energy Situation

Ethiopia is basically an agrarian and forestry based country with land area of 1.22 million square kilometers and a population of about 42 millions. With no proven reserves of fossil fuels such as coal and oil, about 93 per cent of the energy consumed is derived from biomass, mostly wood and cowdung resources.

Due to extensive deforestation and desertification, the country is facing acute shortages of fuel wood. With limited supply and increased prices, an average family in Addis Ababa has to spend about 25 per cent of their income on domestic fuel for cooking.

Unless short and long term measures are taken immediately on a massive scale, the majority of the population may have food but no fuel for cooking.

Preservation of meager existing forests coupled with aforestation programmes should be given top priority to maintain the ecological balance, which unfortunately has drastically changed resulting in acute shortage of food and fuel.

The Government of Ethiopia as well as a number of International organisations are well aware of these problems and certain remedial measures are being taken. However, because of the magnitude of the domestic energy problems, further action-oriented steps should be urgently undertaken by International organisations to supplement the programmes of the Government.

The conservation of petroleum products is an another urgent problem. The major portion of the export earnings of Ethiopia is being consumed for import of oil.

Another major bottle-neck in the domestic energy sector is the transportation of fuel wood and charcoal. With a view to minimise this factor and also considering the remoteness of villages, decentralised energy conversion systems are most suited for countries like Ethiopia. Massive inputs, therefore, are required to further the efforts initiated by the International Agencies to mitigate the hardships being faced by the people of Ethiopia.

To reduce the pressure on already depleted forests as well as to meet the domestic energy demands, the judicious use of agricultural and forest residues can be made as an appropriate alternative. According to a survey (2) 0.6 million tonnes of agro-residues in the form of coffee husk, cotton stalk, cereal straw and maize residues; and about 0.3 million tonnes of logging wastes are collectable.

1.2 PROGRAMME-IDENTIFICATION

As a result of the previous mission of the consultant under UNIDO Biofuels Demonstration Programme[1] (UC/ETH/82/164) during May-June, 1984, a number of biomass based energy conversion technologies demonstration systems were identified. In addition to installation of a couple of gas producer units for irrigation and power, mechanised charring and briquetting of coffee husk and cotton stalk were also recommended.

The following specific projects were identified for immediate implementation.

(1) Development, demonstration and testing of small scale characoaling units for agro-residues like coffee husk, cotton stalk, maize cobs, wheat, barley and Teff straw.

(2) Development of small scale char-briquetting systems.

(3) Design and development, demonstration and testing of domestic cooking stoves for their use with agricultural and forestry residues.

During the last fact finding mission, in addition to identification of specific demonstration projects, the time scheduling of these activities and the financial outlays were also provided.

1.3 Scope of Present Mission

The scope of the work during the recent return mission was in continuation of the previous mission in June 1984 and implementation of some of the activities outlined in the report[1]. These were exclusively confined to : (a) Development, demonstration and testing of small scale charcoaling and briquetting of biomass residues other than wood, (b) development and testing of various domestic cooking stoves using agricultural and forest residues as such and/or in the form of charred briquetted fuel.

1.3.1 Charring Units

In the area of small scale charring, the following units were developed and successfully tested.

(1) Reverse flow drum charring units.

(2) Vertical Retort type continuous mobile kiln.

(3) Modified drum charring units with provision for collection of tar.

(4) In-built charring system in Paru stove.

1.3.2 Briquetting Systems

For hand briquetting the units developed are:

(1) Simple single briquette pipe mould.

(2) Manually operated briquette mould.

(3) Lever-operated briquetting press.

(4) Identification of binders and their mode of utilisation with requisite proportions.

1.3.3 Domestic cooking stoves

For efficient utilisation of agro and forestry residues as domestic fuels, the following types of stoves were developed and tested at the facility provided at Ministry of Mines and Energy by ENEC.

(1) Paru Stove including modified version with bottom filling arrangement.

(2) Sawdust/Coffee husk stoves fabricated out of m.s. sheet as well as from empty paint and milk powder tins of 'NIDO' and 'NESPRAY' brands.

(3) Stoves for burning biomass briquettes being manufactured in Addis Ababa from mixture of sawdust, coffee husk and cotton wastes known as Ethio-briquettes.

(4) Injera (a popular local bread) baking stove.

In addition to development of the above mentioned units, stoves already available in ENEC were also tested for their thermal efficiencies to have their comparative performance evaluation.

These are:

(1) Kenyan Jiko stoves for wood and charcoal and charred briquettes.

(2) Local charcoal stoves already in use in Ethiopia and made out of clay, tin sheet and m.s. iron sheet.

(3) Small wood cum charcoal stoves developed by ENEC under I.L.O. stove development programme.

(4) Stove for Ethio-biomass briquettes obtained from Denmark along with Ethio briquetting plant supplied by Eco Briquette Company, Denmark named as 'Danish' Stove.

The development of these systems and their relative performance evaluation is discussed in subsequent chapters of this report.

To summarise the performance evaluation carried out on these systems, a total of 92 experimental tests were conducted on charring and briquetting as well as 18 different types of cooking stoves. As sufficient tests, 74 in number, have been carried out on stoves and every possible conceivable type of cooking stove has been tested, the major efforts should now be directed toward their dissemination. However, depending upon the feed back obtained from the users, these may be accordingly modified. At present there does not seem to any urgent need to provide further inputs for developing new types of cooking stoves.

1.4 REVISED PROGRAMME

The projects identified in the previous fact finding report[1] have been reviewed and revised programme of activities along with financial outlays has been presented in this report. These take into account the recommendations given by other consultants, one for the gasification of biomass programme[3] and another for setting up a mechanical workshop [4] as the constituent part of Biomass Energy Development Centre in Ethiopia. The work plans for these activities have been presented both as short term programme (1986-87) and as long term project (1986-1990). Depending upon resources available , the implementation of these activities can be accordingly undertaken.

1.5 DISSMINATION/DEMONSTRATION ACTIVITY

As mentioned earlier the appropriate cookstoves have been developed awaiting large scale dissemination programme. Some of the steps for this programme have been given under specific recommendations following this section.

Also during this mission, with the help of ENEC staff, demonstration of 'PARU' Stove sawdust/Coffee husk stove were conducted at the following Institute.

(1) Forestry and Wildlife Resources Institute Wendo-Genet.

(2) Awassa Junior College of Agriculture Awasa,(Home Science Department).

(3) Arsi Rural Development Unit (ARDU) Asela.

Other Institutes could not be visited due to shortage of time. However, all those mentioned under Job description and many other shall be accommodated during the proposed National Workshop.

2.0 DEVELOPMENT OF CHARRING AND BRIQUETTING EQUIPMENT

2.1 Introduction

The data on energy requirements and identification of biomass resources are presented in earlier report(1). In this section, the units developed for charring and briquetting of biomass are described. Most of these units were designed,were fabricated in a local workshop, then duly tested and personnels from ENEC trained for their operation. In this report, term 'biomass' generally refers to agro and forestry residues other than wood or wood derived char coal, traditionally produced in Ethiopia by above ground wood pile (Beehive system) methods. The bio-units that are most appropriate for Ethiopia have only been emphasised for their immediate dissemination.

2.2 Identification of Appliances

The units developed for small scale charring and briquetting of biomass and the status of their availability during the present mission are given in Table-2.1. Some of these units were already available based on the designs made available during the previous mission, some were fabricated in India and transported to Addis Ababa and rest were fabricated locally.

Table 2.1

Status of Availability of Units

Item	Unit	Quantity	Source of Procurement	Drawing No.
1.0	Drum charring unit reverse flow model	one	Already available	2.1
1-a	-do-	Two	Imported from India	2.1
1-b	-do-	Nine	On order with Govt. Workshop	
2.0	Drum charring unit with tar collection	One	Locally fabricated	2.2
2-a	-do-	Three	On order by UNIDO	2.2
3.0	Mobile Kiln	One	Locally fabricated	2.3
4.0	Modified Mobile Kiln	Two	On order by UNIDO	2.4
5.0	Single briquette pipe mould	One	Locally fabricated	2.7
6.0	Hand mould	One	Locally fabricated	2.5
6-a	-do-	Nine	on order by UNIDO	2.5
7.0	Lever Operated Briquetting press	One	Locally fabricated	2.6

2.3 Biomass-Charring Units

As described in Table-2.1. The appropriate charring systems identified for further dissemination programme are given below along with their quantitative number in parentheses.

(a) Drum charring units (12)

(b) Drum charring units with tar recovery system (4)

(c) Mobile kiln (1)

(d) Modified Mobile kiln (2)

The salient features of these units are described in the following sections.

2.4 Drum Charring Units

The unit, as shown in Figure 2.1, can be easily fabricated cut of a standard petroleum drum by incorporating conical

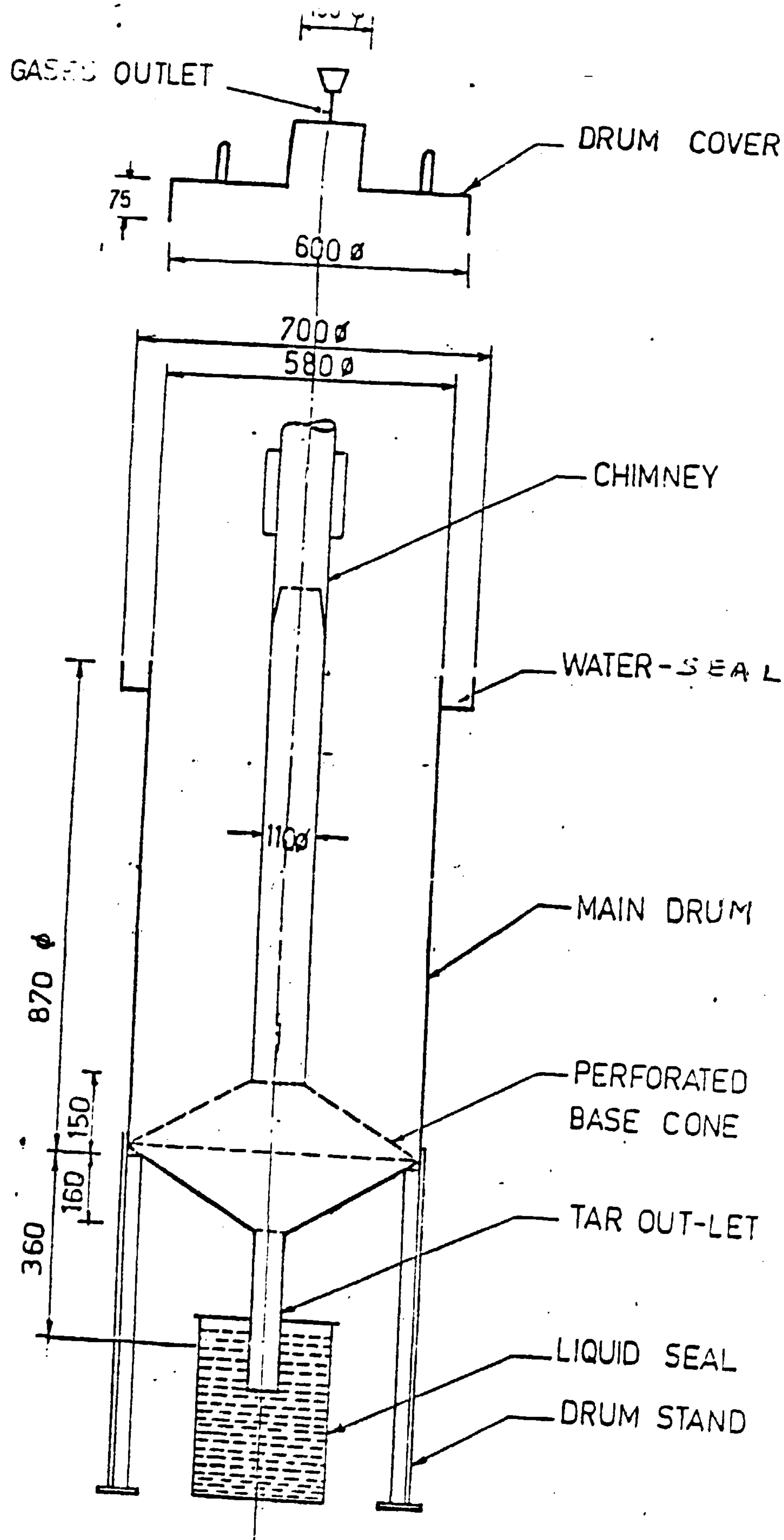


FIG 2.1 DRUM CHARRING UNIT REVERSE FLOW MODEL.

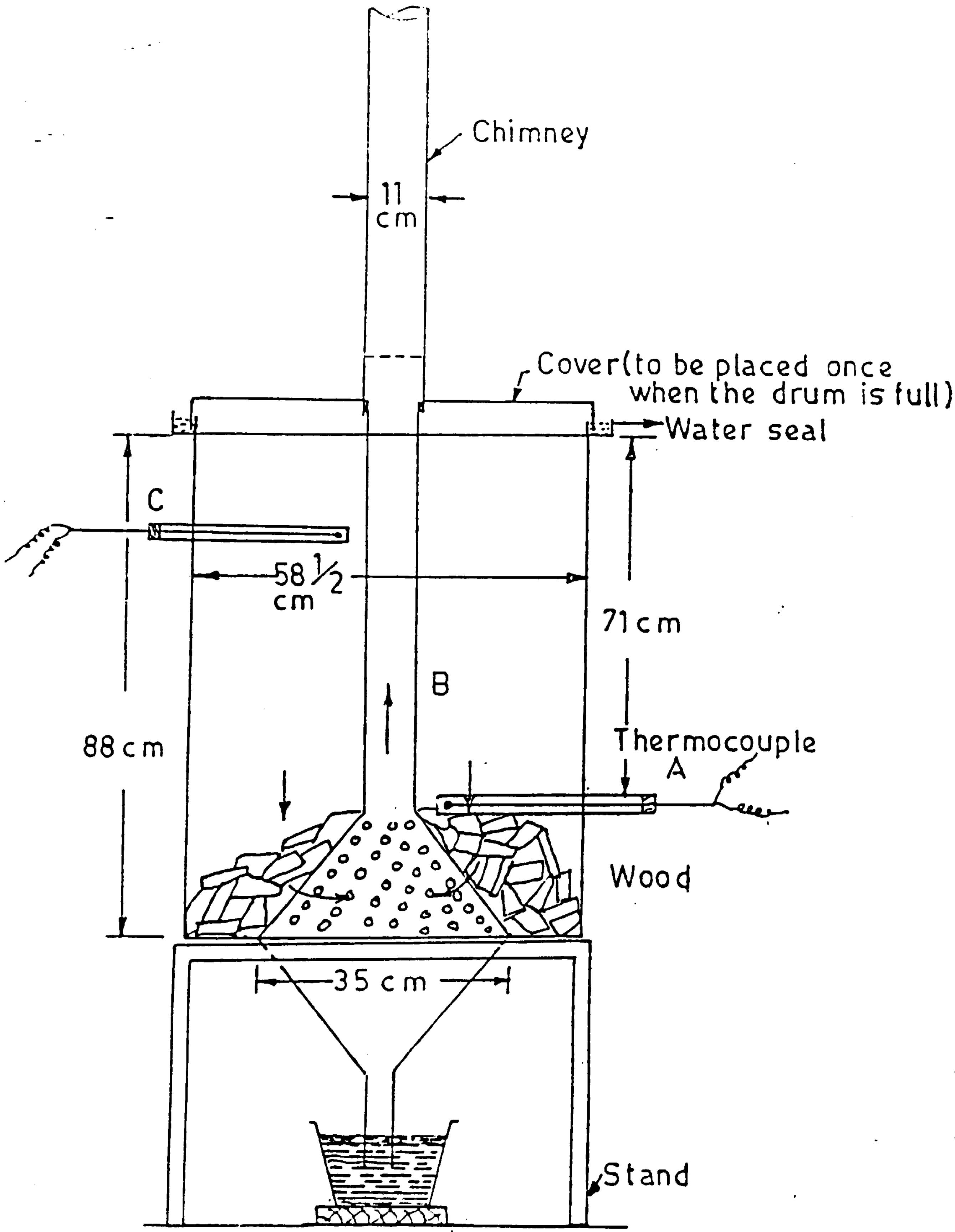


FIG. 2·1-A DRUM CHARRING SYSTEM.

grate, central chimney, water seal and top cover. The cost of such a unit should be about 120 US dollars. It is a batch process and can process about 100 Kg. of materials such as wood blocks of size 75x75 mm in about 6 hours.

In addition to being useful for charring of wood blocks, these drums can be utilised for carbonisation of such materials as corn cobs coconut shell, cotton stalk, cereal stalk, coconut pith and hay like residues. These units are unsuitable for granular materials of the type of coffee husk and rice husk, however along with other materials some portion of latter residues may be used.

As given in Annexure-II materials such as Acacia wood, corn cobs, hay, Eucalyptins twigs and mixed feed of corn cobs and wood were carbonised giving yields ranging from 22 to 45 per cent. Two persons can easily operate 10 drums and make 250-300 kg. of Charcoal/Charcoal briquettes per day making it an attractive commercial proposition.

While char obtained from wood blocks, coconut shell and corn cobs can be directly utilised as fuel. The char from hay and cereal stalk shall have to crushed, mixed with wet binder, briquetted and then used as fuel after drying. These units are also shown in Fig.2.1; P-2.1 and P-2.2.

2.5 Drum Charring Units with Tar Collection (Fig. 2.2-A)

These systems have similar functions and performance characteristics to drum charring units. These are modified so as to have tar collection arrangement as shown in Fig. 2.2. The additional components are the removable horizontal component of chimney and tar collection barometeric leg. The tar so collected is useful for protecting the corrosion of drums during operation and storage.

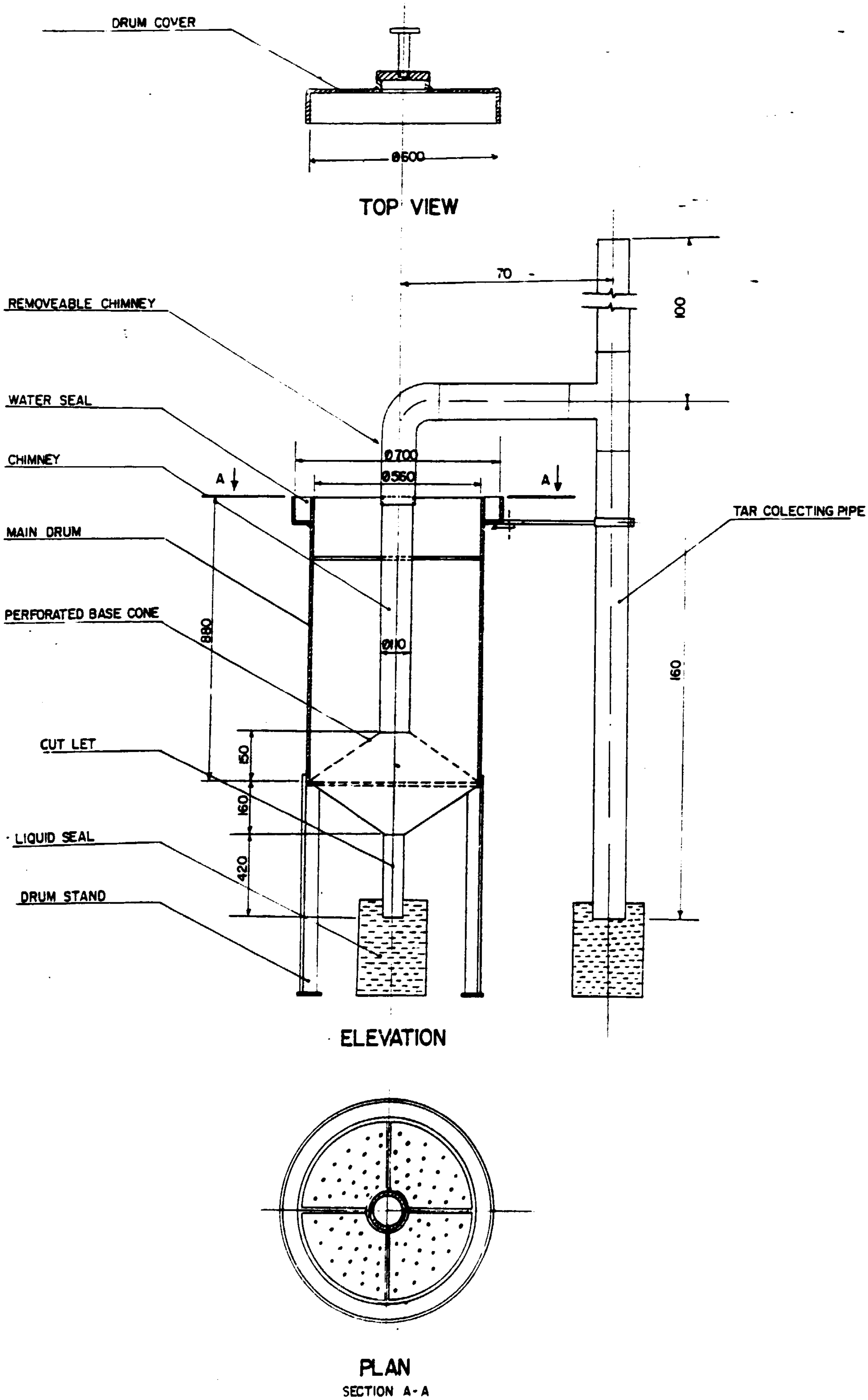


FIG. 23A DRUM CHARRING UNIT WITH TAR COLLECTION

This should be applied just before the firing of the drums. This is also an important raw material for its use as protective coating for wood against attack by termites. One such unit was got fabricated in Ethiopia and qualitatively tested for tar collection.

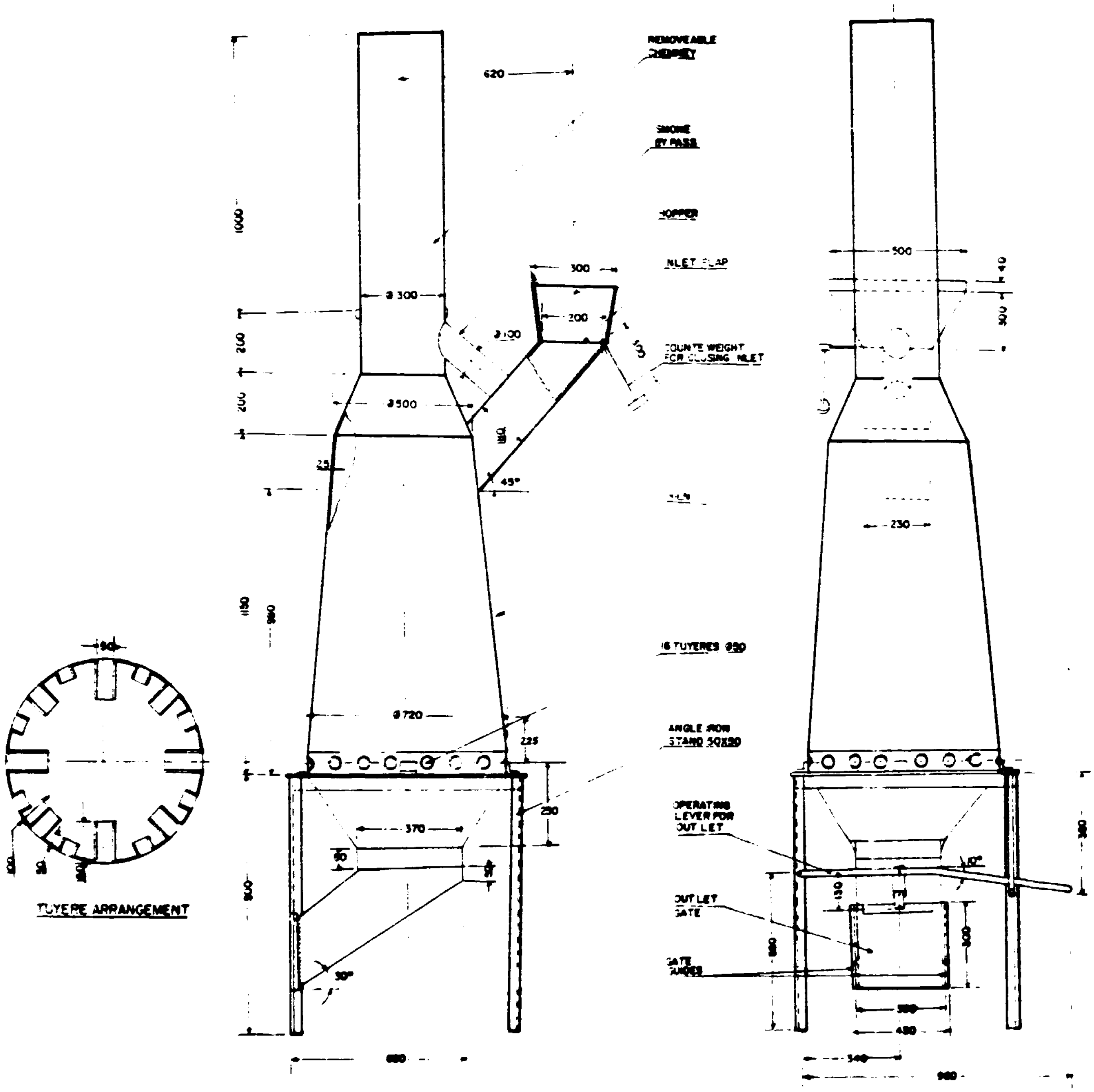
2.6 MOBILE KILN

Unlike batch charring operation in drum units, Mobile kiln has the advantage of sustaining continuous operation, thereby giving higher rates of production. About 100-120 Kg. of sundried corn cobs can be carbonised in an hour giving product yields from 25 to 40 per cent depending upon operating parameters.

The unit basically consists of a feed hopper (Fig. 2.3) connected by chute to the main vertical shaft kiln. In between these two a damper or inlet flap is provided, actuated by outside lever with counter weight, to prevent the gases leaving through the hopper. The base of the kiln has 16 tuyeres to allow the introduction of air for partial combustion of biomass materials, to generate heat necessary for carbonisation. Below the tuyeres enough space is provided for the soaking of carbonised material to attain uniform quality of the product before the product is removed by opening the discharge port operated by a lever handle.

The configuration and respective length of air tuyeres is also shown in Fig. 2.3. This arrangement is necessary to have proper distribution of air. To provide sufficient draft a removable Chimney, telescopically placed on top of the kiln is provided.

To initiate operation, the kiln is first filled with bio-mass just above the tuyere and the material inside is then ignited by providing torch flame through the tuyeres. Once properly ignited, more materials is added through the feed



MOBILE KILN FOR CHARRING WOOD AND AGRO-RESIDUES

FIG - 2.3

hopper. The material is periodically discharged by opening the outlet gate. Initially uncharged material is obtained which can be refed to the kiln, till product carbonised to the proper quality is obtained.

The properly carbonised material discharged through the kiln is quenched to avoid its further combustion.

The kiln can be subdivided into various operational zones. Just above the tuyeres, the material comes in contact with fresh air and this zone can be termed as combustion zone. In this zone, the temperature is the highest reaching upto 1,200°C and may extend upwards to the extent of 10 to 20 cm from the centre of the tuyeres. Above the combustion zones is the pyrolysis zone followed by drying of material. This drying zone extends upto the top level of the material in the kiln.
Below the tuyere level , the space can be termed as soaking zone.

The extent of soaking zone plays an important role in providing the uniformity of charred product. The more space is provided in soaking zone, the more uniformity of product is obtained due to higher retention time. During the present mission, one such kiln was developed and gave satisfactory results. However to further improve the uniformity of the quality of product the design of this kiln was modified. More pictures are shown in Figs. P-2.3 (A-L).

2.7 MODIFIED MOBILE KILN

The modified kiln has the similar overall dimensions except that the soaking zone volume has been increased. The modified design of this unit is shown in Fig. 2.4 in which the pitch centre of the tuyeres has been moved up by 22.5 cm while rest of the dimensions have been kept same. It is recommended that the remaining two kilns should be got fabricated according to this modified design and tested and results compared with original model. Due to high

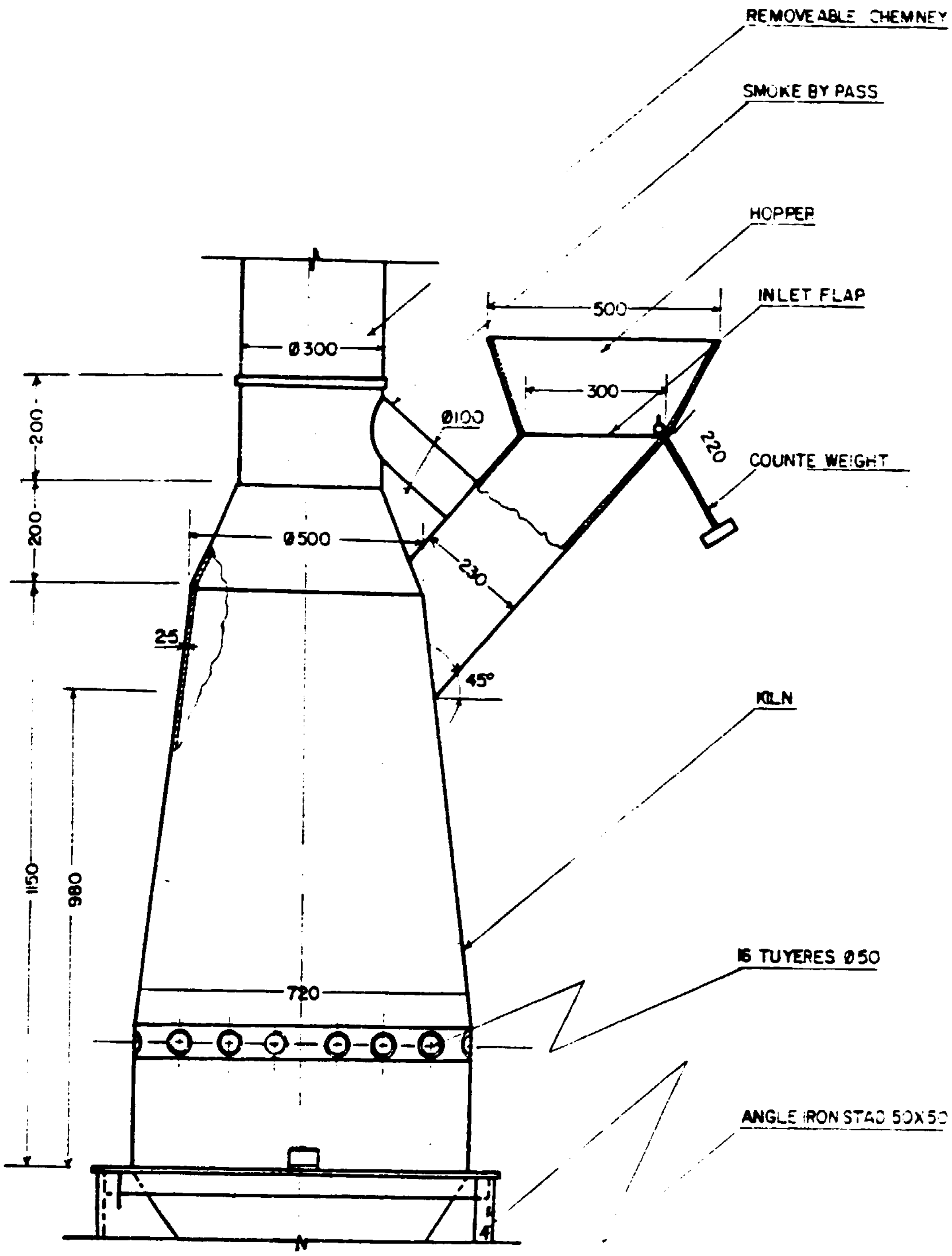
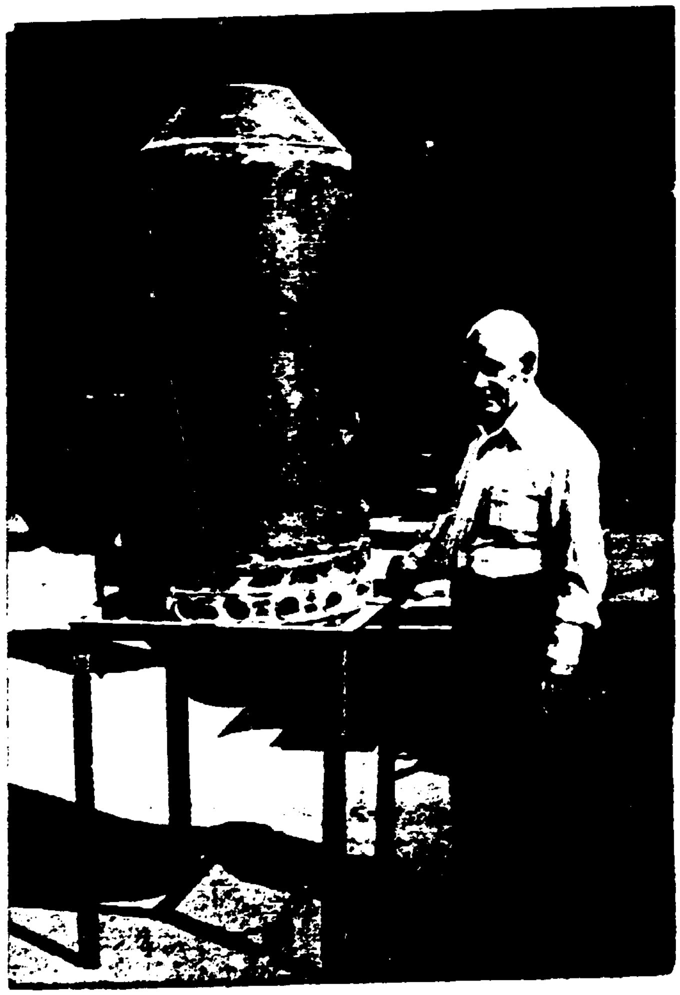


FIG. 2.4 MODIFIED PORTION OF MOBILE KILN
SCALE 1:10

Fig. P-2.3(A): Mobile Kiln under Fabrication



Mr. Gliptis Costantino with Kiln

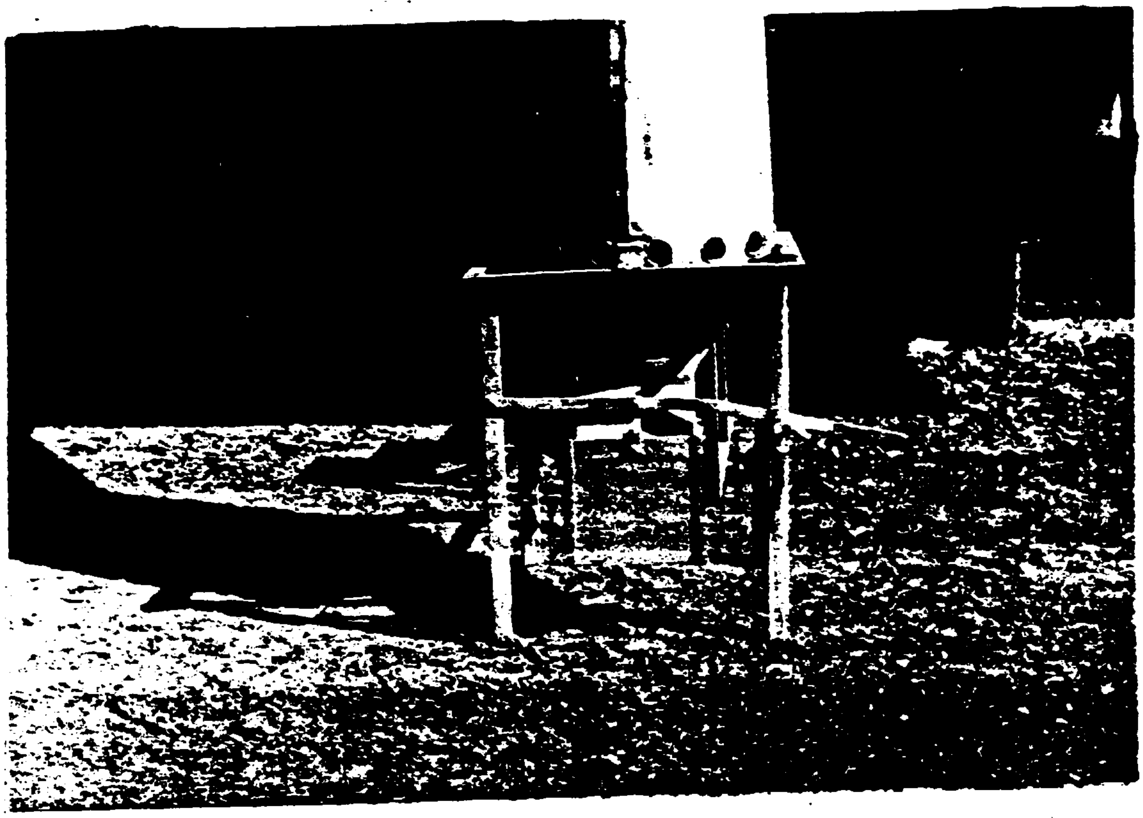


Fig. P-2.3(B): Lever operated Discharge Port of Kiln

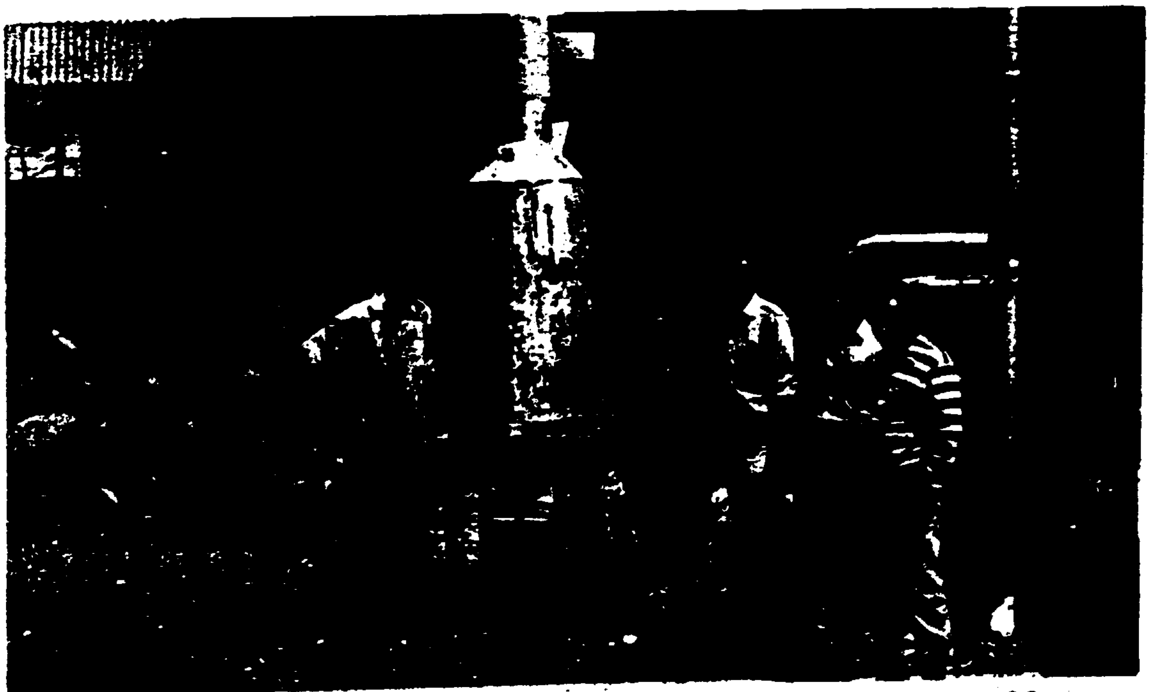


Fig. P-2.3(C) : **Kiln Under Operation with ENEC Staff**

L-R : Shewangzaw, Abebe, LemLem, Kidane Dereje and Misa

Fig. P-2.3 (D) : Kiln Under Operation - Note the Black Charred and White Uncharred corn Cobs.

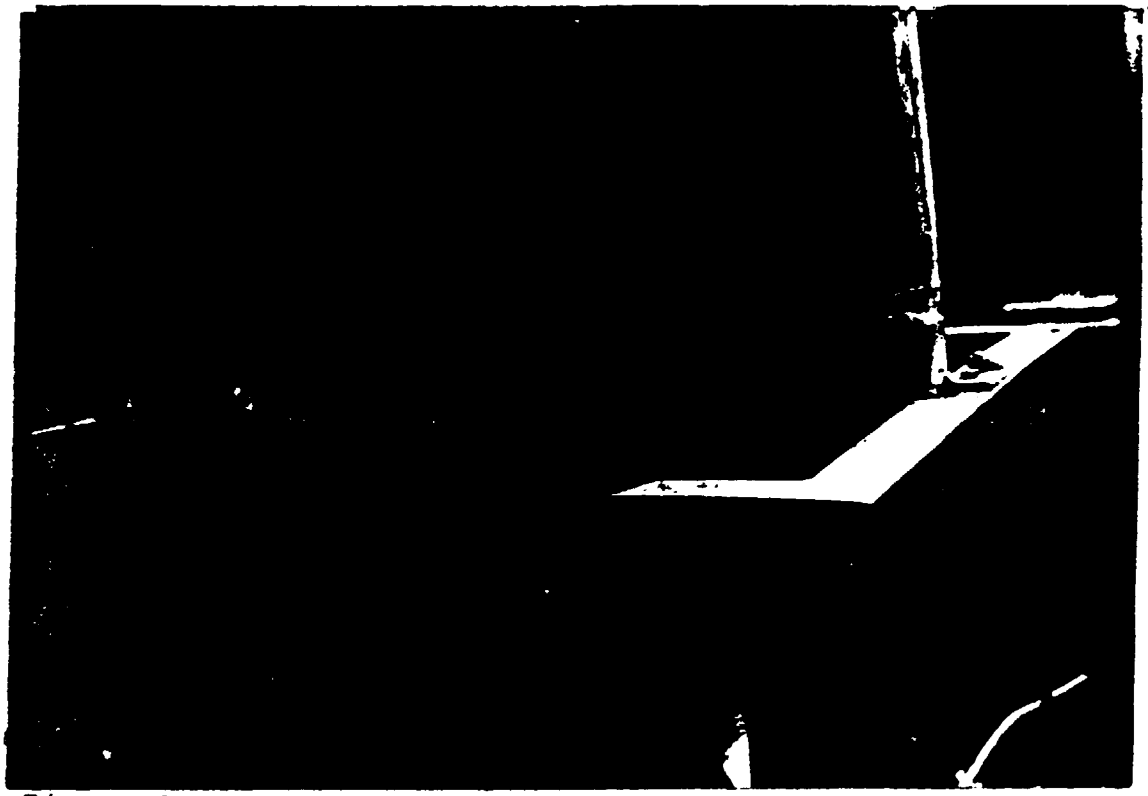


Fig. P-2.3(E): Kiln under operation. Note the red hot Charcoal Through Sixteen Tuyers

Fig. P-2.3(F): Kiln Under Operation Note-The Smoke

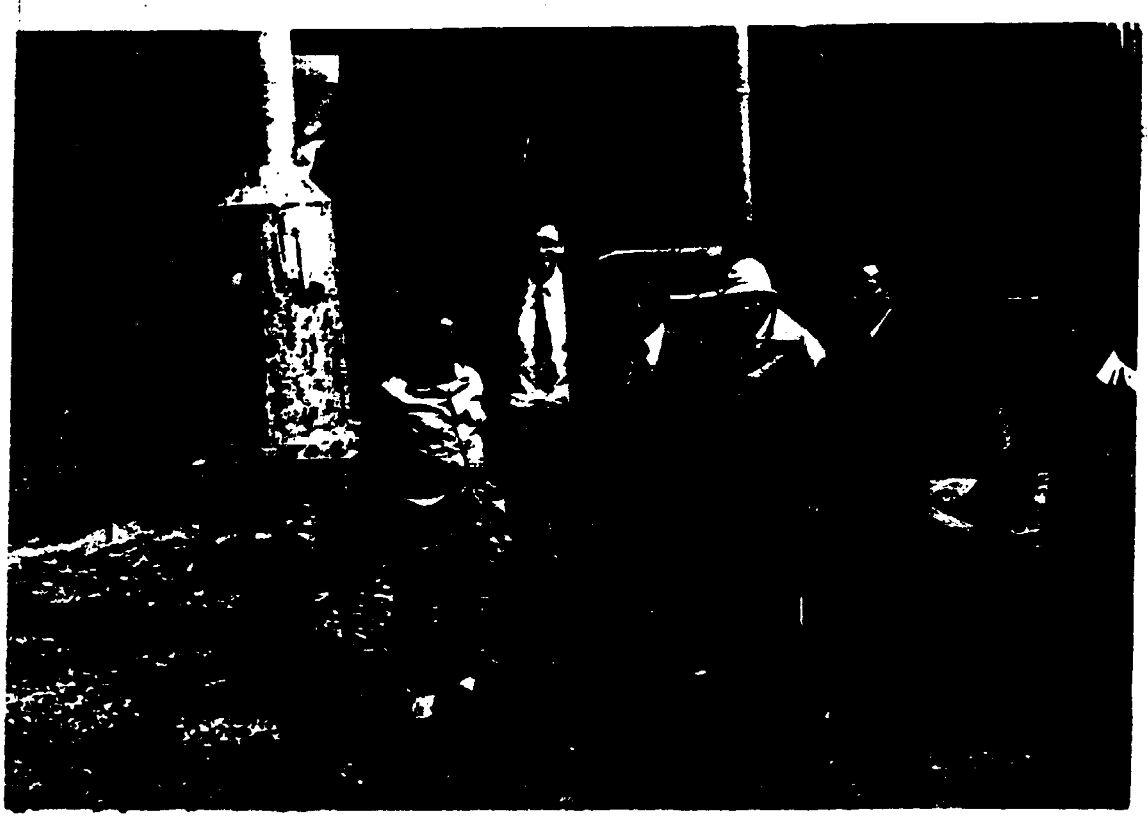


Fig. P-2.3(G) : Mobile Kiln under Inspection

L-R: Dr. Ghobru, (ENEC) Mr. Mayar, UNIDO Dr. Vencatachellum, UNIDO Dr. Grover IIT Delhi

Fig. P-2.3 (H) : Full View of Kiln

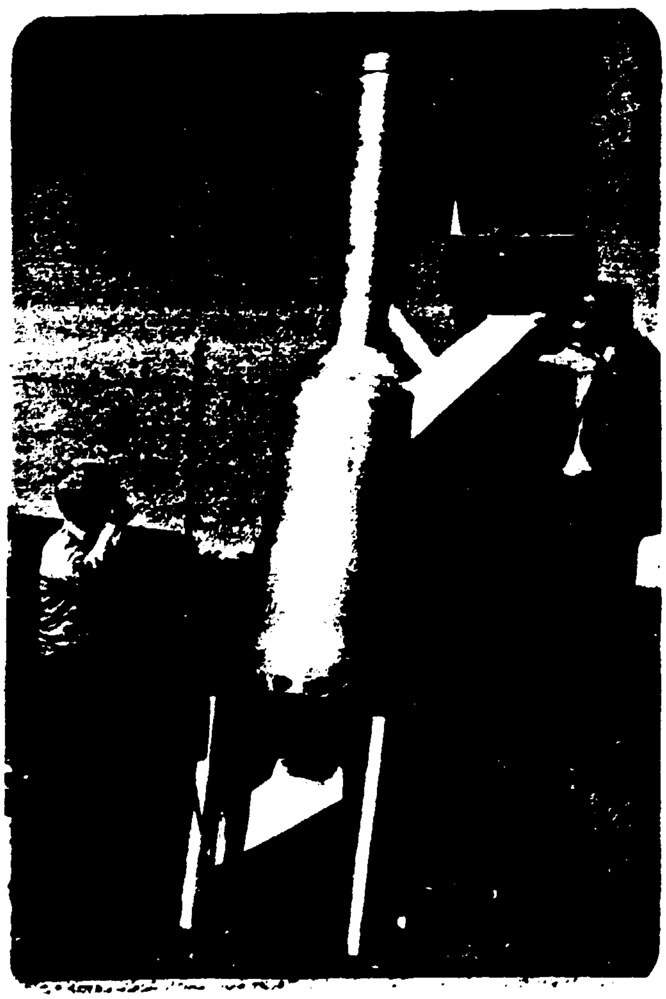


Fig. P-2.3 (J): Top view of Kiln

Fig. P-2.3(L): Corncobs charcoal made from cobs. in Mobile Kiln

Fig. P-2.3 : Kiln under Fabrication

capacity, these units emit excessive smoke. The smoke being injurious, it is strongly recommended that these should be operated in open and windy areas far away from human habitants. Further, the orientation of feed hopper should be so arranged that the smoke is carried away in the direction so as not to effect the operating personnels.

2.8 BRIQUETTING UNITS

2.8.1 Introduction

The densification or briquetting of biomass can be carried out by these processes. Which are :

(a) Direct briquetting without binders.

(b) Direct briquetting with binders.

(c) Briquetting of biomass after partial/complete carbonisation with binders.

Although the present work is directly related to the briquetting of biomass after corbonisation, other two briquetting alternatives are also briefly discussed. This should enable the planners to compare these methods and adopt any one of these depending upon the end uses and proximity of biomass availability.

2.8.2 Direct Briquetting Without Binders

The binderless briquetting of shredded biomass has the major advantage that by densification the bulk density is normally increased by an order of magnitude. Normal bulk density of cereal straw is 50-60 Kg/cu.m. but when briquetted it increases to 500-600 Kg/Cu.m. This increase in bulk density reduces the cost of transportation of biomass.

The briquetting of Shredded biomass is carried out by high pressure compacting machines. The biomass is first shredded to homogeneous size (unless available in this form like coffee husk),moisture controlled to optimal level of about 12 per cent and then subjected to high pressure ranging from 1,700 to 2,000 atmospheres. During compacting, the temperaturesof about 110 to 160°C are attained by friction and under these conditions the lignin component, present in every biomass,gets plasticised and acts as natural binder. The wear and tear on such machine is very high and results in excessive maintenance and operational costs.

By this process the briquette gets a density of about 1.6 gm/cc compared to about 0.6 for normal sundried wood. The briquettes with such high density have very low porosity and are difficult to burn in any type of domestic stove without excessive smoke formation. Such materials are only useful in high temperature industrial furnaces.

2.3.3 Direct Briquetting with Binders

To overcome the disadvantages inherent with high pressure direct compacting, such as excessive maintenance costs and unsuitability of fuels for domestic sector, low pressure machines using external binders have been developed. The binder normally used is sulphonated lignin in powder form. However, this is most suitable for briquetting of soft and shredded biomass materials such as sawdust and cotton ginning wastes. The density of such briquettes is about 0.8 gm/cc and in properly designed wood stoves,these can be used as domestic fuel.

One such plant having a rated capacity of 500 Kg. of briquettes per hour has already been installed at Addis Ababa. This plant has been supplied by Eco-Briquettes company Denmark and briquettes are being made from a mixture of sawdust, coffee husk and cotton linter waste. During the present mission, special stoves were designed and tested for these briquettes known as Ethio-briquettes in Ethiopia.

The mechanical wear and tear for such machines is still substantial and also have the limitation of being suitable for a few type of biomass. As an instance, coffee husk alone cannot be briquetted without excessive overloading of the machines.

2.8.4 Briquetting of Carbonised Biomass

When biomass is partially or fully carbonised, the char obtained can be briquetted easily after mixing it with water and suitable binders. The briquetting can be carried out at any level of production rate. When biomass is heated to about 200°C in the absence or controlled amount of air the fibrous structure gets destroyed which normally offers resistance to compacting. The char obtained is very friable and can be easily crushed and then mixed with binders for moulding into briquettes.

However during carbonisation, a substantial amount of energy is lost but the product obtained becomes smokeless due to removal of smoke forming volatile matter. For example, 50 per cent energy is lost when wood is converted into charcoal. In order to conserve maximum amount of energy in solid char, the charring process parameters such as temperature should be well controlled so that only fibrous structure is destroyed and the maximum amount of char is obtained. This process is termed as thermal degradation by partial pyrolysis whereby only the minimum amount of volatiles are removed.

The briquetting can be carried out either manually or by briquetting machines. The machines normally used are roller presses which produce pillow shaped briquettes called as barbeque briquettes in western countries, and by extruders giving cylindrical briquettes with or without central holes. The density of such briquettes varies between 0.6 to 1.0 gm/cc. and can be used as substitute for charcoal.

According to terms of reference for the present mission, it was envisaged to develop only small scale manually operated appropriate briquetting systems. Accordingly the following types of briquetting press were developed and tested in Ethiopia.

2.9 BRIQUETTING UNITS DEVELOPED

Three units for briquetting were developed. These are: (a) pipe mould for one briquette, (b) hand mould for eight briquettes in one operation and (c) lever operated press. Before giving details of these units, process for making char-binder mixer and type of binders used are described.

2.9.1 Preparation of Char for Briquetting

The char is first moistioned and then crushed or pounded to uniform size. It is then mixed thoroughly with binders with addition of more water such that the total moisture content is about 40-50%. Along with binders, certain inert materials such as powdered lime stone or local clay may be added. For use of these briquettes in domestic sector, it is desired to have 15-25% inert inorganic material to retard the rate of combustion and extend burning time. These inert materials can be termed as energy extenders.

The typical composition of partially carbonised briquettes is given in Table-2.2.

Table 2.2

Typical Composition of Briquette

	Component	Per cent (Wet Basis)
1.	Moisture	5.8
2.	Volatile	15-30
3.	Fixed carbon	50-65
4.	Ash including Energy Extenders.	15-25

2.9.2 Suitable Binders

Depending upon availability and their cost, many types of binder can be used for forming briquettes. Some of these are: Bentonitic clay, clay used for making potteries and bricks, cooked starch, molasses, fermentation sludge, lime and even black cotton soil. These can be used either alone or in combination. The suitability of any clay can be determined by finding its swelling index.

The swelling index can be found by adding 50 grams of powder clay in 200 cc water in a glass measuring cylinder of 250 cc capacity. The height to which the clay gets expanded indicates its binding characteristics. Taking Bentonite as a standard, the comparative swelling height can be taken as an index for binding properties. Higher the height of swelling, better are the binding properties for a particular clay.

The binders and energy extenders should not be added as dry powder. The clay or lime should be soaked in water for atleast 24 hours before these are mixed with the char to make the feed stock for briquetting.

The amount of binder added for compacting depends upon its binding characteristics. Some of the typical composition of char-binder mixtures are given in Table 2.3-2.6. Various compositions are possible and should be tried before recommending these for production purposes. With a view to utilise the locally available materials, the recommended composition should be appropriate depending upon the site for charring and Briquetting operation.

Table 2.3

COMPOSITION OF BRIQUETTING MIXTURES WITH STARCH

Component	Percentage (Wet)	Percentage (Dry)
(1) CHAR (low ash)	38.0	70.0
(2) Starch (cooked)	2.0	4.0
(3) Total moisture	50.0	5.0
(4) Any clay or Lime Stone powder	10.0	21.0

Table - 2.4

Composition of Briquetting Mixture Without Starch

Component	Percentage (Wet)	Percentage (Dry)
1. Char	39.5	75.0
2. Bentonite clay	2.5	5.0
3. Total moisture	50.0	5.0
4. Local clay	8.0	15.0

Table 2·5

Composition of Briquetting Mixture With Molasses

Component	Percentage (Wet)	Percentage (Dry)
1. Char	37.0	70.0
2. Molasses (50% Sugar)	5.3	10.0*
3. Total moisture	47.3	-
4. Clay	10.4	20.0

* 10 percent contains 5 per cent water.

Table - 2.6

Composition of Briquetting Mixture With Clay

Component	Percentage (Wet)	Percentage (Dry)
1. Char	39.5	75.0
2. Clay*	10.5	20.0
3. Water	50.0	5.0

* Clay could be good black cotton soil without sand.

Depending upon the type and content of clay and compacting pressure , the crushing strength can vary.

2.9.3 Single Briquette Pipe Mould (Fig. 2.7)

This mould consists of a single pipe of 5 cm internal diameter and about 20 cm in height in which another pipe with one end closed is inserted acting as plunger. Both the pipes have horizontal rods welded to act as handles as shown in Fig. 2.7.

After the outer pipe is placed on a horizontal base plate. The mixture is added followed by insertion of plunger. The mixture is compressed by putting manual pressure. Then the pipe is lifted from the base plate and plunger is pushed further to remove the wet briquette.

The wet briquettes are later left there for sun drying. This unit, though simple but makes only one briquette during an operation. Hence this is not very suitable for production of briquettes but can be used for making trials.

2.9.4 Hand Mould (Fig. 2.5)

As shown in Fig. 2.5, this simple unit consists of main frame or mould, bottom plates briquette divider and top plate. This is similar to a mould which is used for making bricks. The function of briquette divider is to

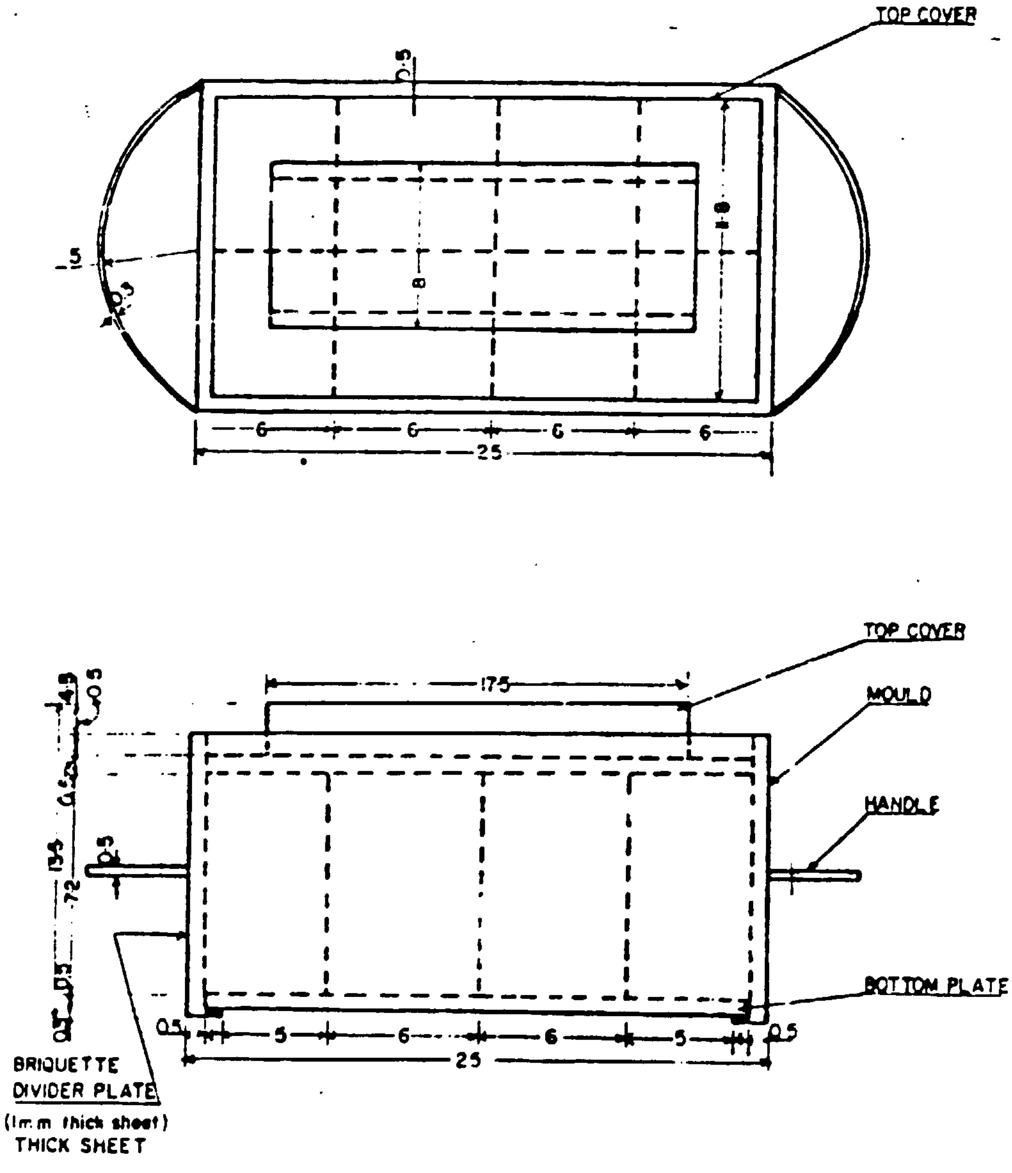
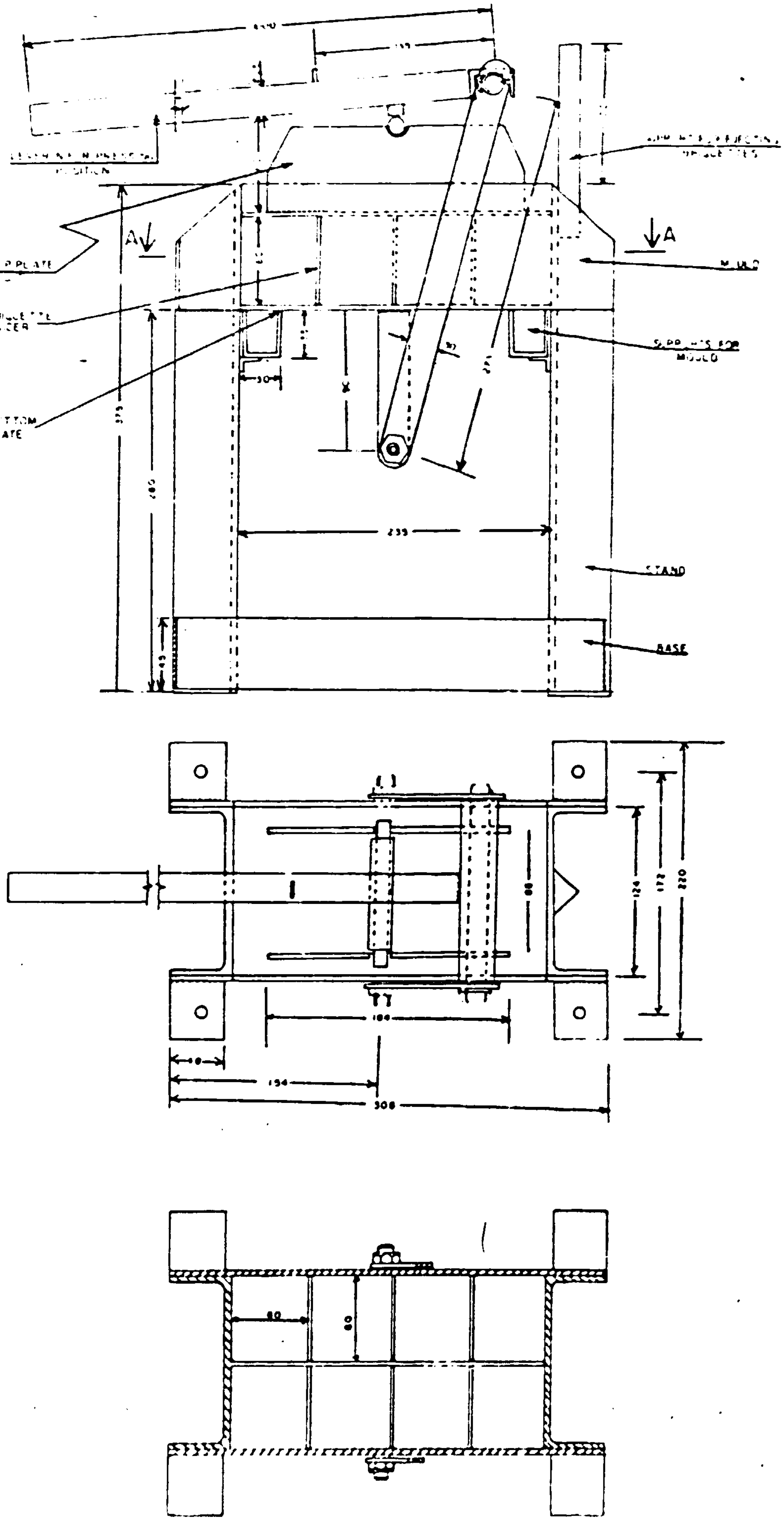


FIG. 2.5 HAND BRIQUETTES MOULD FOR EIGHT BRIQUETTES PER MOULDING

All measurments are in c.m.



SECTION A–A

FIG 2.6 LEVER OPERATED BRIQUETTING PRESS

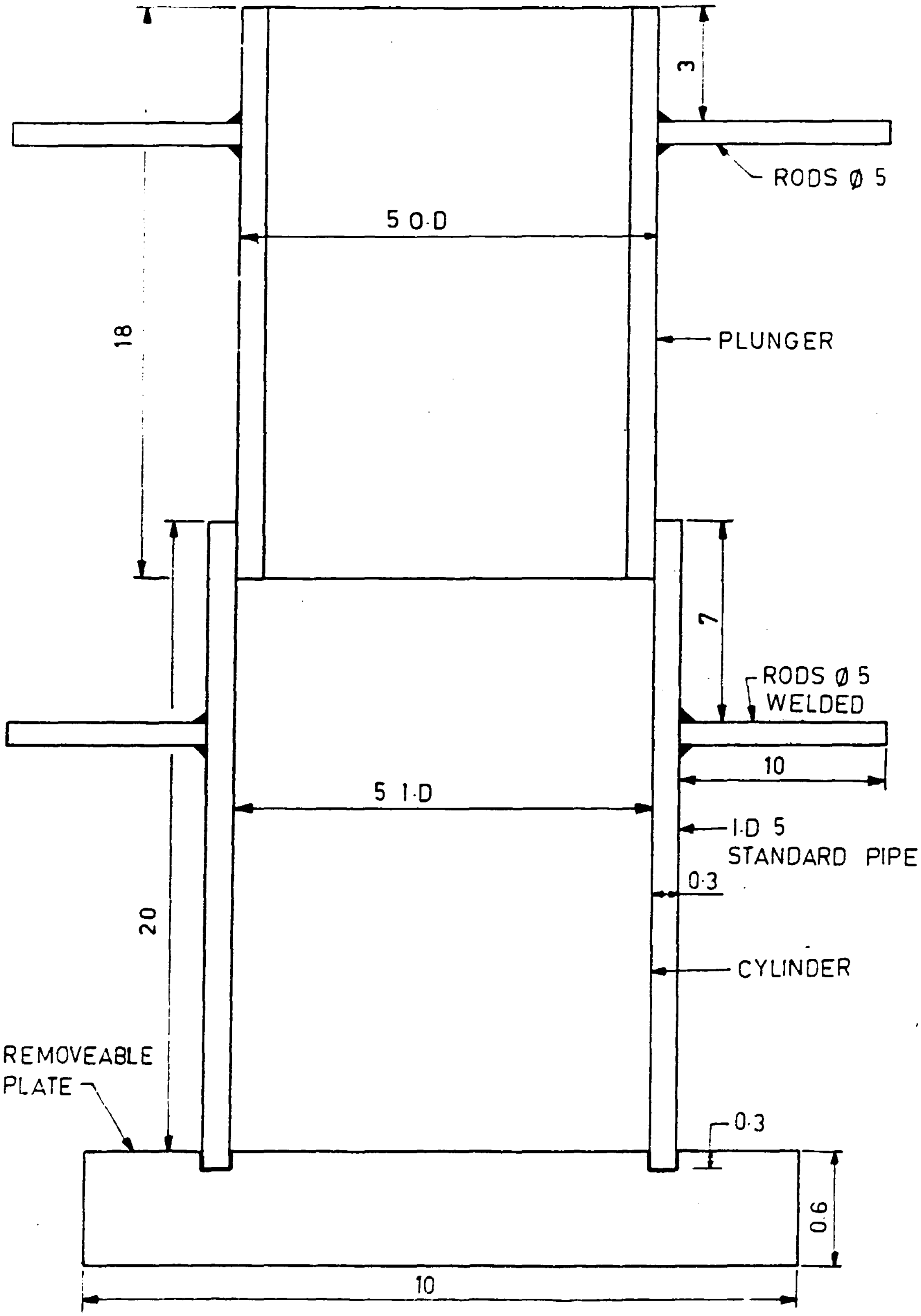


FIG 27 SINGLE BRIQUETTE PIPE MOULD

(ALL DIMENSIONS ARE IN CM)

provide partitions in the mould to make and separate the char block into eight separate briquettes.

The sequence of operation initiates by putting the bottom plate into the mould followed by adding char mixture. The mixture is pressed with hand and then briquette divider is pushed into the char. If required,more char can be added followed by placing the top plate over the char inside the mould. The top plate is pushed by hammering it with a wooden mellot.

In order to take out the briquettes the top plate is removed, the mould is inverted on a flat surface and the bottom plate is pushed down. The mould is taken out, bottom plate is removed from the top of the briquettes and briquette divider is carefully removed so as not to break the briquettes. In one operation, about 2.0 Kg. of char can be briquetted giving eight briquettes of 6x6x6 cms square in shape. These briquettes are left there for sun drying. The whole operation takes about 3-4 minutes.

As given in Annexure VI,four trials were made to prepare briquettes with the mould and satisfactory results were obtained using coffee husk char with various binders. (Sl. No. 6-9 Annexure-VI.

2.9.5 Lever Operated Briquetting Press (Fig. 2.6)

The press was developed in Ethiopia to use lever mechanism for compacting char into briquettes. The mould is similar to the hand mould described in previous section and details are given in Fig. 2.6. As shown in -

Fig. P-2.3 the lever is placed on the ground so that the top of the mould is exposed . This photograph also shows the briquettes divider and top plate lying on the right side of the base plate. The char is added into the mould, briquette divider inserted and top plate is placed on top of the char inside the mould.

The lever handle is lifted and its top fulcrum rod is placed on top of the mould. The lever is pushed down to provide compression on the top plate. Due to linkages provided to the bottom plate, The bottom plate is

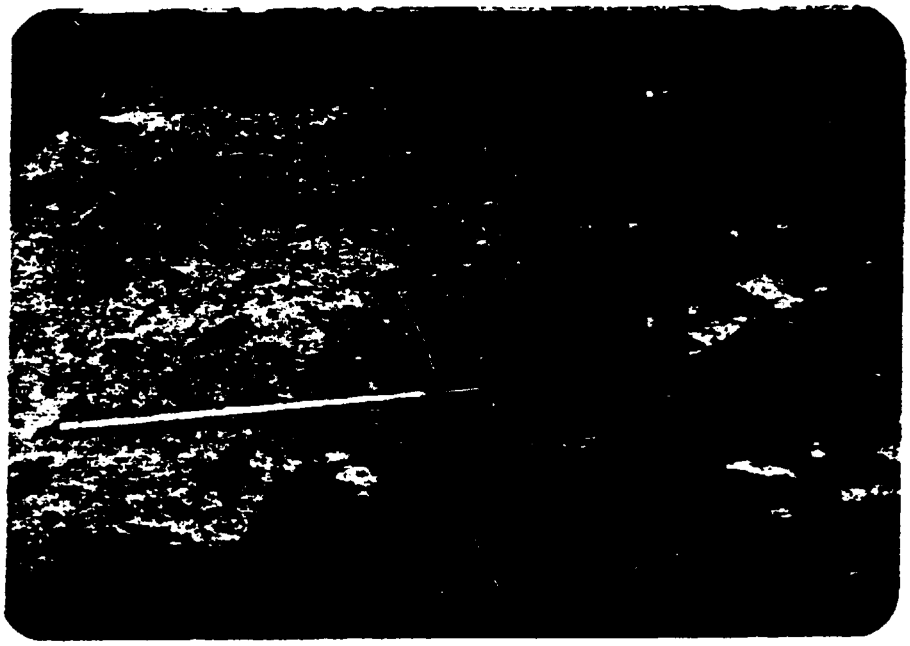


Fig. P-2.2 (M) : Lever Press Char Filling Position
NOTE: Briquette Divider and Top Plate on Right

Fig. P-2.4: Lever Press Char Pressing Position automatically pushed upward, thereby compacting the char both from the top and bottom sides. This position is shown in Fig. P-2.4 and gives better compaction than that obtained in hand mould where compaction is done only by the top plate. The lever is then moved on the other side by 180° and handle place on the fulcrum plate provided on the right side of mould (Fig. P-2.5). When lever is pushed down, the bottom plate is pushed up thereby ejecting out the top plate and the briquettes with the briquette divider. This position is shown in Fig. - P.2.6. The briquettes with its divider are taken out placed on a flat surface and divider is separated from the briquettes.

Although the lever press gives better compaction than hand mould due to extra costs involved it is not recommended for dissemination in the rural areas. It should be propagated in areas where infrastructure does exist for its maintenance. Hand mould being simpler, should be a better alternative to lever press for rural dissemination programme.

Fig. P-2.5 : Lever Press with Crew

Fig. P-2.6 : Lever Press-Briquette Ejecting Mode

3.0 BIOMASS GAS STOVE - 'PARU' STOVE

3.1 Introduction

The 'PARU' stove has been developed to get smokeless combustion from many types of agro and forestry residues such as leaves, cereal straw, coffee and rice husk; and such other biomass. This stove has a unique feature in that the combustion air does not come in direct contact with the biomass. With this arrangement, the disadvantages of incomplete combustion and particulate emission with flue gases normally associated with biomass combustion are completely eliminated. The constructional details of this stove are presented in Section 4.2.2 (page 20) of the previous report[1]. The smaller stove (300 Ø) and the prototype unit (500 Ø) are shown in Fig. 3.1 and Fig. 3.2 respectively.

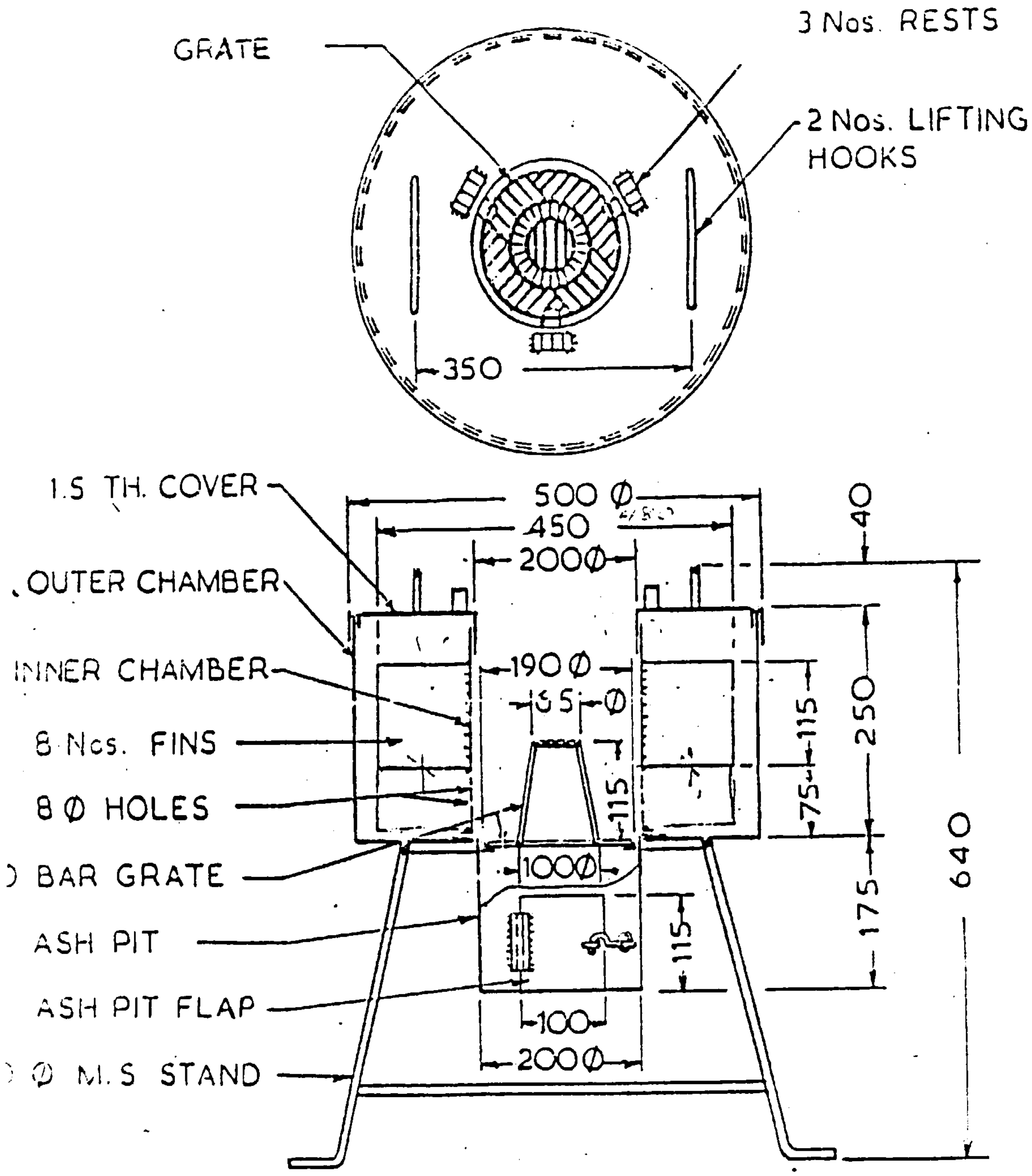
Based on same principle, a twin burner, biomass gas stove has also been developed and is shown in Fig.3.3. These stoves were duly tested during this mission and their performance characteristics are given in Annexure-IV and further discussed in the following sections.

3.2 Units Available

One unit each of 500 mm and 300 mm outer diameter 'Paru' stoves were available on arrival. These units were earlier tested[5] and unsatisfactory results were obtained mainly because not enough stones of proper size were used with the charcoal. The major complaint was that more heat was being recovered from charcoal than that from the biomass. During the mission, when proper size of stones was used the same units gave satisfactory performance.

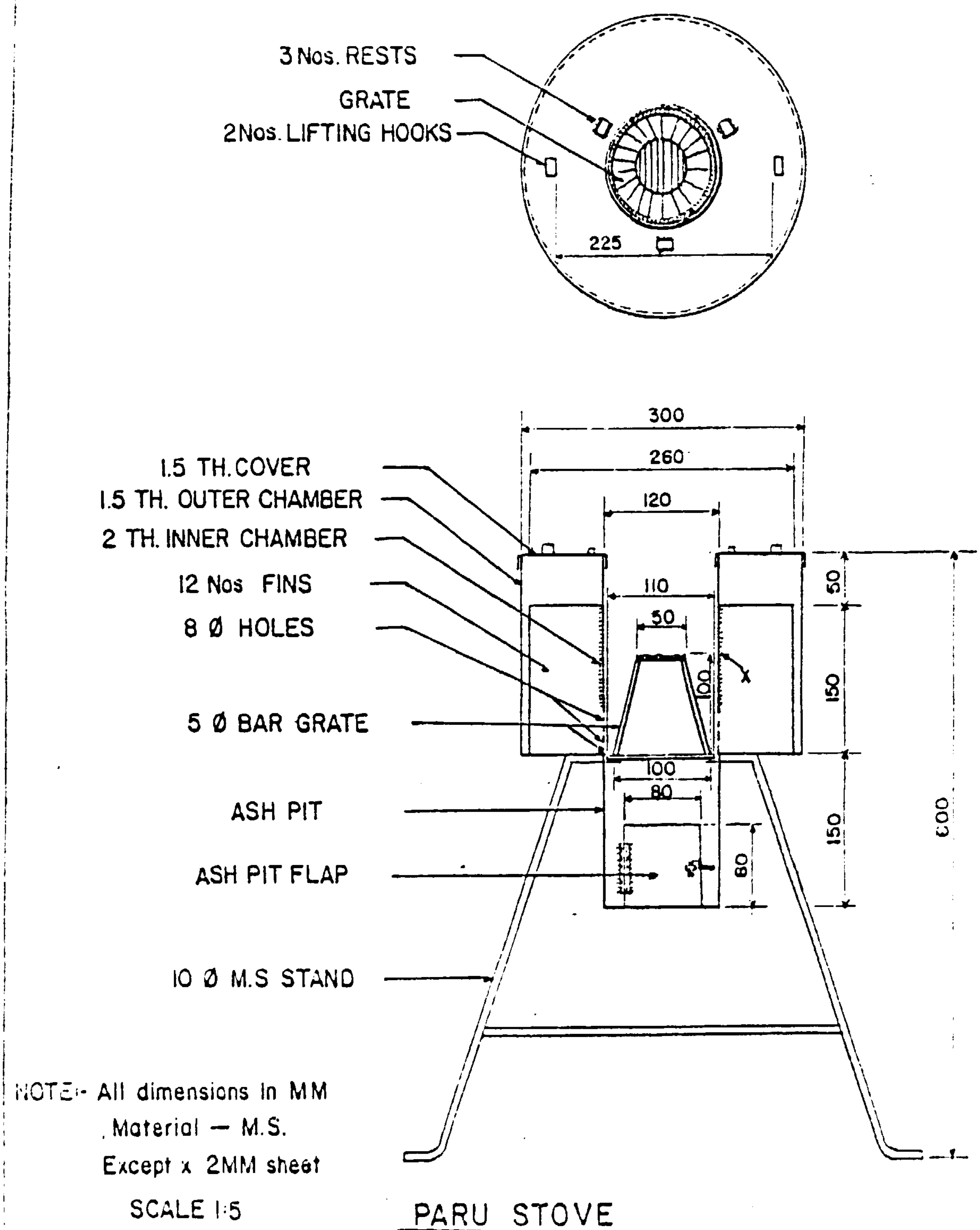
Later two more stoves were obtained from India; one having top cover fixed with swing bolts and the other with push fit cover.

During the mission, one of the stoves was modified by having opening at the bottom with sealed top cover. This is also shown in P-3.1 and P-3.2.



NOTE:- All dimensions in MM
Material - M.S.

FIG. 3.1 PARU STOVE



PARU STOVE

FIG. 3.2

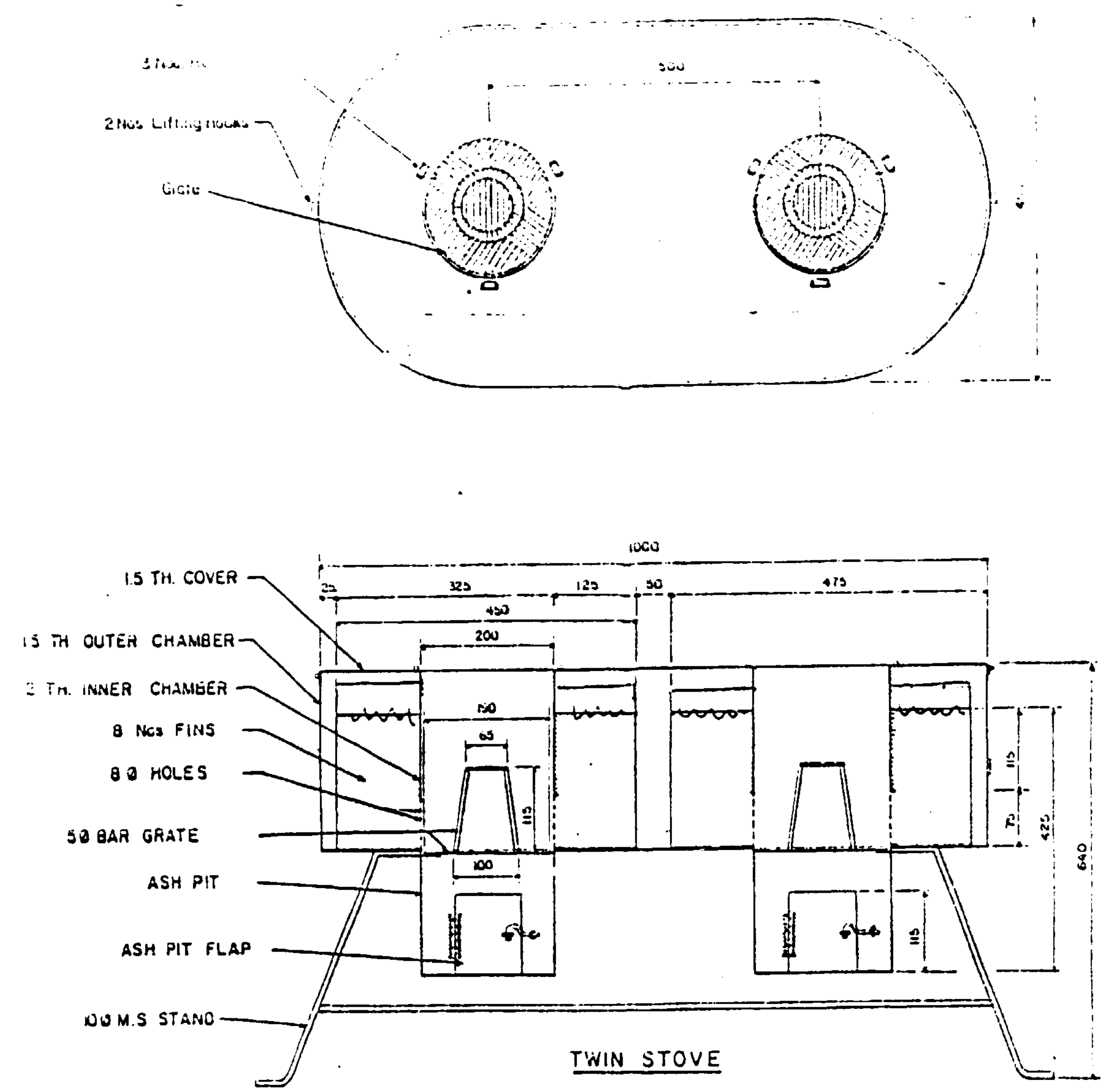

2 Nos. Lifting hooks
Grate
500
1000
1.5 TH. COVER
1.5 TH OUTER CHAMBER
2 TH. INNER CHAMBER
8 Nos FINS
8 Ø HOLES
5Ø BAR GRATE
ASH PIT
ASH PIT FLAP
100 M.S STAND
25
325
125
50
475
450
200
150
65
115
100
115
75
425
640
TWIN STOVE
NOTE : All dimensions in mm
Material = M.S
SCALE 1:5

FIG. 3.3

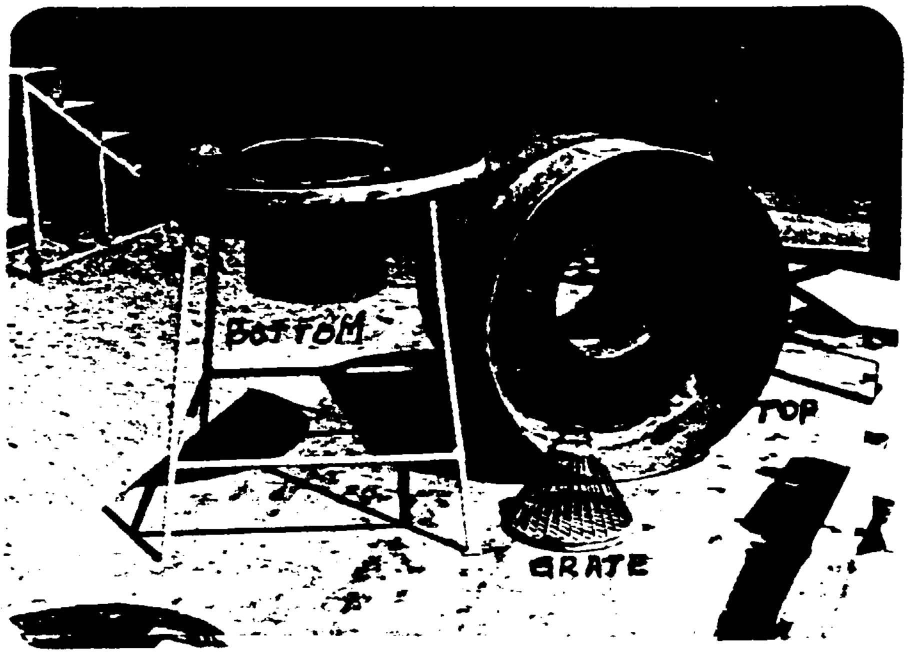


Fig. P-3.1: PARU stove - Parts
L-R Bottom Cover, Grate and Top Portion

Fig. P-3.2: PARU Stove Assembled

Further order was placed for nine 'PARU' stove by ENEC and four modified stoves by UNIDO. With the completion of these stoves ENEC would have collected 19 units enough in number to initiate dissemination programme. The break up of these stoves is given in Table 3.1.

Table -3.1

Type of 'Paru' available with ENEC

	Type	Number
(a)	500 Ø (original design)	12
(b)	300 Ø stove (original design)	1
(c)	500 Ø stove (modified model)	5
(d)	Twin burner stove	1
	Total	19

3.3 MODIFIED "PARU" STOVE

3.3.1 Principle of Operation

In 'PARU' stove the combustion of agro and forestry residue is carried out indirectly. In the central portion, charcoal/briquetted fuel and refractory stones are added and the annulus volume of the jacket is filled with biomass.

When charcoal is ignited, the heat is transmitted to the biomass through the wall of the central stove and eight fins, provided for efficient heat transfer. This biomass, on heating emits combustible gases with substantial amount of biomass tar in vapour form. These gases are prevented from comming out of the jacket and only allowed to exit through the holes provided at the bottom of the charcoal bed. When the gases are brought in contact with charcoal and hot stones the tar vapours, which normally burn with smoky flame, are thermally cracked into clean combustible gases. The stones added with fuel play unique role of :

(a) providing the solid surface area necessary for thermal cracking of biomass tar,

(b) increasing the heat capacity of the stove by retaining heat so that more heat is transferred to biomass, and

(c) occupying space in the central stove so that the consumption of charcoal is reduced and more heat is recovered from biomass.

During this process the biomass in the jacket gets carbonised and should be re-used as fuel after briquetting.

It is not desirable that all the biomass in the jacket should be carbonised. In fact the outer layer of biomass in the jackets should remain as such so that it acts as an insulation and prevent loss of heat through the outer wall. This would not only increase the thermal efficiency but also keep the outer wall cool enough to have congenial working atmosphere.

3.3.2 <u>Modifications Accomplished</u>

Any technological development needs constant updating so the 'Paru' stove in that context is no exception. The top cover which encloses the jacket and make it air tight is rather difficult to fabricate. So after fixing it, it is normally sealed with mud. This makes the operation rather dirty and not liked by the operators.

To solve the problem of the leakage of gases it was decided to provide the cover at the bottom. Even though it solved this problem still tar got condensed at the inside of the outer wall and had a tendency to drain out from the inside of the outer cover. To overcome this, it was suggested to have a small channel around the inside of the jacket of biomass to contain this tar during the beginning of the operation when temperature is low enough for condensation. This collected tar later evaporates and provides heat when temperature in biomass jacket increases.

These modifications were explained to ENEC staff and the fabricator who have agreed to carry out further testing on the modified stove and provide the results. The modifications will also be tested at Delhi. One of the staff members from ENEC Mr. Tekola Shemilis has also been deputed to Indian Institute of Technology, Delhi for one year training under U.N. University fellowship and shall be actively involved in this project.

3.3.3 Testing and Performance Characteristics

During the present mission, 24 performance tests were conducted by the ENEC staff on various types of these stoves. The primary fuels used were coffee husk, Teff straw, and saw dust in the annulus jacket. The secondary fuels used in conjuction with refractory stones were wood charcoal, wood, local charcoal cakes, cowdung cakes, corn cobs charcoal and coffee husk char briquettes. The data obtained are shown in Annexure-I and the calculated results in Annexure-IV.

Most of these tests indicate that the working of these stoves with various biomass materials is feasible. However, different performances were obtained with various combination of primary and secondary fuels. Thermal efficiencies, based on secondary fuel i.e. charcoal etc. ranged from about 20 per cent to 58 per cent with majority of the heat recovered from biomass. With about 8 Kg. of coffee husk and 3 Kg. of charcoal 500 mm diameter stove gave continuous combustion for 7 hours, enough to boil off 13 Kg. of water from pan having diameter of 50 cm. On the other hand, smaller stave of 300 mm diameter used about 1.5 Kg. of husk and 0.4 Kg. of corn cob charcoal and gave good combustion for about 2 hours. (Ref. 30/2412/T Annexure-IV). Based on charcoal, this stove also gives good efficiency of about 60 per cent. Comparable characteristics with 500 mm stove were obtained when coffee husk was used as primary fuel and different secondary fuels such as charcoal, corncobs charcoal, coffee husk and char briquettes.

3.3.4 Conclusions and Recommendations

(a) The 'Paru' stoves have proved to be one of the most appropriate appliances for efficient and smokeless utilisation of biomass for thermal applications including cooking.

(b) While the type 500 Ø is most suitable for restuarants and community kitchen the smaller model 300 Ø is appropriate for family kitchens.

(c) Both these models, when properly operated can give enough charred biomass materials which can be recycled after briquetting and can eliminate the necessity to use any wood charcoal. Therefore, these can be termed as biomass stoves.

(d) As mentioned under recommendations, other locally available materials should be tested at ENEC and concept dessiminated through organised sector such as military and police canteens and other community kitchens.

(d) Such programmes should be given priorities so that the consumption of wood and wood charcoal can be progressively reduced.

(f) Available mass media facilities should be extensively utilised for their popularisation among general public.

(g) Twin hearth 'PARU' Stove (Fig. 3.3) did not give good performance. In its present form it should be replaced by two single hearth 500 Ø (Fig. 3.1) stoves.

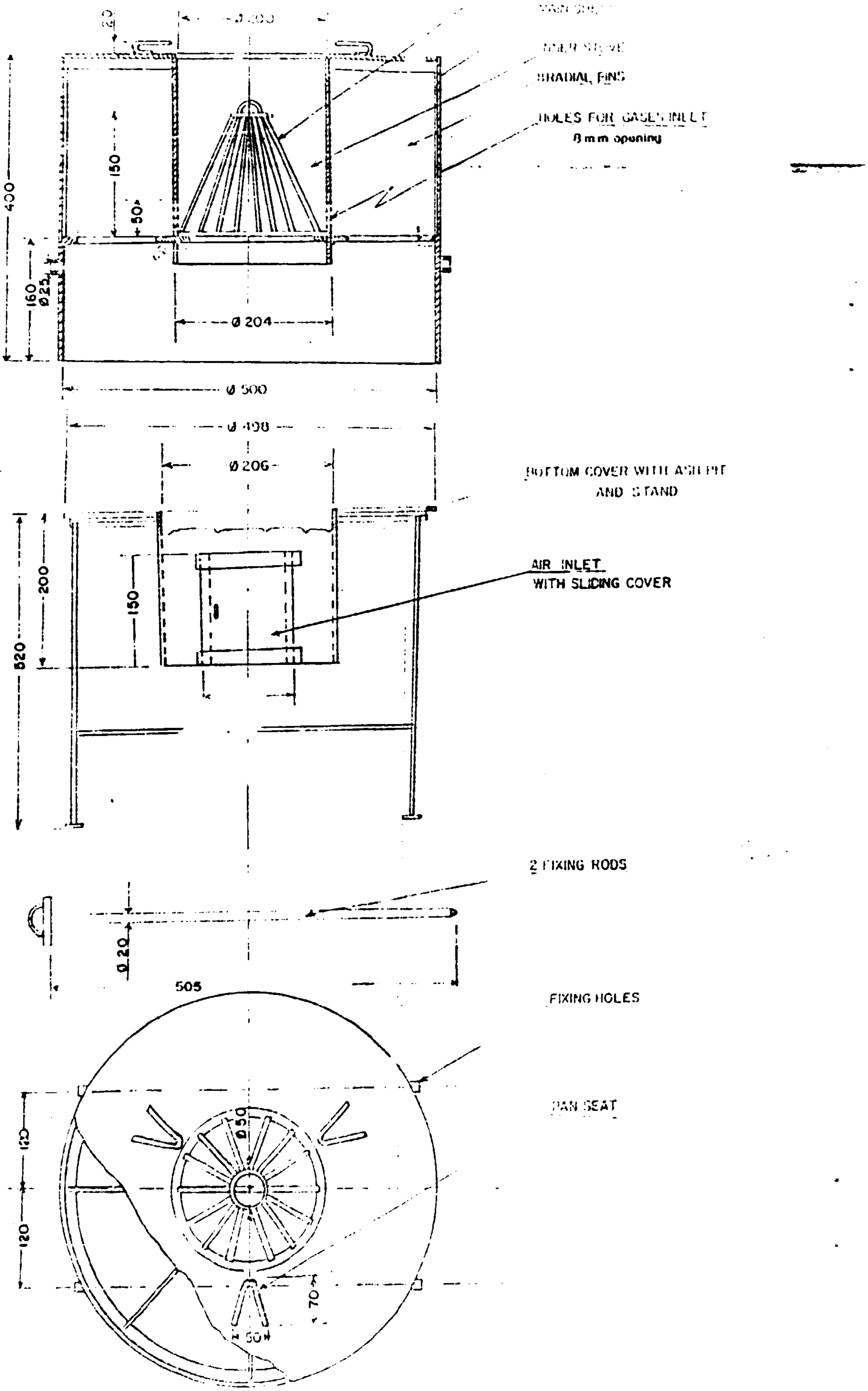


FIG.3.3A. MODIFIED PARU STOVE WITH BOTTOM COVER

All measurements are in c m

4.0 DEVELOPMENT AND TESTING OF DOMESTIC STOVES

4.1 Introduction

With the acute shortages of conventional fuel like wood and charcoal, immediate and result oriented steps are required to be undertaken to preserve the remaining forests. Some of these are:

(a) Widespread reforestation of denuded land.

(b) Conservation of conventional fuel by popularising efficient wood burning stoves.

(c) Replacement of wood by agro and forestry residues by developing efficient cook-stoves using biomass.

(d) Developing and dissemination of technologies for making carbonised briquetted fuels to replace charcoal.

The purpose of the present mission was to carry out above activities (c) and (d) that is, development of biomass stoves and biomass charring and briquetting technologies. This chapter deals with the development of these stoves. The type of stoves developed and their test results for these stoves and others available at ENEC, are also discussed. These stoves were demonstrated and technical personnel at ENEC were also trained.

4.2 Cook Stoves Tested

In all, fifteen different types of stove, were tested and 50 performance tests were carried out during the mission. The test data are presented in Annexure-I and calculated results are given in Annexure-V. Out of these 15 stoves tested, seven were developed while the remainder 8 were available with ENEC.

4.2.1 Stoves Developed

The stoves which were developed and introduced during the mission are given in Table 4.1. These were fabricated locally, tested and demonstrated to the staff at ENEC.

Table 4.1

Cook Stoves Introduced

No.	Type	Fuel	Fig. No.
1.	One Saw dust/Coffee husk metal stove	Sawdust, coffee husk, leaves and straw etc.	4.1
2.	Three above type stoves made from empty paint and milk tins	-do-	-
3.	One Ethio-briquette Stove (Mark I and II)	Biomass Briquettes wood and Twigs	4.2
4.	One Ethio briquettes Stove (Mark III)	-do-	4.3
5.	One Injera Stove	-do-	4.4 & 4.5

4.2.2 Stoves Available at ENEC

As described earlier, all the stoves available at the test facility of ENEC were also tested to compare their combustion characteristics with those that were developed. The stoves available with ENEC are given in Table 4.2.

Table 4.2

Cookstoves Available at ENEC

No.	Type	Fuel	Fig.No.
1.	ILO Model Addis-II	Wood or Charcoal	4.6
2.	ILO, Model Addis-III	-do-	4.7
3.	Danish Stove	Biomass Briquettes without Charring	4.8
4.	Kenyan Jiko-260	Wood	4.9
5.	Kenyan Jiko-310	Charcoal	4.10
6.	Local Charcoal Tin Stove	Charcoal	4.11
7.	Local Charcoal Iron Stove	Charcoal	4.12
8.	Local Clay Stove	Charcoal	4.13

Fig. P-4.1: List of Stoves Tested
L-R: 1st Row: 300 Ø and 500 Ø 'PARU' gas stove,
2nd Row: Local tin stove, Jiko, Ethio (Mark II).
Local Clay Ethio Mark-III, ILO Addis-II, ILO Addis-III,
Local Iron Stove, Saw Dust/Coffee Husk Stove: Empty Paint-Tin Stove, Nespray Empty-Tin Stove with Wood Poles for Bricketting and Mido Tin Stove. Note for Comparison foot Rule is Placed on 'PARU' Stove

Fig. P-4.2: List of Stoves Test with Test Facility at the background.


Fig. P-4.35: Saw Dust/Coffee Husk Stove Metal Type

4.3 Salient Features and Performance Characteristics of Stoves

The traditional cooking and eating habits of a society are not easy to change. Therefore, if a new stove is to be accepted, not only it should be cheap and efficient but must have this inbuilt property. Considering this major aspect, the cookstoves mentioned in Section 4.2.1 were developed. These stoves and also the stoves available with ENEC are briefly described. The range of these stoves are shown in Figs. P-4.1 and P-4.2

4.3.1 Sawdust and Coffee Husk Stove (Fig. 4.1)

This stove is a very simple type, which can even be made out of an empty household tin of 4-5 litres capacity. Biomass like sawdust, coffee, husk, straw and leaves etc. can be used directly without any pretreatment provided There are in shreded form.

The appropriate biomass is first packed in the stove in the form of a loose briquette. The shape of the briquette is such that it has a central hole and a side opening at bottom both of about 5 cm. in diameters. The central port is meant for flame outlet and the side opening is required for the supply of air. These types of stove are extensively used in Asia and have great potentials for their introduction in African Countries.

Fifteen tests were carried out on these stoves and the results are presented in Annexure-V (No. 1-15). The thermal efficiencies ranging from 10 to 20 per cent have been obtained. However, with minor modifications these can be substially increased. One such stove is shown in Fig. P-4.3 and its dimensions are given in Fig. 4.1.

These type of stoves can either be used alone on biomass or in combination with small pieces of wood or twigs. For example, as given at S.No. 15, 1.0 Kg. of dried Eucalptus leaves and 0.5 Kg. of wood give continuous combustion for about 2 hours and 45 minutes with 16 per cent thermal efficiency.

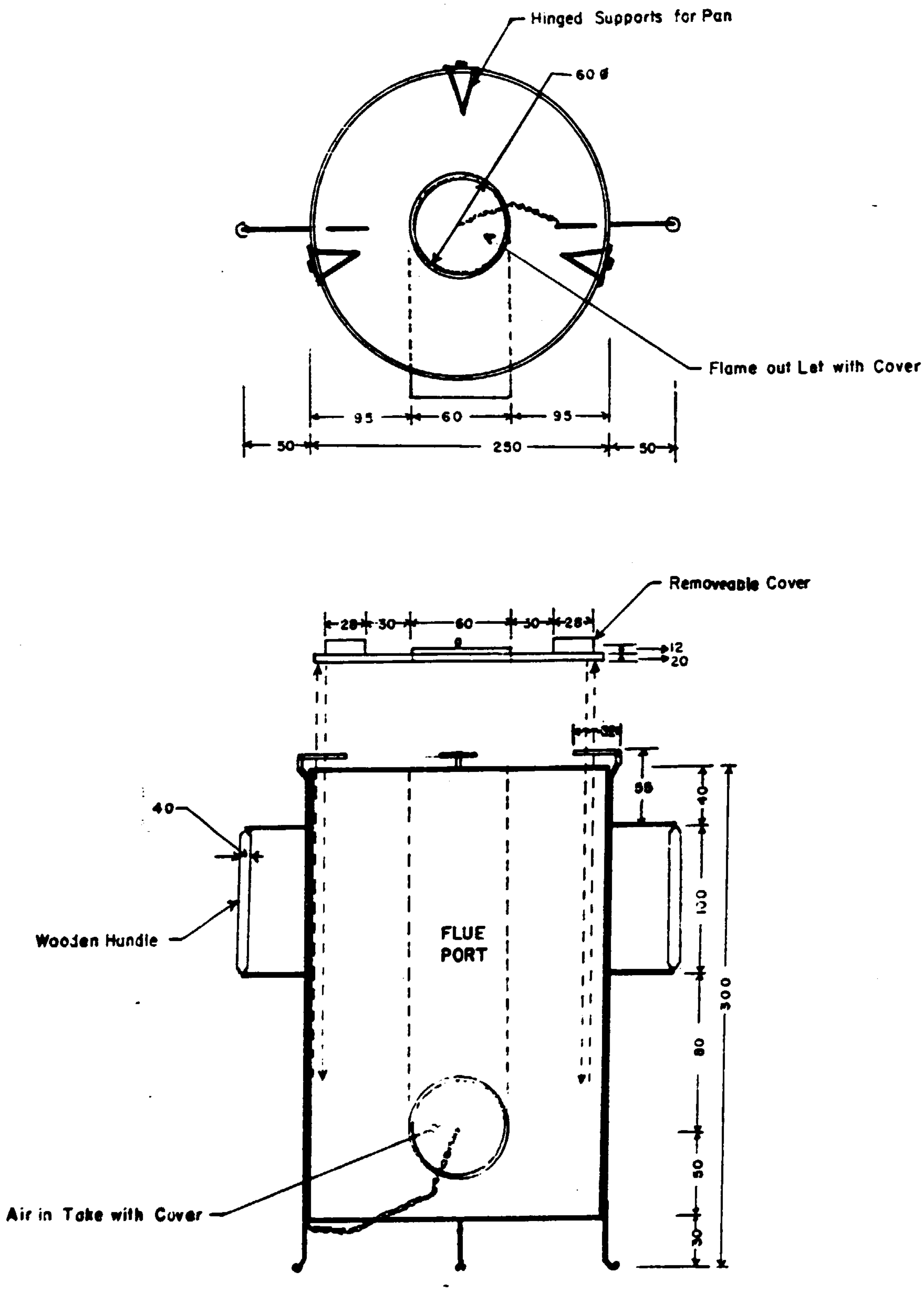


FIG. 4.1 SAW DUST / COFFEE HUSK STOVE

All Measurments are given in m.meter

SCALE 1'4c.m.

The main feature of this stove is its simplicity in construction. Its simplest type can be easily fabricated out of any empty tin by an individual at nominal cost. A slightly modified model, having two covers to block the flame outlet and air inlet ports, has a further advantage that the burning of the stove can be stopped at any time and restarted when required.

4.3.2 Ethio-Briquette Stoves (Figs. 4.2 and 4.3)

As mentioned earlier, that a production plant has been recently established in Addis Ababa producing medium density biomass briquettes having density of 0.7-0.85. known as, Ethio-Briquettes. This company is using a mixture of sawdust, coffee husk and cotton ginning waste as basic raw materials. The plant was supplied by Eco-briquette company of Denmark. Along with plant, the parent company also supplied two samples of cook-stoves for burning these briquettes for domestic purposes. These stoves named as 'Danish Stoves' (Fig. 4.8) were also tested. Not only these gave unsatisfactory results but also were very heavy. Being made from cast Iron, these are very expensive as per Ethiopian standard. Therefore, it became necessary to develop a suitable stove for these briquettes which could also be utilised for burning small wood pieces or twigs more effeciently. Accordingly, two such stoves were developed and their salient features and performance characteristics are described in the following sections.

4.3.2.1 Ethio-briquette stove (Mark-I) (Fig. 4.2)

The constructional details of this stove are given in Fig. 4.2. This is basically similar to any conventional metal stove having perforated plate as grate with an outer shell of 25 cm. in diameter. The unique feature of this stove is the incorporation of a 17.5 cm . diameter circular partition placed in the middle of the outer shell.

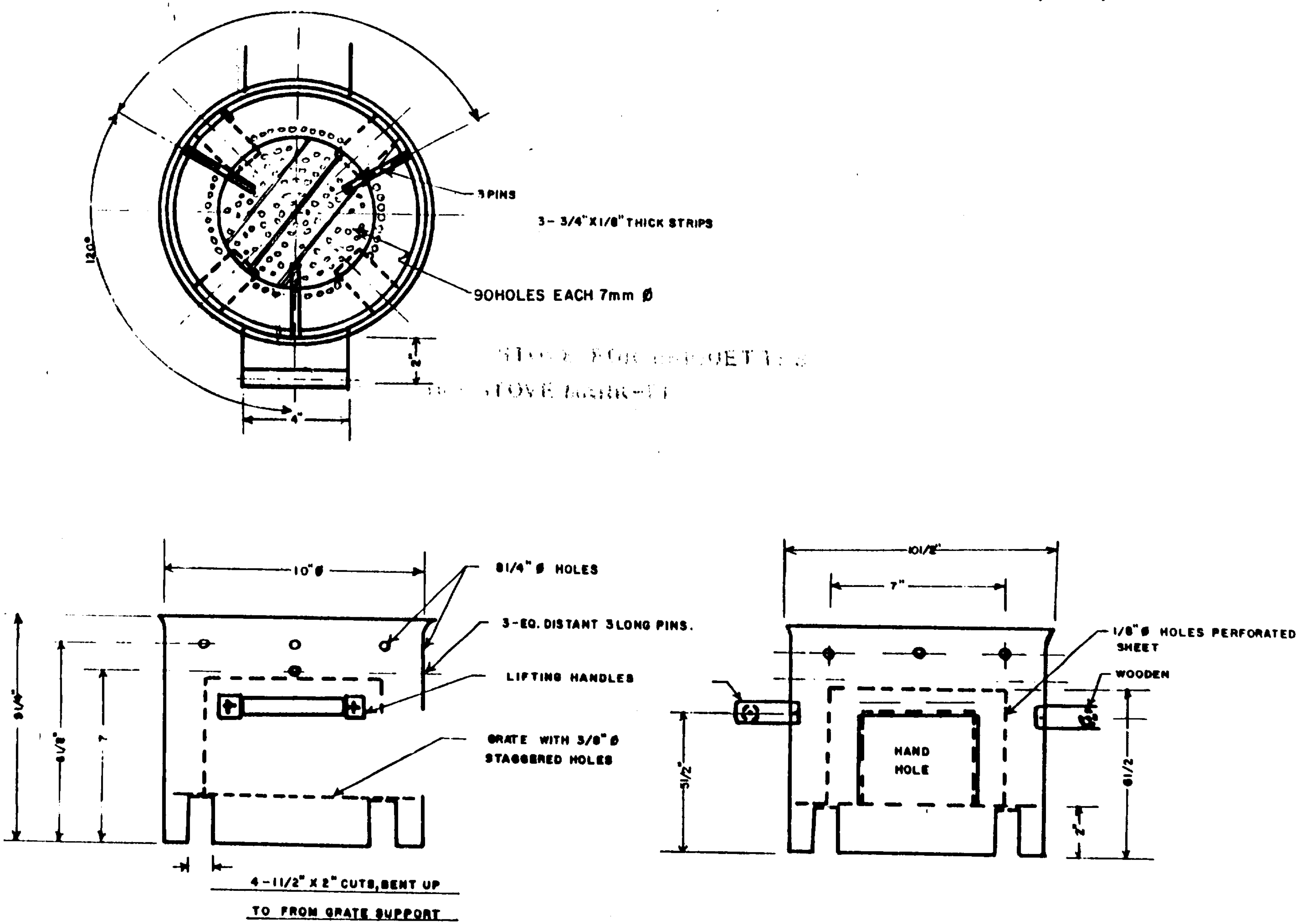


FIG 4.2 & 4.2 A. BIOMASS STOVE FOR BRIQUETTES

The inside partition is made from standard perforated sheet having 3 mm holes. On one side a matching hand hole opening of 8 x 10 cm is provided both in outer shell and inner perforated shell for placing the briquettes inside the stove.

The briquettes are combusted on the grate enclosed by circular perforated cylinder. The advantages of having perforated shell are given below:

(a) Based on classic Davy's safety lamp principle, the flame does not penetrate through this perforated cylinder thereby prevents the flame touching the outer shell. Therefore, outer shell remains cool and radial radiation heat losses are minimised. This, not only adds to the thermal efficiency but also provides congenial cool environment for cooking.

(b) In addition to introduction of primary combustion air through the bottom horizontal grate, secondary combustion air also gets introduced through the holes of the cylinder at various stages of combustion zone. This helps in complete combustion of the briquettes/wood chips etc. thereby giving smokeless burning. Further flow of air through the perforated cylinder keeps this metal relatively cool, thereby extending its life.

Five water boiling tests (S.No. 22-26, Annexure-VI); three with Eithio-briquettes and two with Eucalyptus wood pieces were conducted. While good results were obtained with ecucalptus wood, giving thermal efficiency of the order of 28 per cent, comparatively low efficiencies of the order of 18 per cent were obtained with Ethio-briquettes. Also in the latter case, smoky flame could be observed.

This faulty operation was attributed to the blockage of bottom grate holes by the flat nature of the briquettes. It was then decided to have projections on the grate so that the briquettes do not stay flat to avoid the blockage of these holes. The modified stove was named as Ethio briquette stove (Mark-II).

4.3.2.2 Ethio Briquette stove (Mark-II) (Fig. 4.2)

Five tests (Nos. 27-31) were conducted on this stove with Ethio-briquettes. The modification resulted in the increased thermal efficiency from an average of 18 per cent with (Mark-I) to about 29 per cent with substantial reduction in smoke. Even with wood, the efficiencies were found be comparable.

4.3.2.3 Ethio-Briquette stove (Mark-III) (Fig. 4.3)

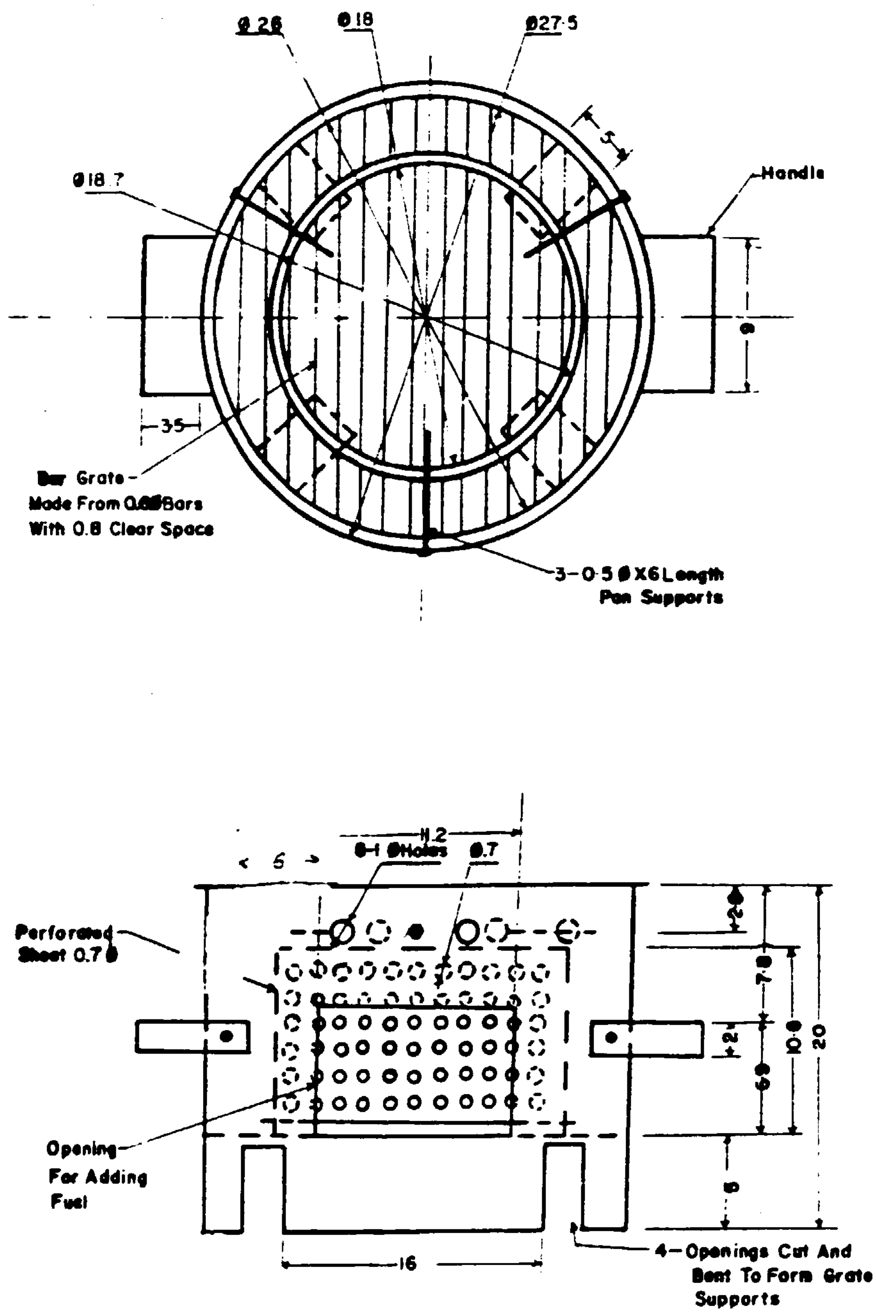
In order to investigates whether the performance of Mark-II can be further improved by having more free area for the grate, another model was constructed. In this stove the punches hole plate was replaced by grate made out of bars.

Experimental tests carried out with Ethio-briquettes indicate that the burning rates were considerably enhanced. For example, under identical conditions, heat transfer rates for this stove obtained were 20 K.cal/min. (test No. 35) compared to 9.8 K.cal/min for mark-II (test No. 31). However the overall efficiency was marginally improved compared to previous models. This stove also gave good efficienceis for burning charcoal.

4.3.2.4 Recommendations

More tests on these stoves have been recommended. However, based on 15 tests carried out on these stoves some general conclusions can be drawn. These are:

(a) Mark-I Stove is simpler and gives good performance for wood blocks. Further for its fabrication the welding operation can be dispensed with and an ordinary tin-smith can manufacture these stoves.



ETHIO BRIQUETTE STOVE MARK-III

SCALE 1:3cm

FIG. 4.3

(b) Mark-II stove is most suitable for Ethio-briquettes and also for wood blocks. This is recommended for further dissemination and gives uniform heating rates.

(c) However, when fast heating rates are required, mark-III is found to be most suitable for Ethio-briquettes. This stove is also ideal for charcoal combustion. For charcoal the opening meant for placing wood/briquettes should be closed by a sliding gate.

(d) Efforts should be directed to get these stoves made in clay and their performance evaluated. Similar stoves are being made in India.

4.3.3 INJERA Stove

Injera is a local bread and staple food for Ethiopians. Traditionally, it is made from grain called Teff, unique to Ethiopia but can also be cooked from other cereal flours. The injera bread is about 50-65 cm in diameter and 2-3 mm in thickness. The average consumption of injera is generally two pieces per head per day. As given in Annedxure-III a 50 cm dia.injera weighes about 460 grams and contain 60 per cent moisture and 40 per-cent solids.

Traditionally, injera is baked on a hot clay plate 65 cm in diameter placed on three stone supports. Every concievable tvpes of fuel including leaves and coffee husk used for baking of Injera. The combustion efficiency of such stoves is very low, in the range of 10 per cent. Further, excessive smoke formation is inherent part of such combustion practices.

To bake good Injera, high heat transfer rates of the order of 47 K.cal/min and high heat capacity of the plate are absolutely essential. Low heating rates and excessive drop in temperature during baking can spoil the texture and hence the taste of Injera. Therefore thick clay plate for traditional stoves and equally thick aluminium plate

SMOKELESS PORTABLE INJERA STOVE MARK-II
FOR TWIGS SMALL WOOD AND BRIQUETTES
UNIDO DESIGN

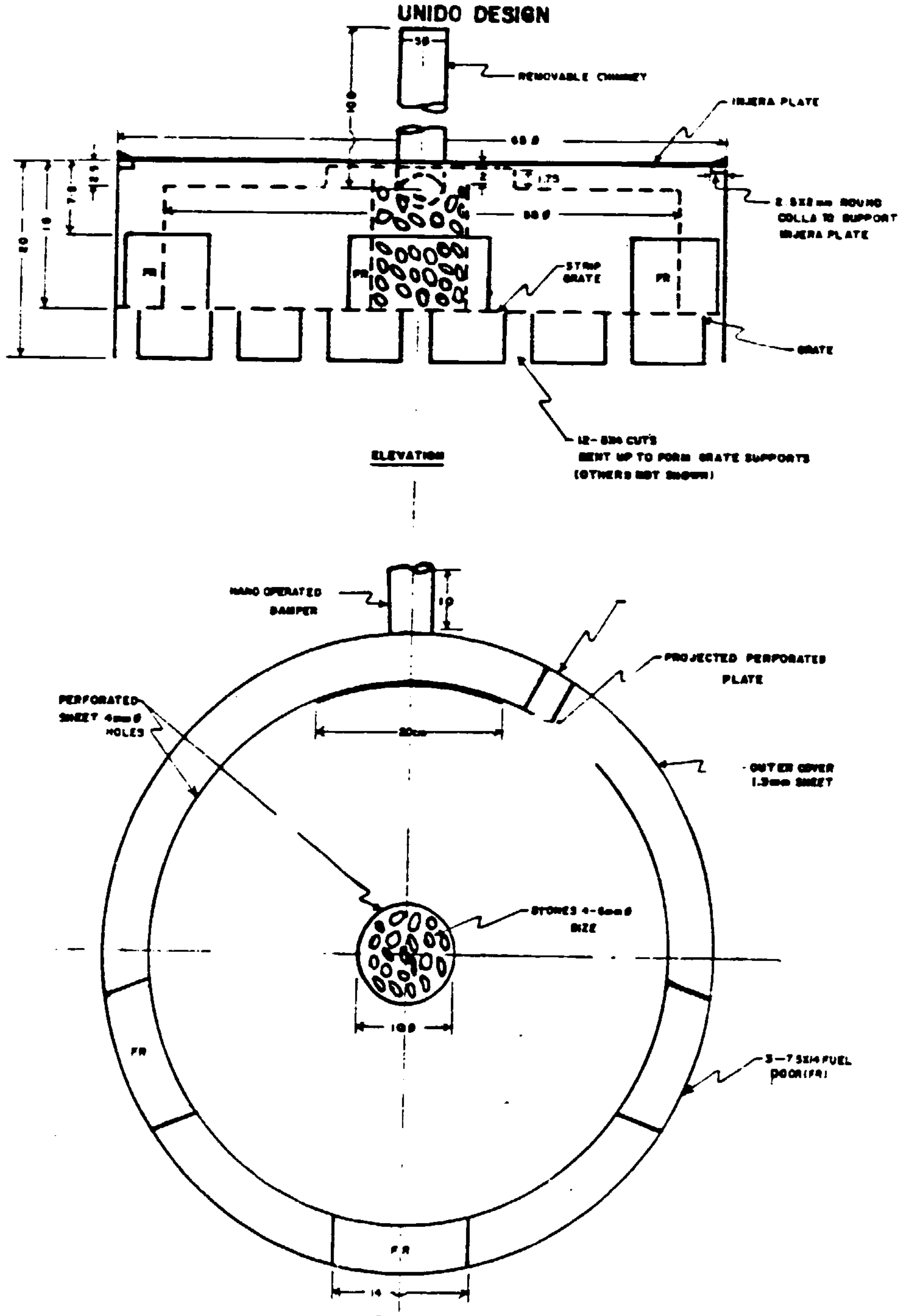
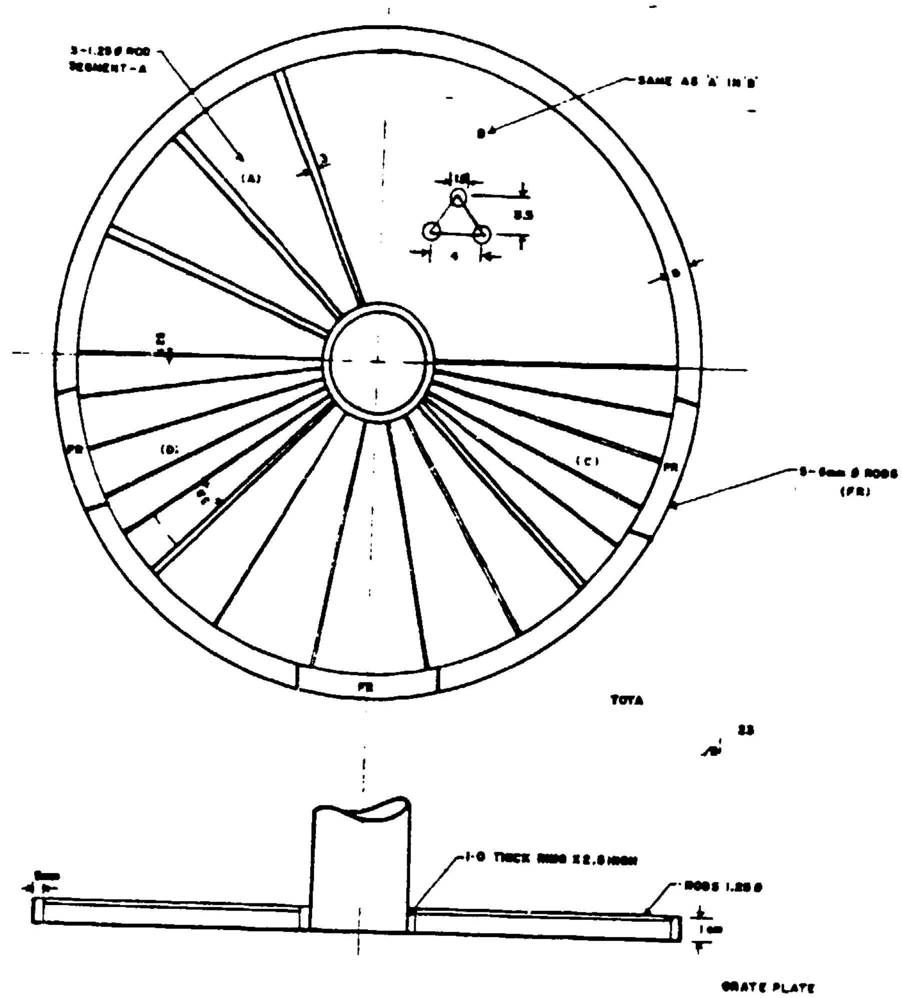


FIG. 4.4 INJERA STOVE FOR BIOMASS BRIQUETTES.



FIG·4·5 GRATE FOR INJERA STOVE

for electric stoves with high heat capacities are commonly employed.

According to the studies undertaken (Annexure-III) about 140 K.Cals of heat is required to bake one Injera. This implies that if 20 per cent heat from fuel is utilised for making Injera, 17.5 Kg. of wood or equivalent fuel will be required to bake 100 Injera. Assuming 10 per cent as normal efficiency, twice the amount of wood i.e. 35 Kg. per 100 injera is a considerable fuel consumption. Any saving in fuel for Injera baking shall contribute significantly towards the conservation of wood.

4.3.3.1 <u>Constructional Features of Injera Stove (Figs. 4.4 and 4.5)</u>

The constructional details of this Injera stove are given in Figs. 4.4 and 4.5. The principles of its design are similar to those for Ethio stoves. Because of its larger diameter of 65 cm compared to 28 cm for Ethio Stove, certain additional features have to be incorporated. The stoves is completely covered by a clay baking plate and a side outlet chimney has been provided to take away the smoke. As in Ethio stove, in addition to outer shell, an annulus protective perforated shell, a 10 cm diameter perforated cylinder has been provided in the centre.

The incorporation of this central perforated cylinder has two major functions. These are;-

(a) The size of stove being large, the entry of secondary air from outer perforated shell is not sufficient. So, an additional amount of air gets through this central cylinder. This two side entry of air gives proper distribution thereby, enhancing the rate of combustion.

(b) Further, there is a normal tendency to put more fuel in the centre of the stove. This can generate higher temperature in the central part of the cooking plate which may result in the overcooking or even burning of Injera bread in the centre while the sides may remain uncooked. By occupying the central space by the perforated cylinder. This tendency can be arrested.

In order to prevent fluctuations of temperature it is imperative than the heat capacity of the stove should be increased. This can be achieved by adding requisite amount of refractory stones of size 4-6 cms inside the perforated cylinder. The actual amount of these stones can, however, be determined by carrying out Injera cooking simulated experiments.

In order to facilitate the addition of fuel three openings of size 7.5 x 14 cms. are provided in the outer and correspondingly in the perforated shells of the stove. Although, it is designed for Ethio-briquettes, other similar fuels such as wood blocks and twigs can be used. This stove is also shown in P-4.4 and P-4.5.

4.3.3.2 Testing of Injera Stove

Due to lack of time only preliminary tests were carried out on actual baking of Injera bread. These tests were conducted in the presence of ENEC staff and the fabricator and gave promising results. However, to improve its performance it was suggested that two fuel feeding holes, instead of three incorporated in original design should be provided. This would prevent the flame coming out from one of the three feeding holes due to cross current of wind. This defect was noticed when it was tested in an open area.

4.3.4 Stoves Available at ENEC

In Section 4.3.2, Table 4.2, a list of stoves has been presented which were available at ENEC. The testing of these stoves were also carried out to compare their performance with those that were developed during the present mission. The constructional features and performance

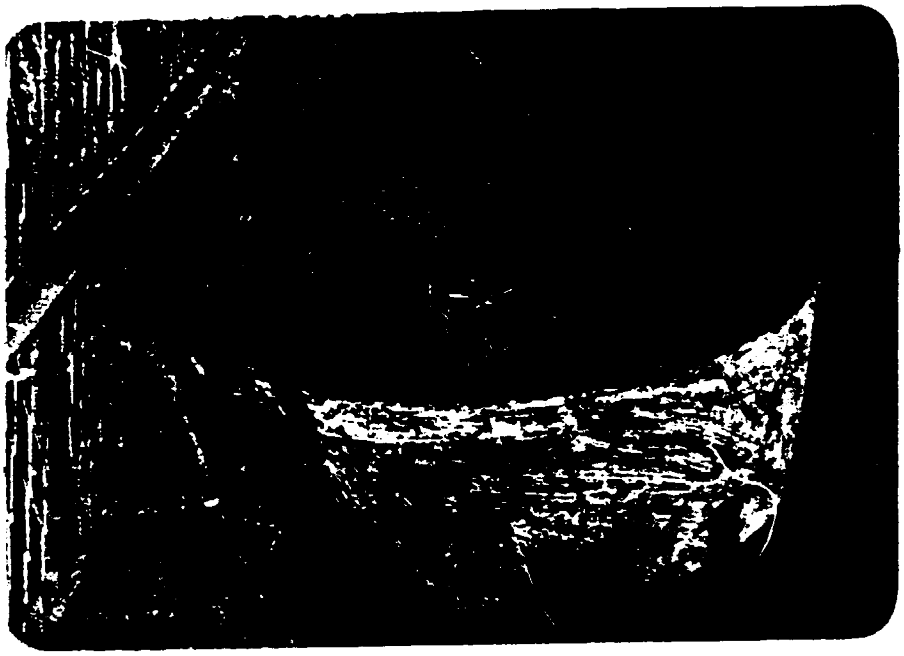


Fig. P-44(A) : Constructional Details of Injera Stove

Fig. P-4.4(B): Constructional Details of Injera Stove

WITHOUT LID
Note Three Openings
for Loading Fuel

Fig. P-4.5: Injera Stove
Under Operation
With LID
NOTE The chimney for
Smoke Emission

Fig. P-4.5(A) : Injera Bread Covered With Traditional Basket Cloth

Fig. P-4.5 (B) : Injera Bread Topped With Meat and Vegetables Cloth-Cover Removed

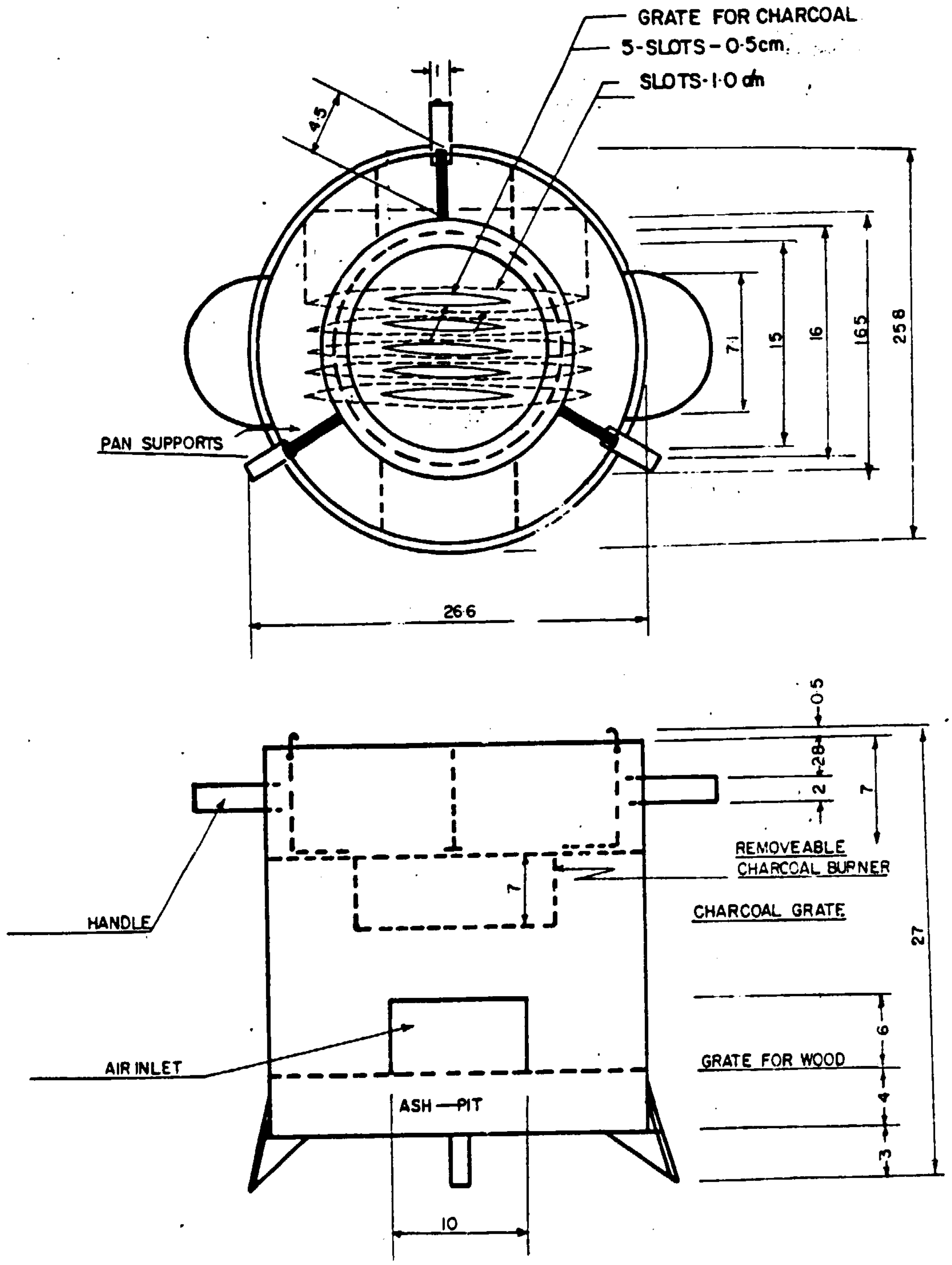


FIG. 4.6 ILO WOOD AND CHARCOAL STOVE
MODEL ADDIS-II

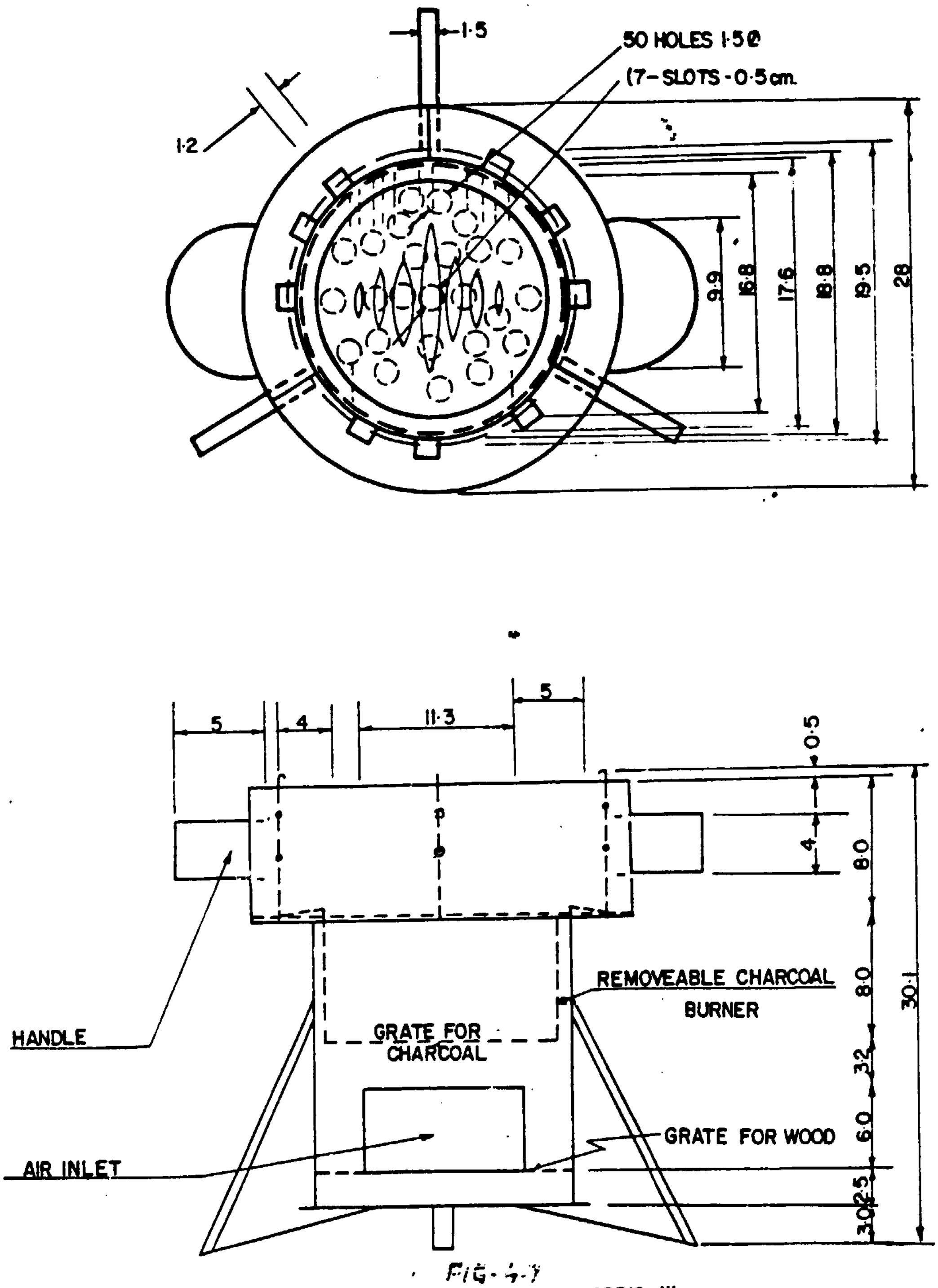
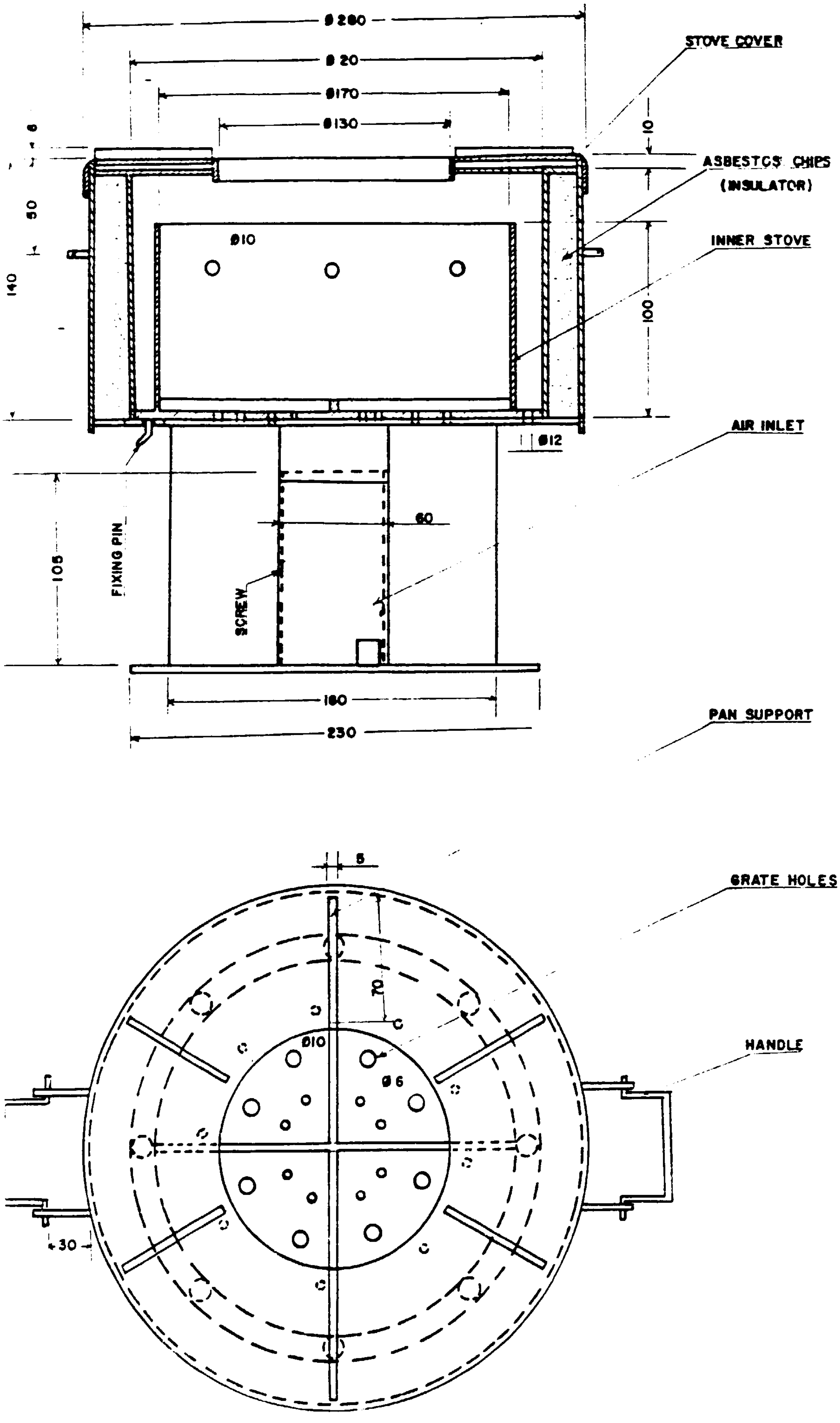


FIG. 4.7 : WOOD AND CHARCOAL MODEL MODEL ADDIS-III



DENMARK BRIQUET STOVE

characteristics of these stoves are briefly discussed in the following sections.

4.3.4.1 <u>ILO Stoves (Fig. 4.6 and Fig. 4.7)</u>

The International Labour Organisation has also initiated a programme to introduce efficient metal wood and charcoal stoves in Ethiopia. This activity is also coordinated by ENEC. As these stove programme is complimentary to the present programme it was decided to test these stoves. However, the major difference between these two programmes is that ILO is concentrating to develop and introduce cook stoves on wood and wood charcoal,but the present programme is to develop and disseminate stoves working on agro and forestry residues.

ILO stoves have been designed in a way that these can be used either for wood or wood charcoal. Efficiencies of the order of 25 percent for wood and 30 per cent for charcoal had been reported by ENEC staff. Under the present programme, limited tests were carried on these stoves using wood and carbonised briquettes (No. 16-18 Annexure-V). Excellent results were obtained when Eucalyptus Charred briquettes were used. However these stoves have limitation that the size of charcoal pan is very small, therefore it can meet the requirement of a limited cooking applications. This is shown in Fig. 4.6.

These stoves are well designed and give good thermal efficiencies. It is recommended that these should be further tested on corncobs charcoal and charred briquetted fuel, so as to save the consumption of wood.

4.3.4.2 <u>Danish Stove (Fig. 4.8)</u>

As mentioned earlier, two biomass briquette burning stoves were supplied by Eco-Briquetting Company of Denmark along with their briquetting plant recently installed at Addis Ababa. One of these stoves was tested and results are

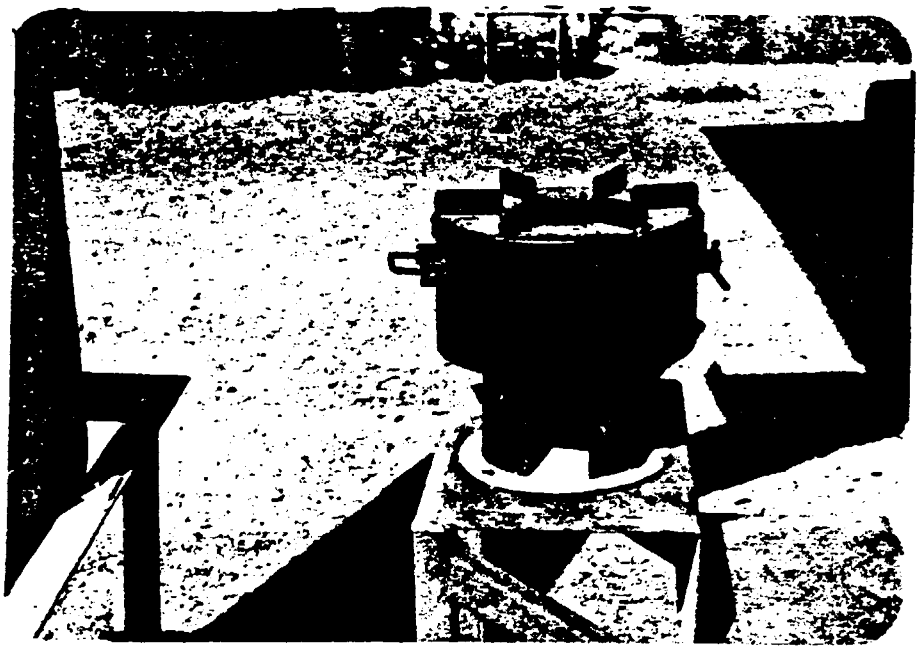


Fig. P-4.6 : Danish Stove Top View

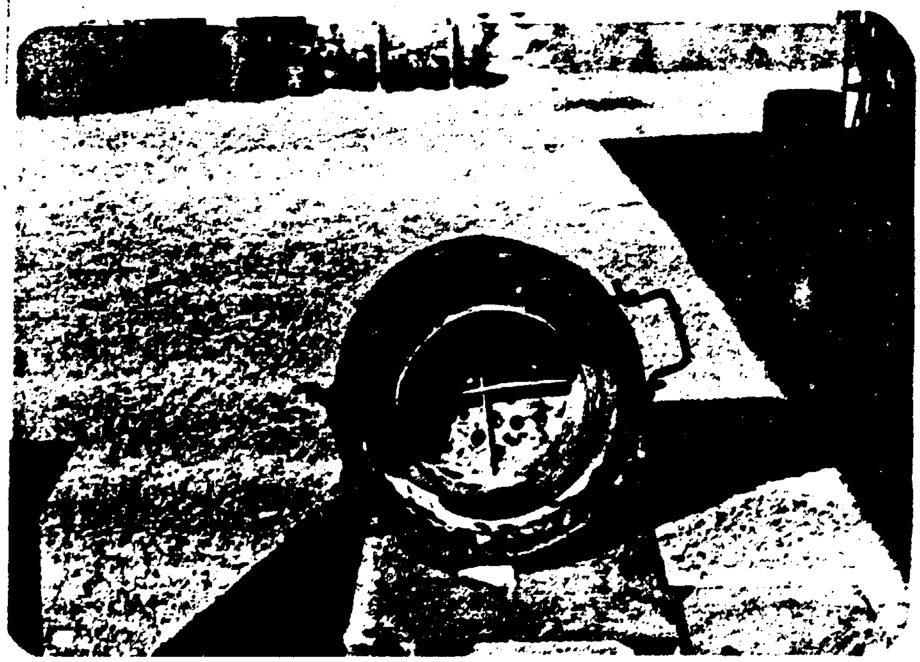


Fig. P-4.7 : Danish Stove Front View

given in Annexure-V(Nos. 19-21). When tested with briquettes the combustion obtained was rather smoky and also thermal efficiency obtained was about 15 per cent compared to 28 per cent with Ethio-stove under similar conditions.

The Smoky nature of combustion is due to the lack of provision in the stove for introduction of secondary air. Further the stove is made in cast Iron and heavy in weight. As shown in Figs. 4-8 and P-4.7, the stove is well designed, but because of abovementioned factors and excessive cost of fabrication it is not all appropriate for Ethiopia. Hence this should not be considered for any dissemination programme.

4.3.4.3 <u>Kenyan Jiko Stoves (Figs. 4.9 and 4.10)</u>

Two types of these stoves were available with ENEC, one having outside diameter of 260 mm for wood burning (Fig. 4.9) and the other of 310 mm in dia and meant for wood charcoal (Fig. 4.10). As shown in drawings and Fig. P-4.8, these stoves are well designed with judicious utilisation of metal and baked clay. In charcoal stove empty space between metal wall and clay lining have been provided to give good insulation. Seven water boiling tests were conducted and the results are presented in Annexure-V (Nos. 37-44) with Fuels such as charcoal, wood and carbonised corn cobs. These tests indicate that using charcoal,Jiko 260, although designed for burning wood, gave better results than charcoal stove 310. For Jiko-260, efficiencies of the order of 28 per cent for wood and above 30 per cent with charcoal burning were obtained. Jiko-310 was found to be most suitable for burning corn cobs charcoal.

Although more expensive than normal stoves but these are very sturdy and fuel efficient. Considering these factors such stoves are appropriate stoves for dissemination for those who can afford the cost.

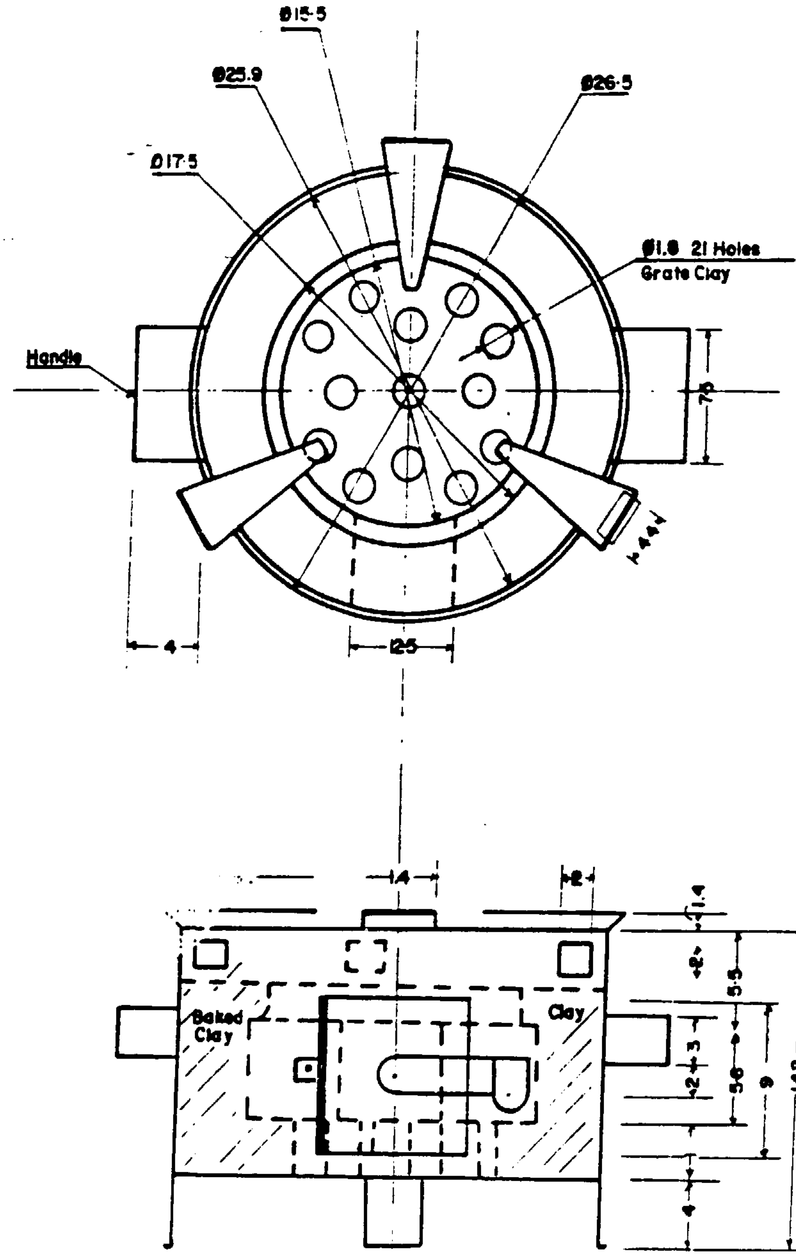


FIG 4·9 KENYAN JIKO STOVE

Scale 1:3 cm

All The Dimonsions Written in real Value

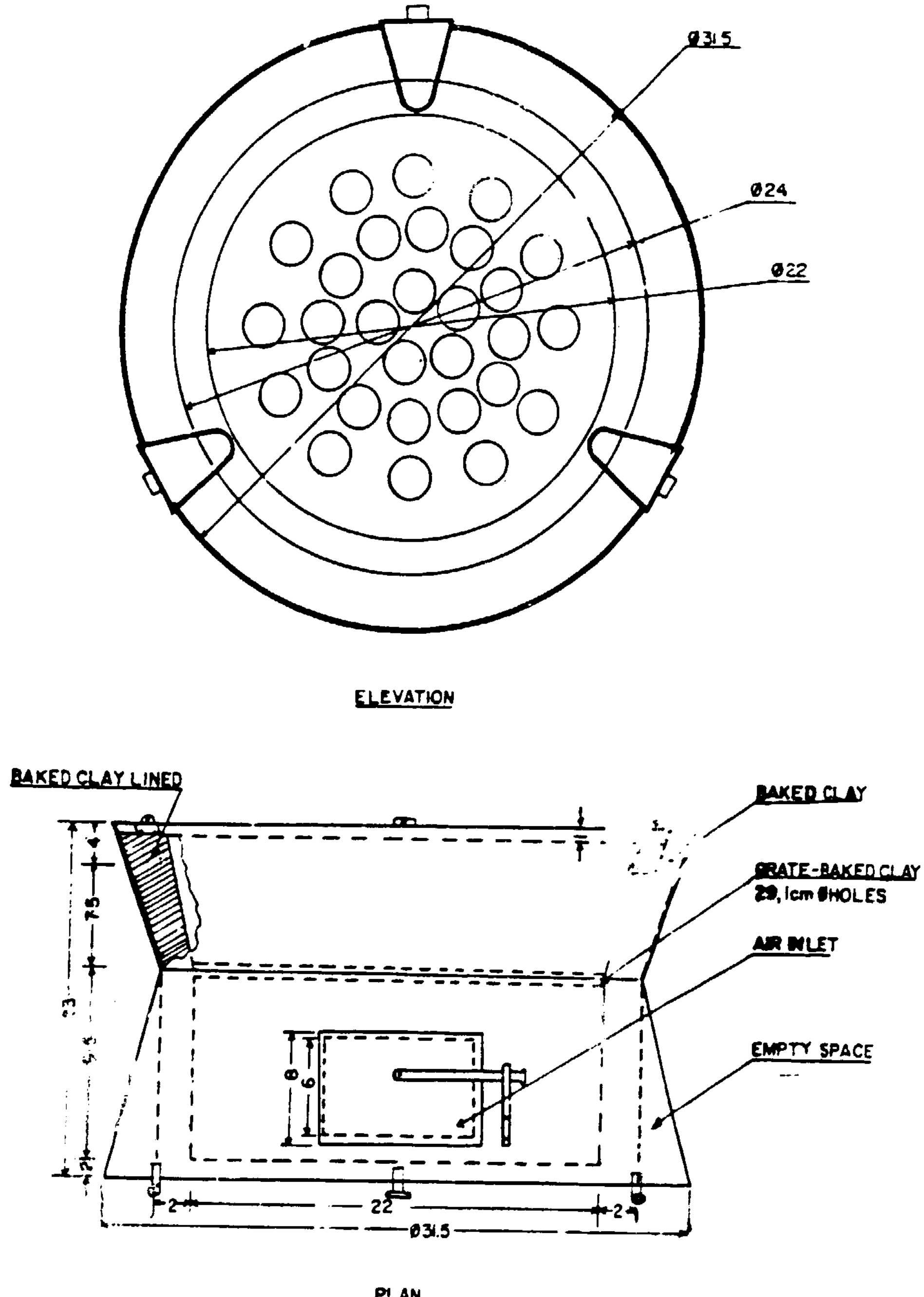


FIG 4.10 KENYAN JIKO CHARCOAL STOVE

All measurments are in c.m.

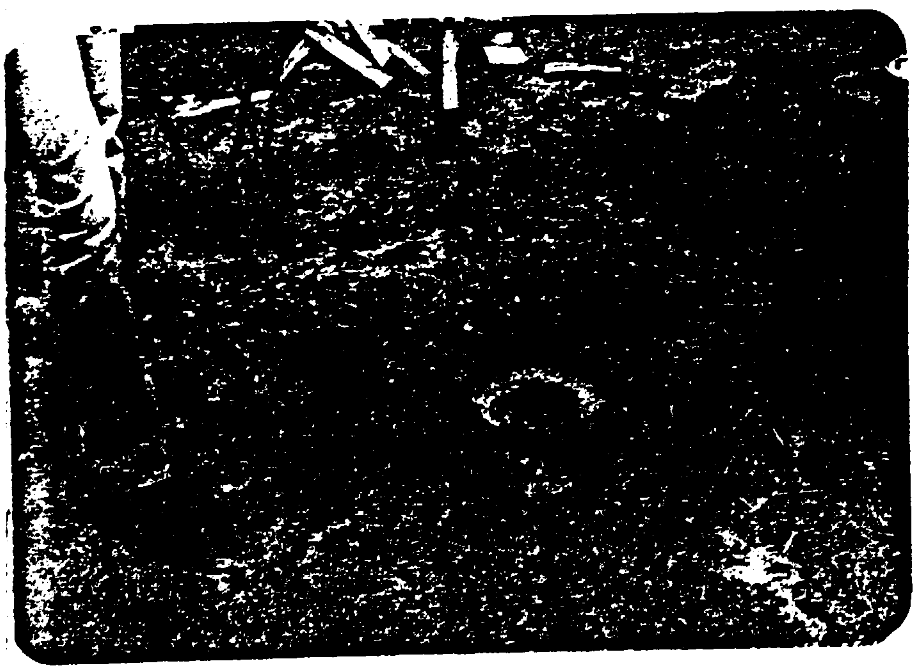


Fig. P-4.8 : Kenyan Jiko Stoves

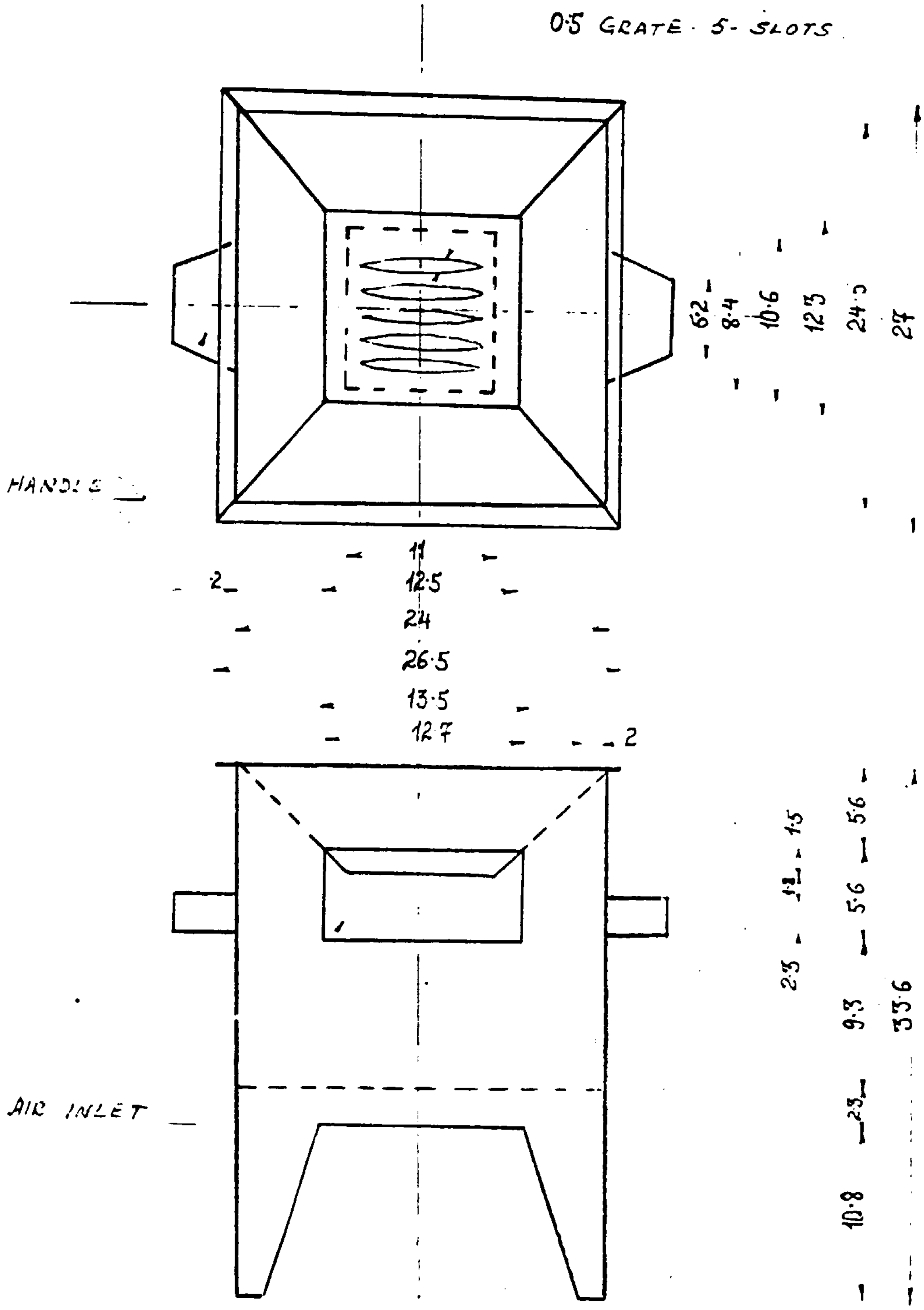


FIG 4.11 LOCAL TIN CHARCOAL STOVE

DIMENSIONS CMS SCALE 1:3

4.3.4.4 Local Tin Charcoal Stove (Fig. 4.11)

These stoves are extensively used in Ethiopia for burning charcoal. Like I.L.O. stoves these also have detachable pot for charcoal. The thermal efficiency of these stoves is about 20 per cent and burning rate is rather slow. Moreover small amount of charcoal is left unburnt which for small amount of cooking operation is advantageous that it can be reused. As the price differential between I.L.O. and this stove is marginal.I.L.O. stove should be preferred over these stoves.

4.3.4.5 Local Iron Charcoal Stove (Fig. 4.12)

These are similar to local tin charcoal stoves but have fixed grate and pot for charcoal. However, there are more sturdy but also more expensive. Further the thermal efficiency of this stove is less than that of tin stove. Due to more grate area these have faster burning rates. Because of larger capacity of the burning zone these may be most suitable for char briquettes. Further tests should be carried out before these can be recommended for dissemination.

4.3.4.6 Local Clay Charcoal Stove (Fig. 4.13)

Although much cheaper due to the absence of any metal parts, this stove has extremely slow rate of burning. For example 0.5 grams of charcoal took 4 hrs. and 25 mts. to get partially combusted (Annexure V No. 50) giving a thermal efficiency of about 20 per cent. This is not at all suitable stove and if clay stoves have to be popularised it is recommended that stoves similar to Ethio stoves should be developed in clay.

4.4 RECOMMENDATIONS

No single type of stove shall meet the requirements of different sections of society and also for different regions in Ethiopia. So, far dissemination various appropriate models, based on availability of the kind of biomass, should be introduced. It is then left to the users to select the appropriate cook stove which meets their cooking practices.

4.4.1 Stoves Recommended for Dissemination

(a) Sawdust/Coffee husk stoves are cheap, simple and easy to make. Without any further delay, steps should be taken for its dissemination.

(b) Ethio-briquette stove mask-III is ideal for biomass briquettes/corn cobs charcoal, charred biomass briquettes and waste wood pieces and should be popularised. Steps may also be taken to develop this in clay. Ethio briquette stove mask-II is equally suitable for these fuels.

(c) Further tests and modifications, as recommended, should be carried out on Injera stove and steps may be taken for its dissemination.

(d) I.L.O. stoves are ideal for small amount of cooking specially using charcoal. These should be disseminated along with their use on corn cabs charcoal and charred biomass briquettes to save on wood charcoal.

(e) Kenyan-Jiko - 260 is very efficient and versatile stove for wood and wood charcoal. Also Kenyan - Jiko - 310 is most suitable for charred biomass briquettes or corn cobs charcoal. Both these models are study and should have prolonged service life. Although expensive,these may also be introduced in Ethiopia for those who can afford.

(f) The use of other stoves such as local tin or charcoal iron stoves are not energy efficient. These can be easily replaced by I.L.O. type' stoves.

(g) With sufficient varieties of stoves available with ENEC. There is no need to develop any new type of stoves. Instead efforts should be directed to further carryout tests on the above mentioned stoves with various types of briquettes and biomass charcoal.

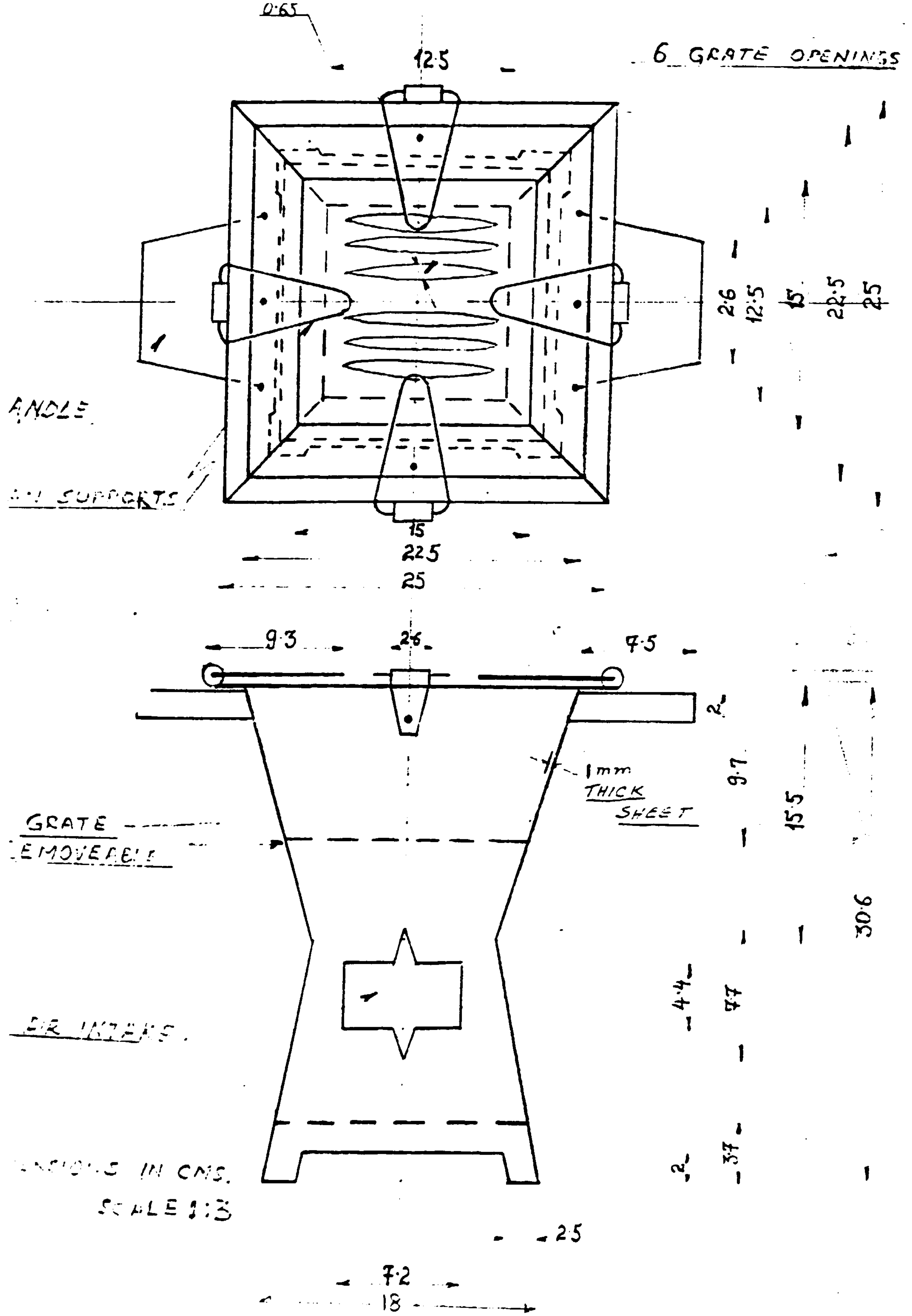
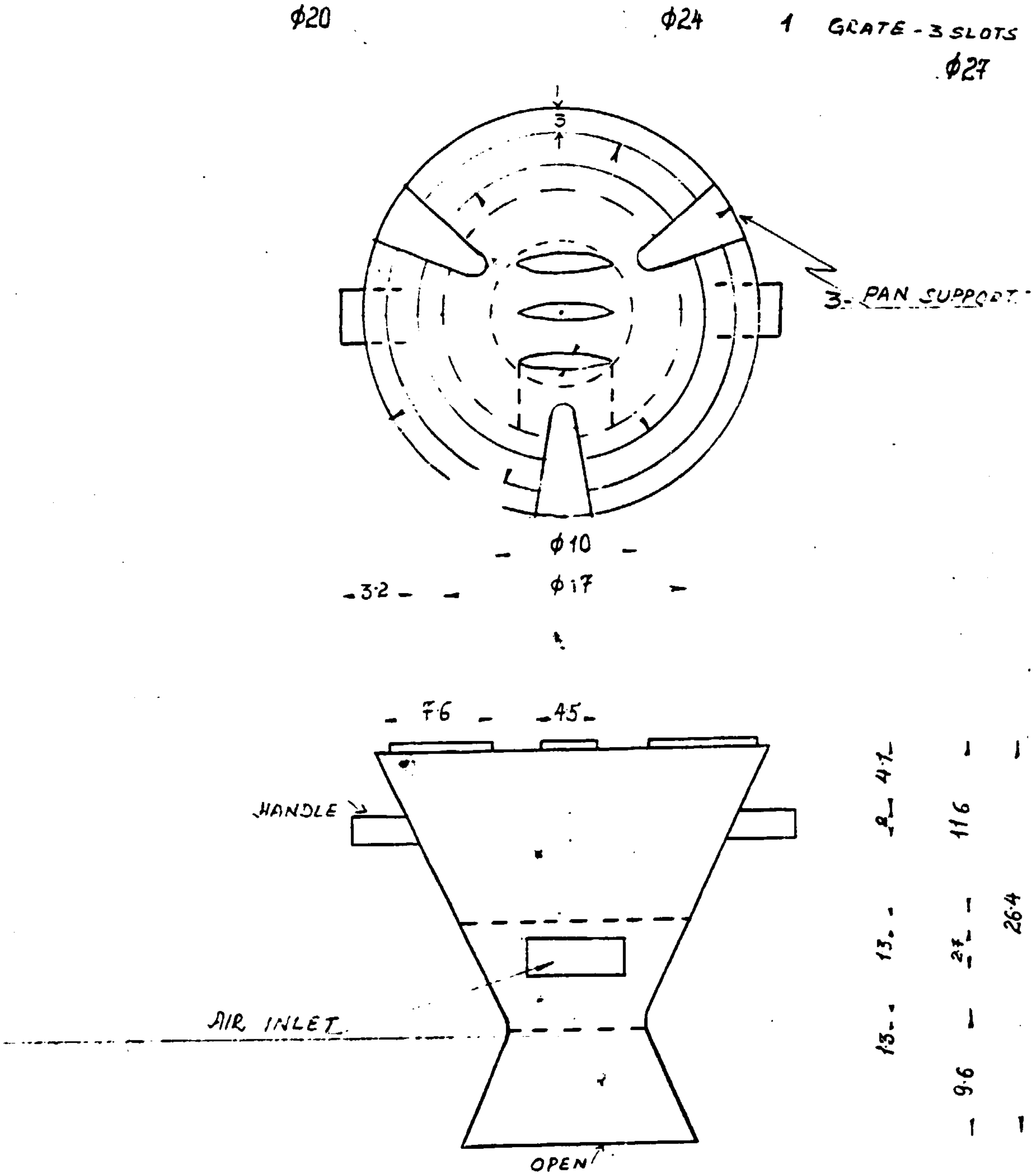


FIG 4·12 LOCAL CHARCOAL IRON STOVE



FIG· 4·13 LOCAL CLAY CHARCOAL STOVE
DIMENSIONS - CMS SCALE 1:5

5.0 BIOMASS ENERGY DEVELOPMENT CENTRE (BEDEC)

5.1 Objectives

The biomass such as wood agro and forestry; and cowdung form the main source of domestic energy in Ethiopia. The judicious exploitation of this main source should be one of the major routes to meet the future energy requirements. As 93 per cent of the total energy requirements are derived from this very source, this aspect automatically gets prime importance compared to other non-conventional sources of energy. This however, does not imply that other sources such as solar, wind and micro hydel power etc. have no role to play in the future energy scenario. Progressively these can also be brought under the jurisdiction of BEDEC.

With scattered population in this vast country, decentralised power generation and installation of small water supply systems are the most appropriate which can be met through the use of agro and forestry residues.

The foremost objective of BEDEC can be briefly summarised as to act as the sole agency, responsible for development and deployment of efficient biomass utilisation technoloties. These can be subdivided as under:

(a) Dissemination of appropriate technologies, already developed such as cook-stoves, charring and briquetting units and biogas plants.

(b) Obtain feed back from the users and accordingly modify these appliances.

(c) Monitoring the performance of Gasifier and other mechanised projects and keep complete records.

(d) Survey of availability of biomass in various regions and their characterisation and identification of specific and appropriate technologies for their uses.

(e) Socio-economic studies to identify the basic problems and also study the impact of introducing biomass technologies.

(f) To impart training/education for operating these appliances either giving in-plant training or holding periodic Seminars/ Workshops.

(g) Popularisation of cookstoves and other appliances through the use of mass-media system such as T.V., Newspaper and also holding workshops in school and colleges.

(h) Through ENEC as the coordinating and executing agency collaborate with various agencies for setting up and running Gasifiers and other briquetting mechanised plants.

5.2 Proposed Mode of Establishment

At present, many International organisation such as I.L.O., and UNIDO etc. are actively working in this area of biomass utilisation. UNIDO has already carried out substantial work and prepared ground for further work. UNIDO has deputed six short term consultants since June 1984. It is, therefore, proposed that one or two consultants may be deputed for one month exclusively to make concrete plans and layouts for such a biomass centre in consultation with Govt. of Ethiopia.

5.3 Location of BEDEC

Due to excessive emission of smoke, specially during the charring, the proposed Biomass Energy Development Centre (BEDEC) should be located away from residential and commercial establishments. However, this should not be far enough to cause excessive inconvenience to staff of BEDEC for daily commuting.

Before a separate site is selected and the buildings are erecred, it is imperactive to acquire an interim appropriate place. This interim place, however, must have the provisions to convert the covered space into a laboratory and has adequate space to construct sheds for the following facilities:

(a) Shed for testing of stoves, small charring and briquetting applicances. Approximate floor area of 64 m^2 x 4.5 m high should be sufficient.

(b) Open space near the shed having free flow of wind for testing charring kiln.

(c) The shed should have an attached covered area of about 40 m^2

for the establishment of a modern laboratory to carryout Chemical testing of raw material and the end products

(d) A workshop shed to house a mechanical shop for fabrication and carryout modificationsof biomass appliance.

(e) Covered space,but this should be open from sides for storage of biomass materials. Approximate 100 m^3 storage space should be provided for this purpose.

(f) In addition, it should have normal infrastructure such as offices, normal conveniences, meeting room,small library and a a Seminar Hall with audio-visual facilities.

(g) Open area near the laboratory and community kitchen to house atleast one biogas plant. The gas can be used in the kitchen and can be tested for running pump and also used for lighting purposes.

5.4 Instruments-Appliances and Machines

The section refers to the program made so far in procuring specifying biogas burners and other appliances, laboratory Instruments and machines for the workshop. These items do not include, charring, briquetting and cookstove with are extensively dealt in this report.

5.4.1 Laboratory Instruments

During the visit of Dr. J. DeWaart,a small laboratory was set up which houses the instruments brought by him. These were mainly required to monitor the performance of biogas plants in Ethiopia,measuring gas flow rate, methane concentration, pH of the slurry and carryout water and ash content of the slurry residues.

Taking these instrument into consideration,a comprehensive list was prepared during the mission. Some of these have been already procured while the rest are intended to be provided to ENEC during the second phase of this programme. These include Bomb calorimeter with accessories, oven and furnaces, rapid moisture determination equipment, platform scale, and other temperature and flow measurement units. These shall be used both for biogas and thermochemical conversion of biomass.

The comprehensive list of equipment was prepared during this mission and is given in Annexure- N.

5.4.2 Bio-Gas Appliances

ENEC has a sufficient stock of such appliances. Taking this into consideration DeWaart has also recommended procurment of some of these appliances. Since this report deals mainly with thermochemical route of biomass conversion,includ-ing gasification,this aspect has not been elaborated.

5.4.3 Workshop Machines and Equipment

Mr. S. Mohammad[4], during his mission in Nov. Dec. 1985 has prepared a comprehensive report outlining the speci-fications of machine tools, equipment for fabrication and a small foundry suitable for manufacturing biomass con-version and biogas utilisation appliances. The cost estimates are also included. In order to procure these equipments before the costs get further escallated,suitable space for the installation of these machines as well as having provisions for other identified activities should be allocated at the earliest.

6.0 FUTURE WORK PLAN

In the previous report[1] many projects under the Biomass conversion demonstration programms have been identified. These essentially remain the same except for some minor modifications. These modifications are basically attributed to rescheduling of activities/projects and updating of financial inputs. The proposed shedule of project/work plan is given in Annexure-A. The key to work plan is summarised in Annexure-B.

Depending upon the availability of funds, the programme has been subdivided to be executed either under short term (1986-87) or long term (1986-90). However, the long term programme is most effective in meeting the objectives of this programme. The financial outlays for the proposed short as well as long term programmes are presented in Annexure-C and D respectively. These estimates also include the recommendations given by other consultants, Dr. Stassen[3] for biomass gasification programme and Mr. Sayeed[4] for laying down specifications for workshop as a part of Biomass Centre.

6.1 PROPOSED ACTIVITIES

These activities are broadly the same as those presented in previous report[1]. The minor changes incorporated in the revised plan are briefly discussed.

6.1.1 Training of ENEC Staff and Study Tour

This first activity is essential for the staff from ENEC to get trained to take up the responsibilities of running and monitoring the performance of various projects. This UNIDO programme is aimed at the transfer of those technologies which are proven and are successfully working in other countries. In addition, these should not be complicated and not heavy on maintenance. These aspects have been taken into consideration while suggesting projects under work plan. To enable the Ethiopian authorities to study and evaluate the relevance of these technologies for Ethiopia , a two months tour for the Chief Executive from ENEC shall be very useful and accordingly proposed.

6.1.2 Activities-Projects

Most of the projects/activities identified under work plan (Annexure-A) have been already discussed. Further these are also mentioned in 'key to the work plan' (Annexure-B). To avoid repetition, only those activities not already covered are briefly discussed.

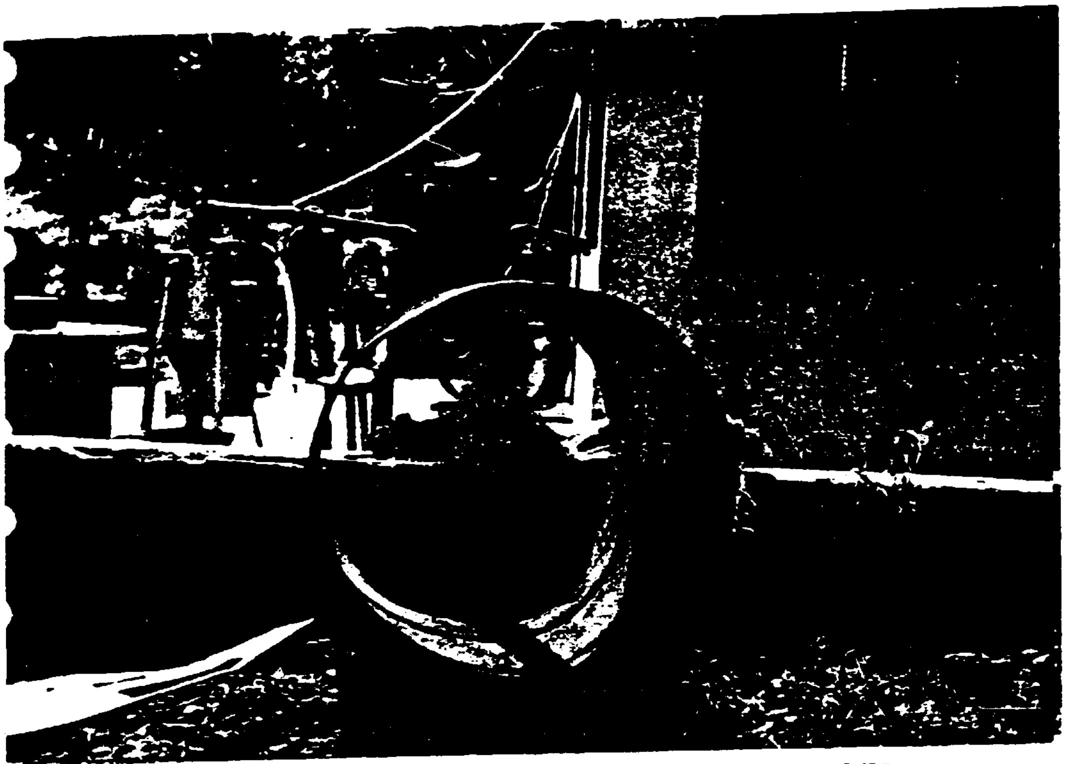
6.1.3 Dissemination Programme

Sufficient work has been accomplished on development and testing of small scale charring and briquetting of agro- and foresty wastes. The cook stoves relevant to Ethiopia have also been identified and developed. Therefore, there is no need to carry out any further developmental work on new types of similar appliances. However, testing and modification of the existing appliances must continue. This can be carried out under the present facility and expedited by the establishment of Biomass Energy Development Centre. The existing facilities being inadequate,top most priority should be assigned to the establishment of biomass centre by UNIDO and the Government of Ethiopia.

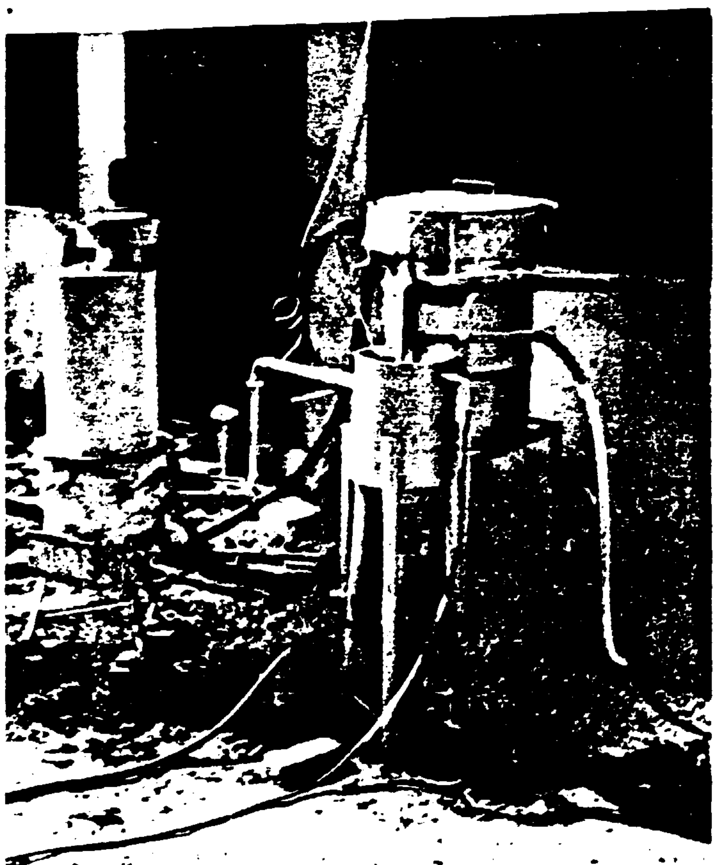
Under the dissemination programme, a number of steps are envisaged to be taken, such as holding national and International regional training cum demonstration workshops, deployment of charring kilns in State farms and distribution of charring-briquetting units and biomass stoves in selected areas of the country. This should also involve the socio-ecnomic evaluation of these programme. Based on feedback , the modifications should be carried out to meet the requirements of different strata of society. Dissemination of simple charring and briquetting units for biomass & judicious distribution of biomass stoves can make effective impact on the conservation of wood in Ethiopia. Therefore, prime importance and adequate funds should be assigned to this major activity.

6.1.4 Gasification Technologies

This aspect of introducing gasification technology has already been elaborated by Stassen(3). In addition to 15 H.P. Gasifier-pump unit already ordered by UNIDO it is worthwhile to introduce two more such systems. These are:



5 H.P. GASIFIER WITH PUMP AT I.I.T. DELHI



PRODUCER GAS BURNING WITHOUT FLAME

(a) 7 H.P. Gasifier for power generation.

(b) 3-5 H.P. Gasifier for running pump for lift irrigation and water supply in small villages (Fig.- P.6.1)

(c) Demonstration of running tractors in Maize state farms on charred corn cobs.

The demonstration of above technologies are essential and should be implemented.

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Annexure - A

PROPOSED SCHEDULE OF ACTIVITIES:- WORK PLAN

PROJECT:-Demonstration Programme On The Use Of Indigenous Biomass Resources (RP/RAF/85/627)
Both For Short Term (1986-1987) and Long term (1986-1990)

STEP NO.	ACTIVITY	PHASE-I 1985 Concluded	PHASE-II # 1st year	2nd year	3rd year
1.	Training				
1-A.	Mechanical Engg.		3m/m		
1-B.	Chem./Mech. Eng.			3/2m/m	
1-C.	Agri. Eng.			3/2m/m	
1-D.	Economist/Data Analyst			2m/m	
1-E.	Chemist		2m/m		
2.	Study Tour				
3.	Biomass Centre		A		
3-A.	Laboratory Equipment	E.O	B		
3-B.	Workshop Equipment	E.S	B	C D	
4.	Dissemination Programme		##		
	a: Socio-economic survey				
	b: Programme monitoring				
4-A.	Charring and Briquetting				
4-B.	Biomass Paru Stoves				
4-C.	Biomass Briquette Stoves				
	a: Developing and testing				
	b: Identifying location field development and field testing demonstration				
	c: Extention programme				
4-D.	National Workshop				
	a: Preparation of manuals				
	b: Workshop in Ethiopia				
4-E.	Charcoaling from Corn Cobs				
	a: Testing and development				
	b: Fabrication and field development demonstration				
	c: Economic analysis and popularisation of process and products with stoves				
	d: Extention programme				
5.	Cotton stalk charcoaling and mechanised briquetting		@ *	**	
	a: Testing in kilns				

Annexure - A (Contd.)

WORK PLAN - contd.

STEP NO.	ACTIVITY	PHASE-I : 1985 Concluded	PHASE-II :--1st year--:--2nd year--:--3rd year-
6.	Coffee Husk Charcoal Mechanised unit		
7. ●	15 HP Gasifier for Irrigation at Golibee Ethiopia		
a	Site selected and order placed		
b	Manufacturing and testing in Holland		
c	Transport to site		
d	Installation, start up and training		
e	Performance monitoring		
f	Feasibility reports for other locations		
8.	7 HP Gasifier for power generation		
9.	Gasifier -Pump 3-5 HP units (2 Nos.)		
10.	Tractor with Charred Corn Cobs Gasifier		
a	Ordering and procurement		
b	Testing at ENEC		
11.	3 Tonne truck		
12.	Expert/Consultants T.A. 40m/m		SEE SEPARATE SHEET
13.	Regional training workshop		

FOOT NOTES:-

1. # Date of initiation of second phase .
2. A Selection and preparation of site/building .
3. E.O Equipment ordered .
4. B Ordering of equipment .

FOOT NOTES :- contd.

5. E.S Equipment specified .
6. C Installation .
7. ▮▮▮▮▮ Long term project .
8. ███ Short term project.(short term activities form part of long term project)
9. ## For charring ,briquetting and stoves .
10. @ Site selection .
11. ●● Duplication in Ethiopia and dissemination .
12. * Ordering,preparation of site ,installation and start-up .
13. ** Socio-economic studies and performance evaluation .
14. ● As given by gasifier consultant .
15. ♣ Field testing .
16. ♥ Testing at ENEC .
17. ♣♣ Two units for long term or only one for short term project .
18. ♥♥ Ordering and procurement of equipment/units .

Future Plans: 4th,year and 5th,year(1989-1990) shall be
: exclusively devoted to

1. Duplication of units in Ethiopia and extensive extention .
2. Carry out performance evaluation of units .
3. Study socio-economic impact of project .

Annexure - B

KEY TO WORK PLAN

PROJECT:-Demonstration Programme On The Use Of Indigenous Biomass Resources In Ethiopia.
(Extention of projects UC/ETH/82/164 and RP/RAF/85/627)
Both For Short Term (1986-1987) and Long term (1986-1990)

STEP NO.:	PROJECT/ACTIVITY :	OBJECTIVE
1.	:Training of ENEC staff from Ethiopia.	:To enable Ethiopian staff to operate and monito: :the performance of biomass convertion systems supplied by UNIDO.
1-A.	:Mechanical Engineer.	:3 months training in Holland or 6 weeks in Ind: and 6 weeks in Holland.Subject:-charring, briquetting and gasification of biomass.
1-B.	:Chem./Mech. Engineer.	:3/2 months training on operation of mechanised charring and briquetting plant based on coffee husk.
1-C.	:Agri. Engineer.	:3/2 months training on operation of small gasifier and preparation of fuels.
1-D.	:Economist/Data Analyst	:Two months training in analyses of data and study socio-economic impact of the programme.
1-E.	:Chemist.	:To train the chemist in analysis of various solid fuels including analysis of biogas and producer gas using chromatograph and modified Orsat apparatus.
2.	:Study tour for chief executive of Energy Committee from Ethiopia.	:2 month tour to study the performance of various biomass and biogas systems working in other countries and their possible adoption in Ethiopia. Recommended:India,Philippines,China,Brazil and Eourope.(Holland)
3.	:Establishment of Biomass energy Development Centre.	:Centre to be established with testing facilities including analytical laboratory for performance monitoring of biomass utilisation systems. Workshop to be included to build prototype units
4.	:Dissemination Programme.	:Small scale charring and briquetting units and various stoves have already been developed.
4-A. to 4-C.	:Dissemination Programme.	:Procurememt of such additioal units and their identification for dissemination in certain locations.Analysis of feed back and possible modification of these systems.

Annexure - B (contd.)

ITEM NO.:	PROJECT/ACTIVITY :	OBJECTIVE
4-D.	:National Workshop	:Training cum demonstration workshop for personnel drawn from various forests and agriculture institutes, peasant associations & distribution of these units for further training and dissemination. Manuals to be prepared in advance.
4-E.	:Charcoaling from corn cobs.	:Deployment of mobile kilns in state farms making charcoal. Charcoal distribution throughgovernment distribution enterprises.
5.	:Charcoal Briquettes From Cotton Stalk.	:Cotton stalk to be partially charred in mobile kilns in the fields. Collection of char at a central site and setting up mechanised briquetting and drying units.
6.	:Coffee Husk Charcoal Mechanised Unit.	:To procure and set up one production/demonstration unit to make 4 tonnes/day of coffee husk charcoal briquettes and distribute to consumers and analyse the feed back.
7.	:15 HP Gasifier-Engine set-up for irrigation.	:The gasifier is already ordered. Set-up and testing it at Golibee, place near zwai lake, training of personnel, carry out performance monitoring
8.	:7 HP Gasifier for power generation.	:Procurement of portable unit for training at Energy Centre and then its deployment in field for electrification of remote and small village
9.	:3-5 HP Gasifier Pump sets.	:Demonstration of these inexpensive small portable units for pumping water for drinking and irrigation purposes.
10.	:Tractor with Corn Cobs.	:Demonstration of mobile gasifier and its deployment in Maize producing state farm along with corn cobs charring systems.
11.	:3 Tonne Truck.	:Procurement of this unit for carrying mobile kilns and gasifiers to various locations for demonstration.
12.	:Experts/ CTA .	:To provide technical assistance and monitor the programme.
13.	:Regional Workshop.	:To organise an international workshop, inviting delegates from African countries, specially from East Africa and share experiances. Also arrange training cum demonstration workshop and provide the delegates with drawings and specifications of charring and briquetting units, and stoves already tested in Ethiopia.

Annexure - C

••SUMMARY••

Estimated Financial Outlays

PROJECT:- Demonstration Programme on the Use of Indigenous Biomass Resources in Ethiopia.
(Extension of Projects UC/ETH/82/164 and RP/RAF/85/627)
LONG - TERM - PROJECT. 1986-1990 #
(Second Phase of UN Programme for Development of Africa)

P	PROJECT/ACTIVITY	UNDP/UNIDO INPUTS US$(Thousands)	Government of Ethiopia Birr Equivalent US$(Thousands) INPUTS Per Yr.	INPUTS Fixed	Potential Revenue Per Yr.
.	Training Component 10m/m	40	-	-	-
.	Study Tour 2m/m	10	-	-	-
..	Biomass Centre				
-A.	Laboratory Equipment	100		120	-
-B.	Workshop	120			
.	Dissemination Programme				
-A.	Charring & Briquetting Units	112	-	28	-
-B.	Biomass-Paru stoves	35	-	8.5	-
-C.	Briquettes/Coffee husk stoves	20		5	
-D.	National Workshop ##	8	-	-	-
-E.	Charcoaling from Corn cobs	@@	89	-	146
.	Cotton stalk charcoaling and briquetting	120	230	60	174
.	Coffee husk charcoal mechanised unit *	200	110	34	150
.	15 HP Gasifier for irrigation **	40	-	-	-

Annexure-C (contd.)

Estimated Financial Outlays

	: PROJECT/ACTIVITY	: UNDP/UNIDO INPUTS US$(Thousands)	: Government of Ethiopia Birr Equivalent US$(Thousands) INPUTS Per Yr.	: Fixed	: Potential Revenue Per Yr.
.	: 7 HP Gasifier for power generation	: 20	: -	: -	: -
.	: Gasifier-pump 3 HP units(2 units)	: 10	: -	: -	: -
..	: Tractor with charred corn cobs gasifier	: 30	: -	: -	: -
1.	: 3 Tonne truck	: 20	: -	: -	: -
2.	: Experts/Consultants STA : 40 m/m @	: 400			
3.	: Regional workshop	: 40	: -	: -	: -
	: Sub. Total	: 1,325	: 429	: 255.5	: 470
	: Sundries/Contigencies	: 93	: 30	: 18.0	:
	: Inflation 5%	: 71	: 23	: 14.0	: 47
	: Total	: 1,489	: 482	: 287.5	: 517

OOT NOTES:-

. # This also includes the financial outlays for short term project 1986-87
. ## Including preparation of operational manuals
. * With gasifier
. ** Gasifier already ordered
. @ Includes for gasifier and workshop
. @@ Cost of kilns included in step 4-A.

Annexure - F

SUMMARY

Estimated Financial Outlays

PROJECT:- Demonstration Programme on the Use of Indigenous Biomass Resources in Ethiopia.
(Extension of Projects UC/ETH/82/154 and RP/RAF/85/627)

SHORT - TERM - PROJECT. 1986-1987

F	PROJECT/ACTIVITY	UNDP/UNIDO INPUTS US$(Thousands)	Government of Ethiopia Birr Equivalent US$(Thousands) INPUTS Per Yr.	Fixed	Potential Revenue Per Yr.
.	Training 5m/m	20	-	-	-
.	Study Tour 2m/m	10	-	-	-
.	Laboratory Equipment (Biomass Centre)	15	-	-	-
.	Dissemination:charring, briquetting and stove programme (Including Workshop)	86	-	20	-
-E	Charcoaling From Corn Cobs	* -	** 89	-	146
.	Cotton stalk charring and briquetting	120	230	60	*** 174
.	Charcoal/Corn cobs 15 HP Irrigation Gasifier	40	-	-	-
.	3 HP Gasifier pump set (one unit)	7	-	-	-
1.	3 tonne truck for transportation of kilns with spares	20			
2.	Overseas experts 10m/m	100			
	Sub. Total	418	319	80	320
	Sundries/Contigencies	30	22	6	-
	Inflation 5%	23	16	4	32#
	TOTAL	471	357	90	352

Notes:-
- * Cost included in item no. 4.
- ** Operating cost (labour)
- *** Production can be doubled with same machinery
- \# For two years

Annexure - E

PROPOSED VISITS OF EXPERTS CTA FROM OVERSEAS

Sl.	DESIGNATION	1st yr.	2nd yr.	3rd yr.	4th yr.	5th yr.
1.	Expert on gasifier.	■1#	■1#			
2.	Expert on mobile gasifier and tractor.			■■1#		
3.	Expert on installation of workshop and training.		■■■■■4#			
4.♣	Expert on charcoaling, briquetting, stoves, gasification, setting up labs. ect.		■■■■■■8#	■■■2#		
5.	Expert on mechanised charring and briquetting.			■■■■3#		
6.	Expert on evaluation of project. Socio-economic evaluation.			■■1#	■■1#	■■1# 1#■■
7.*	CTA - Expert in charring, briquetting, gasification, setting up labs., fabrication of equipment and economic evaluation.	2#■■	12#■■■■■■■■		■■■■■■■■12#	2#■■

FOOT NOTES:-

1. ■■■■ Short project, 10m/m.
2. ■■■■ Long term project, 40m/m.
3. # Month.
4. ♣ Expected to look after overall activities.
5. * Overall incharge including all activities plus supervising associated biogas programme including training component.

Annexure - F

Specifications of Aluminium Pans used for Testing of Various Domestic Stoves

No.	Pan-weight (gms)	Height (cms)	Internal Diameter (cms)	Volume (litres)
1.	220	8.6	20.2	2.7
2.	270	10.2	22.5	4.0
3.	300	12.5	19.6	3.8
4.	340	12.2	25.7	6.3
5.	460	13.2	28.3	8.3
6.	520	14.5	31.5	11.3
7.	540	14.0	29.5	9.6
8.	590	14.5	32.4	12.0
9.	1460	18.7	44.6	29.2
10.	1930	21.7	50.0	42.6

ANNEXURE - G

CALORIFIC VALUE OF VARIOUS FUELS USED

Due to the nonavailability of facilities for finding the calorific values of various fuels and biomass used by bomb calorimeter, the following values were used. These were approximately estimated on the basis of ash and moisture contents of a specific fuel. For absolute tests, these values may have 5-10% deviation from actual values. However, for comparison the performances of various stoves should not make much difference.

	Fuel/Biomass	Moisture Content (wet basis) %	ASH (dry basis) %	CALORIFIC VALUE (Kcal/Kg)
1.	Eucalyptus Wood	-	1.3	4500
2.	Ethio Biomass	-	8.0	4000
	Uncharred briquettes	-	3.4	
3.	Sawdust	-	-	4500
4.	Wood Charcoal	-	6.2	5400
5.	Corn Cobs charcoal	-	6.2	5000
6.	Coffee Husk	-	-	4418
7.	Dry Eucalyptus leaves	7.5	6.0	4500
8.	Local charcoal Mud cakes	5.0	41.1	3410
9.	Acacia wood chips	6.7	-	4500
10.	Teff Straw	-	-	3500
11.	Cowdung	8.6	26.1	3150

Annexure-H

Procedure for Testing of "PARU STOVES

Step-1. A specific amount of charcoal/briquettes or other fuel is wighed and kept aside for testing.

Step-2. The broken refractory bricks or ballast stones capable of withstanding high temperature, having sizes ranging from 4 to 7 cm in size are also weighed and kept for the testing of stove. The weight of stones should be about 4.5 kg for 500 dia stone or 1½ times the weight of charcoal fuel envisaged to be used.

Step-3. The weighed amount of biomass such as Coffee husk, Leaves, sawdust or pine needles are added to the annulus portion of the stove.
For modified bottom opening stove, the filling is carried out by placing the top portion of stove in upside down position (Fig.P-3,1).The bottom plate with ash-pit and stand is then placed over the stove. The bottom portion stand . is well secured by clamping and/or inserting two rods and stove is arranged in upright position.

Step-4. The conical bar grate is placed in the central portion of the stove.

Step-5. Except for bottom opening modified stove, the top cover is placed and secured tight with bolts or made push tight. The possible leakage of gases from the cover is blocked by applying mud paste.

Step-6. A portion of charcoal/briquetted fuel is now placed so as to cover the grate. The charcoal is covered by a layer of stones followed by filling the remaining volume by charcoal.

Step-7. Meanwhile, the pan is weighed and a specific quantity of water is added so as to fill it by 75-80% of its total volume.

Step-8. The stove is ignited by placing ignitor fuels below the grate till the charcoal/briquettes starts burning.

Step-9. The pan with water is placed on the stove and the temperature and time of placing the pan on the stove are recorded. After about 15 minutes the gases produved by carbonisation of biomass start burning near the end of the stove.

Step-10. The rise in temperature of water as a function of time is periodically recorded till the water starts to boil.

Step-11. The grate is periodically shaken and further amount of charcoal and stone pieces are added. This procedure is continued till and the charcoal and stones cooled down.

Step-12. The test is concluded when the gases cease to burn and the boiling of water stops indicated by the small drop in temperature. Due to high altitude, water boils at 90°C in Addis Ababa.

Step-13. The weight of water remaining in the pan is recorded and water evaporated during the test is calcuated.

Step-14. The stove is allowed to cool by shutting off the air damper. The operation is carried out to avoidd introduction of any air into the jacket which may burn the remaining fuel.

Step-15. After the stove has been cooled, the remainder biomass, both charred and partially charred are taken out and weighed.

Step-16. The charred material is separated from uncharred or partially charred material by screening it through 3 mm size wire mesh screen simultaneously giving some rubbing action so that the friable char material gets into powder form. The undersized charred material and over sized partially charred materials are then weighed.

Step-17. The charred material can be later converted into briquettes and used as a secondary fuel for next operation while uncharred can be used along with fresh biomass during the subsequent operation.

Annexure - J

SAMPLE CALCULATION

WATER BOILING TEST FOR "PARU" STOVES

(CODE 70/2201/w)

Stove: 500 Ø PARU STOVE ENEC (Fig.3.1)

(A) DATA

Amount of Coffee husk placed inside the annulus jacket	=	8.00 Kg.
Amount of charcoal used	=	3.00 "
Amount of Refractory bricks	=	4.57 "
Wt. of Aluminium Pan	=	1.93 "
Wt. of water in the Pan	=	25.00 "
Time of firing with charcoal and about 1.5 Kg. of bricks	=	8-30 AM
Time of placing pan on stove	=	8-50 AM
Initial temperature of water	=	14°C
Boiling temperature of water	=	93°C
Time of initiation of boiling	=	10-14 AM
Time of stoppage of boiling	=	03-50 PM
Weight of pan and water after boiling	=	13.80 Kg.

Time - Temperature history

Time (AM)	8-50	9-10	9-49	9-58	10-05	10-12	-	10-14
Temp.(°C)	14	34	55	70	80	90		93

Amount of carbonised coffee husk = 2.4 Kg.

Amount of partially carbomised Coffee husk = 2.0 Kg.

(B) CALCULATIONS

(1) Amount of water evaporated

25 + 1.93 - 13.8 = 13.13 Kg.

(2) Duration of operation

3-50 (PM) - 8-50 (AM) = 7.0 hours

(3) Heat Recovered in the pan + Water (i) Sensible heat of pan

= Wt. of pan x specific heat of pan x Rise in Temp.

= 1.93 x 0.22 x (93-14) = 33.54 Kcal.

(ii) Sensible heat of water

= 25 x 1 x (93-14) = 1,975 Kcal

(iii) Latent heat of water

= Wt. of water evaporated x latent heat

= 13.13 x 543 = 7,129.6 Kcal.

Total heat recovered = (i) + (ii) + (iii) = 9,138.13 Kcal.

(C) RESULTS

(1) Average heat transfer rate before boiling of water

= Heat Received/Time for boiling

$$= \frac{33.57 + 1,975}{(10-14)-(8-50)} = \frac{2008.57}{84}$$

= 23.9 Kcal/min.

(2) Average heat transfer rate during boiling

= Heat Recovered during boiling/boiling time

$$= \frac{7,129.6}{336} = 21.2 \text{ Kcal/min.}$$

(3) Thermal efficiency based on charcoal fuel alone taking Coffee husk at no cost value.

= Total hear recovered/amount of charcoal x clorific value

$$= \frac{9138.13}{3x5,400} = \underline{56.4} \%$$

(4) Thermal efficiency based on charcoal and coffee husk - not taking into account the char and coffee husk left.

$$= \frac{9138.13}{(3x5400)+8(4418)} = \underline{17.72} \%$$

(5) Thermal efficiency based on fuels consumed.

Charcoal: 3 Kg.

Coffee husk: 8 kg.

Fuel left : 2.4 Kg. carbonised Coffee husk

2.0 Kg. partially carbomised coffee husk

Energy in charcoal = 3 x 5400 = 16,200 Kcal

Energy in Coffee husk= 8 x 4478 = 35,344 Kcal

Energy in charred

Coffee husk = 2.4 x 5400 = 12,960 Kcal

Energy in partially Carbonised Coffee husk	= 2.0 x 5000 = 10,000 K.cal
Fuel Energy Consumed =	
Charcoal	= 16,200 Kcal
Husk	= (35,344-12,960-10,000) 12,380 Kcal
Energy consumed	= 16,200 + 12,380 = 28,580 Kcal
Thermal efficiency	= Energy Recovered/Energy Consumed
	= 9138.13/28,580 = 32 %

(6) In case the carbonised fuel is briquetted and used instead of charcoal, additional fuel energy that may be required is:-

Energy Required	= 16,200 Kcal
Energy available in Carbonised husk	= 12,960 Kcals.
Additional that may be required	= 3,240 Kcals

This is presumed on the basis that Coffee husk, in coffee growing areas, is available at no cost value.

This implies that by consuming 3,240 Kcal of energy equivalent to 0.6 kg charcoal or 0.72 kg of wood, one can recover 9,138 kcals of heat for cooking. However, the husk and labour involved are available at no cost basis. Neglecting these factors the efficiency involved is (9138/3240) = 282 %. The output to input factor of 2.82 can be further improved by optimising the performance of 'PARU' stove by adjusting the proportions of Coffee husk, charcoal briquettes and refractory stones. Further work should be carried out by ENEC staff to make this unit to work at no cost basis except for the inputs of biomass and manual labour.

Annexure - K

PROCEDURE FOR TESTING OF ALL STOVES EXCEPT 'PARU' STOVES

Step-1 A specific amount of fuel such as briguettes, charcoal, wood or biomass is weighed and kept aside for test.

Step-2 The pan is weighed and then filled with specific amount of water. The amount of water added should be calculated. The pan should be filled to about 75 % of its volumetric capacity.

Step-3 A portion of fuel such as charcoal, depending upon the capacity of the stove, is added and ignited with minimum amount of ignitor fuel.

Step-4 As soon as the smoking period is over, indicated by reduced amount of smoke, the pan with water covered with lid, having a hole to accommodate thermometer stem is placed on stove. The time of placing the pan on stove and temperature of water are recorded.

Step-5 After regular intervals of time, the temperatures as a function of time are recorded till the water temperature reaches boiling point of water. Due to high altitude of Addis Ababa, the water boils at about 93°C.

Step-6 During the boiling test, the fire is maintained by adding remaining fuel (if any).

Step-7 The moment simmering or boiling stops and a slight drop in temperature is noticed, the pan is removed and time is recorded.

Step-8 After cooling of pan its weight with remaining water is recorded.

Step-9 The amount of unburnt charcoal/fuel if any is weighted

Step-10 The ash is collected and weighed.

Step-11 During step-6, if the water is insufficient and level goes down, a specific amount of water is added and after mixing the temperature of water and time of addition are recorded. The temperature and time history is recorded till the water starts boiling again. If required, this may repeated.

SAMPLE CALCULATION

WATER BOILING TEST FOR ALL STOVES EXCEPT "PARU" STOVES

CODE. 86/2801/T (Annexure V)

(A) DATA

STOVE: LOCAL IRON CHARCOAL STOVE
(FIG.4.12)

Wt. of Pan	=	0.27 Kg.
Wt. of Charcoal	=	0.50 Kg.
Wt. of Water added	=	3.00 Kg.
Wt. of water + Pan after boiling stopped	=	2.69 Kg.
Wt. of unburnt charcoal left	=	0.07 Kg.
Initial Temp. of water	=	13°C
Boiling Temp. of water	=	93°C
Time when pan kept on stove	=	8.58 AM
Time when boiling started	=	9.23 AM
Time when boiling stopped	=	10.47 AM

Temperature - Time History

Temp.(°C)	13	20	25	30	40
Time (AM)	8.58	9.03	9.06	9.08	9.12
Temp.(°C)	45	50	55	60	70
Time (AM)	9.13	9.14	9.15	9.16	9.18
Temp.(°C)	80	90	93		
Time (AM)	9.20	9.22	9.23		

(B) CALCULATIONS

1.0 Water evaporated:

Initial weight of Pan + Water	= 3.27 Kg.
Final weight of Pan + Water	= 2.69 Kg.
Water evaporated	= 0.58 Kg.

2.0 Time taken for boiling (hr.min) = (9-23) - (8-58) = 25 mts.

3.0 Boiling time of water = (10-47)-(9-23) = 84 mts.

4.0 Duration of Test = (10-47)-(8-58) = 109 mts.

5.0 Heat recovered before boiling.

(Wt. of pan)(Specific heat of pan)(Rise in temperature)
+(Wt. of water)(Specific heat of water)(Rise in temperature)

= (0.270) x (0.22) x (93-13)
+ (3.0) x (1.0) (93-13)

= 4.752 + 240 = 244.752 K.cals.

6.0 Heat recovered in Pan during boiling.

(Water evaporated)(Latent heat of boiling at 93°C)

= 0.58 x 543 = 314.96 K.cals.

7.0 Total heat recovered in Pan = 244.752 + 314.96 = 559.69 K.cals.

(C) RESULTS

1.0 Average heat transfer rate before boiling
= Heat Recovered/Time for boiling
= 244.752/25 =9.8 K.cals/min.

2.0 Average heat transfer rate during boiling

= Heat Recovered/boiling time
= 314.96/84 = 3.75 K.cals/min.

3.0 Overall efficiency of stove

$$= \frac{\text{Total heat recovered in Pan}}{\text{Amount of charcoal x clalorific value of charcoal}}$$

= 559.692/(0.5x 5400) = 20.7 %

4.0 Incase unburnt charcoal is recovered and used again the efficiency of stove

$$= \frac{559.692}{(0.5-0.07)\text{x } 5400} = 24.1 \%$$

Annexure - M

STAFF ASSOCIATED WITH PROJECT AT ENEC

1.	Dr. Eng. Gebru Woldegiorgis	Executive Secretary, ENEC
2.	Omar Mohammad Geta	Planning Head
3.	Abrhet G/Selassie	Office Secretary
4.	Almaz Taye	Office Secretary
5.	Yahya Mohammad	Engineer
6.	Tekola Shimles	Engineer
7.	Abebe Ergeto	Engineer
8.	Kidane Workneh	Chemist
9.	Shewangzaw Kifle	Chemist
10.	Siltan Abrha	Engineer
11.	Moges Kassie	Public Relation
12.	Lem lem W/Gabreal	Attendant
13.	Dereje	Engineer
14.	Teka Birenda	Draftsman
15.	Misa	Driver
16.	Lema Gelagay	Driver
17.	Shimelis Zewdil	Driver
18.	Habte Tensu	Driver

Annexure - N

PROPOSED MODIFIED LIST OF EQUIPMENT

The following instruments and equipment are needed for testing the performance of charcoal kiln and biomass gas stove:

List of Equipment and Instruments	Quantity
1. Handheld Digital temperature indicator with K-type thermocouple probes of various types with cold junction compensation. Temp. range 0-300°C with accuracy of 0.1°C Other Specifications: a) Both Battery and Mains operated 220 V Ac, b) Provision to attach different S.S. sheathed probes with leads to measure i) surface wall temperature ii) liquid bath temperature	Two
2. Bomb Calorimeter complete with accessories including oxygen gas cylinder to measure heating values of solid fuels such as woody biomass, charcoal etc. with standard Benzoic Acid Samples Gallenkamp Model CBA 302 with ignition working outfit (page 113 Gallen-Kamp* Catalogue (20 in Edition). Accessories: CBA - 150 C and spares CBA 505 W Remote firing switch assembly CBA 510 W with two medium size oxygen cylinders.	One
3. Single Pan Mettler Balance with accuracy of 0.1 mg and capacity upto 200 gms.	One
4. Muffle furnace with temperature control giving temperature upto 1200°C. Size sufficient to take 25 cc silica crucibles Gallen Kamp*. Box Furnace Model FSL 300 - 010Y capacity 4 liters	One

Normal Spares
Fuse 1200°C - FSL 360-180 K
Thermocouple Sleeve FSL 360 - 190 H
Thermocouple FSL 360 - 210 E

5.	Laboratory oven with thermostatic control range upto 200°C (Serin Model) or Gallen-Kamp* moisture extraction Oven O.V.H. 520	One
6.	Silica Crucibles with lids, sizes 10,25, 50 ml capacity	Three each
7.	Glass wares, general lab. equipment such as: dessicators, petry dishes, (various sizes) Measuring Cylinder, Beakers, Tongs, Asbestos Sheets etc.	
8.	Chemicals such as calcium chloride, Benzoic Acid, laboratory mineral acids and common alkalies, Acetone etc.	
9.	Mercury in glass thermometers, ranges 0-150°C in various sizes	One Dozen
10.	Digital Stops Watches:	
	a) Stop watches: Model TKM 500 U Gallen Kamp	Two
	b) Stop Clock: TKL 400 P Gallen Kemp*	One
11.	4½ digital temperature indicator with at least 6 inputs for K type thermocouples with multiple switch duly caliberated with cold junction compensation: range upto 1200°C. With six SS Sheathed thermocouple probes 15 cm. in length with sufficient (3 m) connecting lead wires.	One

Accessories:

Refractory sheathed K type thermocouple probe to measure furnace temperature SS 316 AISI sheathed K type thermocouple probe having 1 m length suitable for the above mentioned indicator. Two

12. Table platform balance capacity 50 Kg with accuracy of 1 gram, either digital or needle indicator. One

13. Alfa-numerical Programmable Desk top calculator with printout for use in the Laboratory. CASIO latest or HP preferred One

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* Gallen Kamp Catalogue 20th Edition

Annexure - I

Operational Data Project RP/RAF/85/627/11-04/32.1.I
Testing and Demonstration of Biomass Stoves, Charcoaling and Briquetting Appliances

I	II	III A	III B	IV		V		VI	VII	VIII
Test Code	Operation Type	Bio-Mass Primary	Secondary	Additional Inputs		Outputs		Pan gms	Duration Hr - Min	Remarks
01/2911/F	Paru Stove ENEC 500	C.Husk[1] (6.12)	Charcoal (2.46)	Stones (1.33)		Water (8.63)	Evap. (5.89)	540	4 - 25	Residue (2.9) 70% Carbonised Old Husk Ash = 2.7% MC/B = 14%
02/2911/F	Paru Twin ENEC 500	C.Husk[1] (12.85)	Charcoal (4.8)	Stones (3.81)		Water (8.75)	Evap. (4.09)	590	3 - 40	
						Water (8.51)	Evap. (3.28)	520	2 - 25	Residue (5.63) Partially Carbonised
03/3011/SA	Visited local restuarants in Mercato to study Furances using wood fuel to be replaced by Ethio-Briquettes									
03/3011/SA	Paru Twin ENEC 500	C.Husk (-)	Charcoal (2.46)	Stones (1.33)		Water (6.64)	Evap. (2.02)	540	3 - 00	Blank Test
04/0212/M	Visited ETHARSO Wood Board Factory to study boiler operation on wood to be replaced by Ethio-Briquettes. Brought Refractory Bricks for Paru Stove operation.									
05/0312/T	Paru Stove ENEC 500	C.Husk[4] (7.54)	Charcoal (2.52)	R.Bricks (2.5)		Water (10.47)	Evap. (8.01)	540	4 - 55	Residue Carbonised (1.81) Uncarbonised 1.63
06/0412/W	Paru Stove 3I - 500	C.Husk (7.54)	Charcoal (2.52)	R.Bricks[3] (2.5)	Chick[2] Peas (0.5)	Water (7.91)	Evap. (3.92)	540	3 - 20	Residue Carbonised (1.81) Uncarbonised (1.13)
Legend										
No/Date-Month/Day		Biomass	Biomass (kg)	(kg)	(kg)	Water Added (kg)	Evaporated (kg)	gms	Hr - Min	(kg)

(1) Old Coffee Husk (2) Chick Peas as food (3) Refractory Bricks (4) New Coffee Husk

Operational Data – Contd.

I	II	III A	III B	IV	V	VI	VII	VIII
07/0512/Th	Paru Stove ENEC 500	C.Husk (7.21)	Wood[5] (6.50)	R. Bricks (2.5)	Water (13.46) Evap. (9.57)	530	5 – 20	Residue (4.51)
08/0512/TH	Briquetting	Char Coffee Husk (1.0)	–	Starch (0.1) Clay[6] (0.1)	Water (0.6) –	–	–	Preliminary experiment unsatisfactory due inadequate mixing & grinding of Char
09/0612/F	Visited Mercato market to purchase local pester mortaor equipment for mixing & grinding of Char with binders.pipe mould got fabricated by 3I workshop.Visited local workshop making ILO designed metal stoves.							
10/0712/Sa	Briquetting	Char C.Husk (2.0)	–	Starch, Clay, Lime (0.1) (0.23) (0.1) water (1.74)	Briquettes Briquettes	–	1 hr.	Densily wet = 1.33 – 1.35 Density Dry =1.0
11/0912/M	Paru Stove ENEC 500	C. Husk	Local Charcoal Cakes (3.2)	R.Bricks (2.5) – –	water (8.58) Evap. (6.56)	460	6 – 11	Biomass residue (4.66)
12/1012/T	Burning Test ILO-Stove	C. Husk Charcoal Briquetts (0.32)	–	– – –	Pan not used	–	1 – 35	Briquettes fully burnt. Smooth Combustion
13/1012/T	Coffee husk Stove Metal-250	C. Husk	–	– – –	Pan Used			Preliminary test at 3I workshop

(5) Eucalyptus wood. (6) Ordinary Black – Cotton – Soil

Operational Data - Contd.

I	II	III A	III B	IV	V	VI	VII	VIII
14/1112/W	Drum Charring ENEC	Acacia Wood (83.08)	-	- - - -	Charcoal (18.8)	-	(7) 4 - 00	Fully carbonised Charcoal Yield = 22%
15/1112/W	Husk Stove Metal- 250	C. Husk (2.16)	-	- - - Water (5.34)	Evap. (1.08)	460	2 - 30	-
16/1212/Th	Paru Stove ENEC - 500 Husk Stove Metal-250	Saw Dust	Charcoal -	R.Bricks Demonstration to workers and officials of Arsi Rural Development unit Asela.				
17/1312/F	Paru Stove ENEC - 500 Husk Stove Metal-250	Local Saw dust Local Saw dust	Charcoal -	R.Bricks } Repeat demonstration in the presence of Mr. Dekela Dinka - Agri. Development Officer - South-Eastern Zone and Mr. Dalh Berga - SIDA Experts				
18/1412/Sa	Paru Stove ENEC - 500 Husk Stove Metal - 250	Local Saw Dust	Charcoal	R.Bricks } Demonstration to students, workers and staff of Forest Resource Institute at Wendo Genet including Mr. Hans Von Schoults Dean Academic and SIDA Expert.				
19/1612/M	Paru Stove ENEC - 500 Husk Stove Metal-250	Pine Needles C. Husk	Charcoal -	R.Bricks } Demonstration to staff, workers and students of Home Science Department of Awassa Junior College of Agriculture Awassa.				
20/1712/T	On way back to Addis collected one sack full of corn cobs from Awassa State Farm.							
21/1812/W	Drum Charring ENEC	Corn(8) Cobs (41.57)	-	- - Corn Cobs (CC) Charcoal (14.63)	-		1 - 15(7)	14.2 kg. Carbonised 0.43 kg. Partially Carbonised YIELD = 33.1%

(7) Only for firing Charcoal - removed next day

(8) M C W B = 3.9%

Operational Data - Contd.

I	II	III A	III B	IV			V		VI	VII	VIII
22/1812/W	Paru Stove ENEC 500	Teff Straw (2.87)	Charcoal (2.6)	R. Bricks (2.5)	-	-	Water (10.04)	Evap. (7.7)	460	4 - 50	Residue Carbonised = 0.55 Uncarbonised = 0.20
23/1912/Th	Paru Stove ENEC - 500	Teff Straw (3.0)	Caw dung[8] Cakes (3.55)	R. Bricks (1.60)	-	-	Water (6.46)	Evap. (2.42)	460	5 - 15	
24/1912/Th	Briquetting	Teff Straw Char (0.05)	-	Starch (0.05)	Lime (0.24)	Water (1.48)	-	-	-	1 - 30	Density: Wet = 0.641 Dry = 0.322
25/2012/F	Paru Stove ENEC 300	C. Husk (1.63)	Charcoal (1.04)	R.Bricks (0.6)	-	-	Water (4.63)	Evap. (0.92)	410	5 - 20	Char = 0.43 Fully Carbonised
26/2012/F	Husk Stove NIDO Tin	C. Husk (-)	-	-	-	-	Water (2.0)	Evap. (1.2)	150	2 - 26	Preliminary Test
27/2112/Sa	Husk Stove NIDO Tin[9]	Teff Straw (0.83)	-	-	-	-	Water (2.06)	Evap. (0.46)	150	1 - 50	Well Combusted
28/2312/M	Briquetting	Char C.Husk (1.36)	-	Starch (0.05)	Lime (0.05)	Water (0.87)	-	-	-	2 - 00	Strong Briquettes
30/2412/T	Paru Stove ENEC - 300	C.Husk (1.49)	Charcoal (0.36)	R.Bricks (0.10)	-	-	Water (3.0)	Evap. (1.69)	220	2 - 06	Residue = 0.4 kg. Fully Carbonised

Operational Data Contd.

I	II	III A	III B	IV			V		VI	VII	VIII
31/2612/Th	Paru Stove ENEC - 300	C Husk (1.45)	Corn Cob Charcoal (0.40)	R. Bricks (0.10)			Water (4.23)	Evap. (1.08)	350	2 - 01	Residue = 0.45 Fully Carbonised
32/2712/F	Drum Char-ring ENEC	Hay (-)	-	-	-	-	Char (1.0)	-	-	1 - 50	Fully Carbonised
	(8) NCWB = [illegible] ASW = 26.1%		(9) Made from Empty NIDO Mill Tin With LID								
33/3012/W	Paru Stove ENEC - 300	C. Husk (1.54)	Carbonised C. Husk Briquettes (0.22)	R. Bricks (0.10)	-	-	Water (3.0)	Evap. (0.73)	300	2 - 00	Residue = 0.45 Fully Carbonised
34/3112/T	Husk Stove NIDO - TIN	Saw Dust (1.16)	-	-	-	-	Water (2.0)	Evap. (0.44)	300	1 - 35	Sustained Flame
35/3112/T	Paru Stove(10) Indian-500/I	C. Husk (4.65)	Charcoal (2.0)	R. Bricks (1.6)	-	-	Water (7.96)	Evap. (1.6)	540	4 - 00	Residue = 2.03 kg.
36/3112/T	Paru Stove(11) Indian 500/II	C.Husk (3.76)	Charcoal (1.99)	R. Bricks (1.35)	-	-	Water (7.00)	Evap. (3.16)	560	3 - 50	Residue = 1.58 kg.

Operational Data Contd.

I	II	III A	III B	IV				V	VI	VII	VIII
37/3112/T	Paru Stove ENEC - 300	Saw dust (1.28)	Corn Cobs Charcoal (0.30)	R.Bricks (0.10)	-	-	Water (2.0)	Evap. (0.65)	300	1 - 54	Residue 0.36 Carbonised
38/0101/W	Danish-Briquette Stove	Ethio[12] Briquettes (1.0)	-	-	-	-	Water (3.0)	Evap. (0.75)	300	0 - 29	Smoky Combustion
39/0101/W	Ethio Briquette Stove (I)	Ethio Briquettes (1.0)	-	-	-	-	Water (3.0)	Evap. (0.82)	300	0 - 22	Preliminary test
40/0201/Th	Danish Briquette Stove	Ethio Briquettes (0.675)	-	-	-	-	Water (2.275)	Evap. (0.325)	375	0 - 22	Charcoal left = (0.21)
41/0201/Th	Ethio Briquette Stove - I	Ethio Briquettes (0.675)	-	-	-	-	Water (2.20)	Evap. (0.475)	275	0 - 22	Charcoal left = (0.21)

(10) Stove with cover - not properly made difficult to stop leakage of gases

(11) Stove with bolted cover - no leakage of gases

(12) Compacted briquettes manufactured in Addis Ababa from mixture of sawdust + C. Husk + cotton waste.

Operational Data Contd.

I	II	III A	III B		IV	V		VI	VII	VIII
42/0301/F	Danish Briquette Stove	Ethio Briquettes (2.0)	-	-	-	Water (2.7)	Evap. (1.75)	300	3 - 53	Continuous Excessive Smoke
43/0301/F	Ethio Briquette Stove - I	Ethio Briquettes (2.0)	-	-	-	Water (2.7)	Evap. (2.36)	300	3 - 26	Smoke when new Briquettes are placed
44/0401/Sa	Husk Stove Metal - 250	Eucalyptus Leaves (2.52)	-	-	-	Water (2.17)	Evap. (1.72)	300	2 - 04	Initially Smoky flame for 10 mts later good flame
45/0601/M	Husk Stove Paint tin	C. Husk (1.35)				Water Evap (1.5)	Evap. (0.7)	300	2 - 12	Satisfactory operation
46/0901/Th	Husk Stove NIDO - Tin	Eucalyptus Leaves (1.14)	-	-	-	Water (2.29)	Evap. (0.51)	300	2 - 17	Satisfactory operation
47/0901/Th	Ethio Briquette Stove - I	Eucalyptus Wood (1.0)	-	-	-	Water (2.7)	Evap. (0.95)	300	1 - 40	- do -
48/1001/F	Ethio Briquette (#3) Stove - II	Eucalyptus wood (1.5)				Water (3.225)	Evap. (3.045)	270	2 - 22	- do -
49/1001/F	ILO Stove Mark - II	Eucalyptus Wood (1.5)	-	-	-	Water (3.225)	Evap. (2.995)	270	2 - 22	- do -

Operational Data Contd.

I	II	III A	III B	IV		V		VI	VII	VIII
50/1101/Sa	Preparation of Fuel	Eucalyptus Twigs	Design + supervision of Ethio Briquette stove mark[13] II							
51/1401/T	Drum Charring	Eucalyptus Twigs (39.67)	–	–	–		Char (14.36)	–	1 – 20	good quality yield = 36.2%
		(13) Similar to Ethio Briquette Stove I but with bar grate instead of perforated plate								
52/1501/W	Ethio Briquette Stove II	Ethio Briquettes (2.0)	–	–	–	Water (3.16)	Evap. (2.38)	300	2 – 54	Satisfactory operation
53/1601/Th	– do –	Eucalyptus Wood (1.5)	–	–	–	Water (3.225)	Evap. (2.625)	270	2 – 55	– do – Ash. 20 gms.
55/1601/Th	Husk Stove Nespray tin	Sawdust (0.54)	Wood (0.19)	–	–	Water (4.38)	Evap. (0.2)	420	1 – 27	Excessive water added while packing
54/1601/Th	Ethio Briquette Stove II	Ethio Briquettes (1.5)	–	–	–	Water (3.225)	Evap. (2.675)	270	3 – 09	Ash = 90 gms
56/1701/F	Husk Stove NIDO Tin	Sawdust (0.75)	Wood (0.19)	–	–	Water (5.23)	Evap. (0.65)			Satisfactory operation
57/1701/F	Husk Stove Metal – 250	Sawdust[14] (1.30)	Wood (0.19)	–	–	Water (5.56)	Evap. (1.16)	420	2 – 00	– do –
58/1701/F	Ethio Briquette Stove – II	Charcoal (0.8)	–	–	–	Water (3.0)	Evap. (1.28)	300	3 – 15	– do – Ash = 50 gms

Operational Data Contd.

I	II	III A	III B	IV			V		VI	VII	VIII
59/1801/Sa	- do -	Ethio Briquettes (1.5)	-	-	-		Water (3.0)	Evap. (2.7)	270	3 - 53	- do - Ash = 50 gms
60/1801/Sa	Briquetting	Eucalyptus Char (2.48)	-	Lime (0.025)	Cotton Soil (0.250)	Water (-) (2.35)	-	-	-	2 - 00	Total weight of mixture = 5.41kg. In 2.4 kg. Char Further 50 gm. lime added.
61/1901/Sa	Ethio[15] Briquette Stove - III	Ethio Briquettes (1.5)	-	-	-	-	Water (3.0)	Evap. (2.025)	500	3 - 05	Tested at Costantino 3I W/Shop Pot = 22Ø Top = 19Ø Bottomx13ht. (cms)

(14) NCWB = 8% ash = 2.5 Dry basis (15) 1 cm top layer of inner perforated sheet removed from Ethio Briquette Stove mark II

62/2001/H	Ethio Briquette Stove I	Corn Cobs Charcoal (0.8)	-	-	-	-	Water (3.0)	Evap. (0.92)	300	3 - 29	Ash 50 gms = 6.25%
63/2001/H	Ethio Briquette Stove III	Eucalyptus Wood (1.5)	-	-	-	-	Water 3.225	Evap. 2.345	270	1 - 55	Ash = 30 gms = 2%
64/2001/H	- do -	Ethio Briquettes (1.5)	-	-	-	-	Water (3.0)	Evap. (2.59)	270	3 - 37	Ash = 80 gms. 5.3%

Operational Data Contd.

I	II	III A	III B	IV	V		VI	VII	VIII
65/2001/M	Husk Stove NIDO Tin	C. Husk (2.08)	Wood (0.5)	– – –	Water (5.76)	Evap. (1.62)	540	1 – 58	wt. of stove 400 gms. 19 cm ∅ x 21 cm. 2 – 6 cm. holes
66/2001/M	– do –	C. Husk (1.58)	–	– – –	Water (6.63)	Evap. (0.25)	540	1 – 33	
67/2101/T	Ethio Briquette Stove III	Charcoal (0.8)	–	– – –	Water (3.0)	Evap. (1.85)	270	3 – 33	Ash 70gm = 8.7%
68/2101/T	Paru Stove ENEC – 500	Charcoal 2.46	–	R. Bricks (1.33) –	Water 6.64	Evap. 3.55	540	4 – 16	Blank run for Comparison
68/2101/N	Paru Twin Stove – 500	Charcoal(16) (1) (2.4) (2) (2.4)		R. Bricks (1.9) – (1.91) –	Water (8.16) (7.99)	Evap. (1.30) (2.54)	590 520	4 – 24 4 – 00	Blank run for comparison
69/2101/T	Husk Stove Nespray Tin	Eucalyputus leaves (1kg)	Wood (0.5)	– –	Water (4.37)	Evap. (1.35)	340	2 – 45	Weight of stove = 330 gms. 15.5∅ x 23 cms. 6 cm ∅ holes
70/2201/N	Paru Stove ENEC – 500	C. Husk (8.0)	Charcoal (3.0)	R. Bricks (4.57)	Water (25)	Evap. (13.13)	1930	7 – 00	Smokeless flame
70/2201/W	Kenyan Jiko	Charcoal (0.8)	–	– –	Water (3.71)	Evap. (3.03)	270	2 – 13	Excellent performance

(16) Separately for each pot

Operational Data Contd.

I	II	III A	III B		IV		V		VI	VII	VIII
71/2301/Th	Local Tin Charcoal Stove (Kesel Mididja)	Charcoal (0.5)	-	-	-	-	Water (3.0)	Evap. (1.34)	270	2 - 51	Good performance
72/2301/Th	Kenyan Jiko	Charcoal (0.8)	-	-	-	-	Water (3.91)	Evap. (2.35)	270	3 - 28	Good Performance
73/2301/Th	Paru Stove ENEC - 500	C. Husk (8.0)	Charcoal (3.4)				Water (25)	Evap. (11.36)	1460	8 - 33	Good Performance

Operational Data Contd.

I	II	III A	III B	IV	V		VI	VII	VIII
74/2401/F	Local Tin Charcoal Stove (Kesel Mididja)	Charcoal (0.5)	-	- - - -	Water (3.0)	Evap. (0.86)	270	2 - 08	Repeat of 71 not satisfactory
75/2401/F	- do -	Charcoal (0.5)	-	- - - -	Water (3.0)	Evap. (0.39)	540	2 - 05	Not suitable for large pan
76/2401/F	Kenyan Jiko 260 (17)	Charcoal (0.8)	-	- - - -	Water (3.88)	Evap. (2.03)	540	-	
77/2501/Sa	Briquetting	C.Husk Char (5.0)	(0.1)	Soil (0.5) Lime (0.1) Water (3.5) Starch (0.1)	-	-	-	0 - 35	With Iron mould 22.3 x 12.1 x 6.6 high cms. additional water 0.49 kg. added in 4.71 kg. mixed Char.
78/2501/Sa	Kenyan Jiko Stove 260	Charcoal (0.8)	-	- - - -	Water (4.0)	Evap. (2.12)	520	2 - 58	
79/2501/Sa	Kiln (18) Charring	Corn Cobs (58)	Wood (8)		Charcoal (30)				Preliminary Test at 3.I workshop Yield = 45%

(17) Outside diameter of stove 260 ∅ for wood burning.

(18) Mobile kiln manufactured by 3.I workshop Estimated Capacity 100 kg/hr

Operational Data Contd.

I	II	III A	III B	IV			V		VI	VII	VIII
80/2701/M	Local Charcoal Stove (Iron Sheet)	Charcoal (0.5)	–	–	–	–	Water (3.0)	Evap. (0.49)	540	1 – 36	Unburnt Charcoal (0.14)
81/2701/M	Jiko Charcoal coal Stove 310	Charcoal (0.8)	–	–	–	–	Water (3.0)	Evap. (1.51)	1460	3 – 20	Unburnt Charcoal (0.075)
82/2701/M	Paru Stove (19) 3 I 500M	C.Husk (8.0)	Charcoal (3.0)	R.Bricks (4.0)			Water (25.0	Evap. (4.48)	1930	6 – 44	Unsatisfactory Operation-Leakage of Tar from Bottom Plate
83/2801/T	Jiko Charcoal Stove 310	Corn Cobs Charcoal (1.5)	–	–	–	–	Water (9.53)	Evap. (6.5)			Corn Cobs Charcoal refer 21/1812/W
84/2801/T	ILO Stove	Eucalyptus Char Briquettes (0.25)	–	–	–	–	Water (2.0)	Evap. (0.62)	270	2 – 39	Good burning no unburnt fuel Briquettes refer 51/1401/T
85/2801/T	Paru Stove 3 I – 500M	C.Husk (10.0)	Charcoal (3.3)	R.Bricks (3.3)			Water (25.0)	Evap. (12.53)	1930	6 – 52	Good performance Bottom plate holes blocked with mud
86/2801/T	Local Charcoal Stove (Iron Sheet)	Charcoal (0.5)	–	–	–	–	Water (3.0)	Evap. (0.58)	270	1 – 45	Unburnt charcoal (0.010)

Operational Data Contd.

I	II	III A	III B	IV		V		VI	VII	VIII
87/2801/T	Kenyan Jiko 260 Stove	Wood Eucalyptus (1.5)	-	-	-	Water (4.0)	Evap. (2.8)	520	1 - 55	Good performance
	(19) Modified Paru Stove with bottom filling system made by 3 I									
88/2901/W	Briquetting of Eucalyptus Char Ref. 51/1401/T	Char (5.0)	-	Bentonite (0.5)	Water (6.5)					Bentonite 0.5 kg was soaked in 2 kg water for 48 hours-Mould briquetting
89/2901/W	Local Clay Stove	Charcoal (0.5)	-	-	-	Water (3.0)	Evap. (0.54)	540	4 - 25	Unburnt Charcoal (0.1) Slow burning
90/2901/W	Kenyan Jiko Charcoal Stove 310	Charcoal (0.8)				Water (3.0)	Evap. (1.5)	540	3 - 05	Unburnt Charcoal (0.12)
91/2901/W	Paru Stove 3 I - 500M	Corn Cobs Charcoal Ref. 21/1812/W (3.0)	C. Husk (10.0)	R. Stones (3.4)		Water (25.0)	Evap. (10.53)			Some bottom leakage noticed even after closing with mud.

Annexure – II

Calculated Results – Operation – Small Scale Charcoaling

Test Code	Feed Stock	Unit	Time (1)	Batches (2)	Avg. Rate	Product	% Yield	Remarks
			Hr – Min		kg/hr	(kg)		
14/1112/W	Acacia Wood (83.08) + Bark on top (2.65)	Drum ENEC With Loose Top Chimney	4 – 00	(14.57) (15.77) (14.64) (8.00) (11.00) (9.78) (9.32) (83.08)	20.77	Charcoal (18.8)	22	Avg. size of wood = 15 cm x 4 cm ø Wood (M C W B) = 13% Good quality
21/1812/W	Corn Cobs from Awassa State Farm	Drum ENEC with well fitted Chimney	1 – 35	10 equal batches (41.57)	26.25	Charcoal (14.2)	34.1	0.43 Uncarbonised at the bottom of the drum

(1) Time only for adding the feed stock

Annexure - II (contd.)

Test Code	Feed Stock	Unit	Time (1)	Batches (2)	Avg. Rate	Product	% Yield	Remarks
			Hr - Min		kg/hr	(kg)		
32/2712/F	Hay	Drum ENEC	1 - 50	7 batches well Rammed	NA	Powdered Char (7.0)	-	Investigating test
51/1401/T	Eucalyptus Twigs Size - 6"-10"	Drum ENEC	1 - 20	10 batches (39.67)	29.75	Granular Char (14.36)	36.2	good quality
79/2501/Sa	Corn Cobs & wood	Mobile Kiln	0 - 45	Corn Cobs (50) Wood (8)	77.3	Charcoal (30)	45.0	Preliminary test discharge gate welding came out

Energy For Injera Baking Annexure - III

Data was collected on cooking of Injera a local staple bread in the canteen of the Ministry of Mines and Energy on 22nd January, 1986.

Average diameter of Injera = 50 cms.

Sample No.	1	2	3	4	5	6
Amount of Mixture added (gms)	640	630	650	630	650	650
Weight of each Injera (gms)	470	435	465	430	480	470
Loss in weight (gms)	170	195	185	200	170	180
Duration (min)	3	3.5	3	3.5	3	3

Average weight of baked Injera is about 458 grams obtained from 641 gms of fermented Injera mixture made by mixing Teff flour with water.

On an average baked Injera contains about 60% moisture and 40% solids.

During baking water vapour and carbondioxide come out. It is difficult to know their respective amounts. However to be on the safe side it can be presumed that the vapours are mostly steam. It is then estimated that about 130-140 kCals of heat is required for baking one Injera. Taking 20% efficiency that is, the heat that goes into Injera baking 17.5 kg of biomass fuel of Net Calorific Value of 4,000 kCal/kg.

Basis for calculation = One Injera of 50 cm diameter

Ambient Temp. = 20°C Injera temp. = 93°C water boiling point

	Solids	Liquid	Total
Injera mixture (gms)	183	458	641
Baked Injera	183	275	458

.../

Heat released to Injera baking:

(a) Sensible heat to solids

$$= 0.183 \times 0.25 \times (93 - 20) = 3.4 \text{ kCal}$$

(b) Sensible heat to water

$$= 0.458 \times 1 \times (93 - 20) = 33.4 \text{ kCal}$$

(c) Latent heat to evaporate water

$$0.183 \times 543 = 99.37$$

Total (a) + (b) + (c) 136.17 kCal 140 kCal

Fuel required to bake 100 Injeras

$$= \frac{140 \times 100}{0.2 \times 4000} = 17.5 \text{ kg.}$$

Average Heat Transfer rate $= \frac{140}{3} = 46.7$ kCal/min

Annexure - IV

Calculated Results

Modification And Testing Of Paru Stoves

	I	II	III	IV	V	VI	VII		VIII		IX
No.	Code No.	Type	Primary Fuel (kg)	Secondary Fuel (kg)	Bricks (kg)	Pan	Avg. Heating Rates		Efficiencies Percent		Remarks
						Duration 9m / Hr - Min	Before boiling kcal/min	After boiling kcal/min			
1	01/2911/F	ENEC 500	C.Husk (6.12	Charcoal (2.46	(1.33)	540 / 4 - 25	18.62	14.53	29.1	15.2	Preliminary test Amount and weight of stone in-adequate
2	03/3011/Sa	ENEC 500	C.Husk NIL	Charcoal (2.46)	(1.33)	540 / 3 - 0	15.70	751	12.3	12.3	Compared with 01/2911/F 42.0% Energy from Coal 58.0% Energy from C. Husk
3	05/0312/T	ENEC 500	C.Husk 7.54	Charcoal 2.52	(2.5)	540 / 4 - 55	19.03	16.1	38.24	18.66	79% Energy from Husk
4	07/0512/Th	ENEC 500	C.Husk 7.21	Wood (6.5)	2.5	530 / 5 - 20	33.35	17.15	21.5	-	- -
5	11/0912/M	ENEC 500	C.Husk (7.5)	Local Char-coal Cakes (3.2)	2.5	460 / 6 - 11	18.02	13.31	38.76	-	

Annexure - IV

	I	II	III	IV	V	VI	VII		VIII		IX
6	22/1812/W	ENEC 500	Teff Straw (2.87)	Charcoal 2.6	2.5	4 $\frac{460}{-}$ 50	18.80	15.50	35.50	23.9	82.5% Energy from Husk
7	23/1912/Th	ENEC 500	Teff Straw (3.0)	Cow dung cakes (3.55)	1.6	5 $\frac{460}{-}$ 15	16.8	4.6	16.20	13.8	-
8	68/2101/T 68/2101/	ENEC 500	C. Husk NIL	Charcoal (2.46)	1.33	4 $\frac{540}{-}$ 16	9.33	10.5	18.53	18.53	-
9	70/2201/W	ENEC 500	C.Husk (8.0)	Charcoal (3.0)	457	7 $\frac{1930}{-}$ 00	23.9	21.22	56.4	36.31	Ref. 01/2911/F 85% heat released by C. Husk
11	73/2301/Th	ENEC 500	C.Husk (8.0)	Charcoal (3.4)	(4.57)	8 $\frac{1460}{-}$ 33	28.26	13.89	44.21		Pan was kept higher than needed
12	25/2012/F	ENEC 500	C. Husk (1.63)	Charcoal 1.04	(0.6)	5 $\frac{410}{-}$ 20	1.99	3.02	15.2	9.4	Being Small diameter of grate, amount of charcoal was too much to give good combustion

Annexure - IV Contd.

	I	II	III	IV	V	VI	VII		VIII		IX
13	30/2412/T	ENEC 300	C. Husk (1.49	Charcoal (0.36)	(0.14)	220 / 2 - 06	15.18	8.34	60.0	18.3	Major Energy from husk, enough Char to recycle as fuel, good performance
14	31/2612/Th	ENEC 300	C. Husk (1.45)	Corn Cobe Charcoal (0.4)	(0.1)	350 / 2 - 01	14.4	4.80	45.5 52.0*		*Based on 0.35 kg Charcoal 50 gm added in the last was not utilised
15	33/3012/M	ENEC 300	C. Husk 1.54	C.Husk Char Briquettes (0.22)	(0.1)	300 / 2 - 00	6.8	34.66	57.80	11.6	Briquettes burn slowly compared to corn cobs charcoal. For Briquettes (28/2312/M)
16	37/3112/T	ENEC 300	Saw dust 1.28	Corn Cobs Charcoal (0.3)	(0.1)	300 / 1 - 54	4.9	3.83	34.4	13.84	Likely moisture in Saw dust

Annexure - IV Contd.

	I	II	III	IV	V	VI	VII		VIII		IX
17	02/2911/F	Twin ENEC	C. Husk (12.85)	Charcoal (4.8)	3.81	(1) 590 / 3 - 40 (2) 520 / 2 - 25	(1) 19.6 (2) 23.0	(1) 11.4 13.4	21.0	9.8	Efficiencies are comparable to ENEC 500. But more difficult to handle.
18	68/2101/T	Twin Stove	NIL	Charcoal (1) 2.4 (2) 2.4	(1.9) (1.91)	590 / 4 - 24 520 / 4 - 00	7.3 17.0	4.0 7.1	10.5 15.58	- -	Overall efficiency = 13.0 Compared with 21.0 when husk used.
19	06/0412/W	3 I 500	C. Husk (7.54)	Charcoal (2.52)	(2.5)	540 / 3 - 20	21.0	24.8	36.4	15.4	Had Leakage problem. Performance satisfactory.
20	35/3112/T	Indian 500 I	C. Husk (4.65)	Charcoal (2.0)	(1.6)	540 / 4 - 00	16.0	4.3	14.0	7.1	Problem of Leakage of Gases Performance not satisfactory
21	36/3112/T	Indian 500 II	C. Husk (3.75)	Charcoal (1.99)	(1.35)	560 / 3 - 50	12.0	9.32	21.1	11.7	Satisfactory Performance
22	82/2701/M	3 I 500M	C. Husk (8.0)	Charcoal (3.0)	(4.0)	1930 / 6 - 44	15.0	9.5	27.0		Unsatisfactory due to Leakage of Tar.
23	85/2801/T	- do -	(10.0)	(3.3)	(3.3)	1930 / 6 - 52	21.0	21.4	49.5	21.5	
24	91/2901/T	- do -	C. Husk (10.0)	Corn Cobs Charcoal (3.0)	(3.4)	1930 / 7 - 08	35.9	15.4	51.5		

Annexure – V

Calculated Results
Modification And Testing Of Stoves

No.	Code	Stove Type	Fuel (kg)	Water (kg)	Pan (gm)	Duration Hr – Min	Heat Transfer Rates kCal/min		Efficiencies Percentage		Remarks
							For Boiling	Boiling	(1)	(2)	
1	13/1012/T	Husk 3 I-250	C. Husk	–	–	–	–	–	–	–	Preliminary Test for Fabrication
2	15/1112/W	– do –	C. Husk (2.16)	5.34	460	2 – 30	14.8	4.8	10.5	(3)	
3	44/0401/Sa	– do –	Eucalyptus leaves (2.52)	2.17	300	2 – 04	11.9	8.5	10.3	(3)	Smoky flame for 10 mts. good combustion
4	57/1701/F	– do –	Saw dust (1.30) wood (0.19)	5.56	420	2 – 00	9.1	8.5	15.8	(3)	Satisfactory operation
5											
6	26/2012/F	Husk NIDO Tin	C.Husk (NA)	2.0	150	2 – 26	10.8	5.0	–	–	Preliminary Test
7	27/2112/Sa	– do –	Teff Straw (0.83)	2.06	150	1 – 50	8.0	2.8	15.6	(3)	Well Combusted

No.	Code	Stove Type	Fuel (kg)	Water (kg)	Pan (gm)	Duration Hr - Min	Heat Transfer Rates kCal/min.		Efficiencies Percentage		Remarks
							For Boiling	Boiling	(1)	(2)	
8	34/3112/T	- do -	Saw dust (1.16)	2.0	300	1 - 35	7.13	3.3	9.4	(3)	Saw dust was tightly Packed with excess moisture
9	46/0901/Th	- do -	Eucalyptus Leaves (1.14)	2.29	300	2 - 17	12.5	1.8	10	(3)	Satisfactory operation
10	56/1701/F	- do -	Saw dust (0.75) wood (0.75)	5.23	420	1 - 17	12.5	8.4	19.8	(3)	- do -

(1) Based on total fuel burnt

(2) Based on net fuel, that is, (fuel added - charcoal recovered)

(3) Residual fuel not accounted but char can be briquetted and used as charcoal

Annexur - V Contd.

No.	Code	Stove Type	Fuel (kg)	Water (kg)	Pan (gm)	Duration Hr - Min	Heat Transfer Rates kcal/Min		Efficiencies Percentage		Remarks
							For Boiling	Boiling	(1)	(2)	
11	65/2001/M	Husk NIDO Tin	C. Husk (2.08) Wood (0.5)	5.76	540	1 - 58	10.7	8.0	12.0	(3)	Wt. of stove = 400 gms Dimensions 19 cm. ∅ x 21 cm. Two - 6cm holes
12	66/2001/M	- do -	C. Husk (1.58)	6.63	540	1 - 33	11.0	3.1	9.7	(3)	-
13	45/0601/M	Husk Paint Tin	C. Husk (1.35)	1.5	300	2 - 12	1.0	3.3	8.6	(3)	-
14	55/1601/Th	Husk Neepray Tin	Saw dust (0.54) wood (0.19)	4.38	420	1 - 27	7.7	2.6	15.0	(3)	Satisfactory Operation
15	69/2101/T	- do -	Eucalyptus Leaves (1.0) Wood (0.5)	4.37	340	2 - 45	5.0	5.8	16.6	(3)	Satisfactory Operation
16	12/1012/T	ILO A-III	C. Husk Char Briquettes 0.32	-	-	1 - 35	-	-	-	-	Preliminary test Good combustion residual carbon

Annexur -- V Cont.

No.	Code	Stove Type	Fuel (kg)	Water (kg)	Pan (gm)	Duration Hr - Min	Heat Transfer Rates kcal/Min		Efficiencies Percentage		Remarks
							For Boiling	Boiling	(1)	(2)	
17	49/1001/F	I L O A-II	Eucalyptus Wood (1.5)	3.2	270	2 - 22	16.2	12.8	27.8	-	Good performance
18	84/2801/T	I L O A-III	Eucalyptus Char Briquettes (0.25)	2.0	270	2 - 39	8.7	2.4	39.4	-	No residual Char CV = 5000 kcal/kg
19	38/0101/W	Danish	Ethio Briquettes (1.0)	3.0	300	1 - 05	9.6	8.5	15.2	-	Smoky performance CV = 4000 kcal/kg
20	40/0201/Th	Danish	Ethio Briquettes (0.675)	2.20	375	0 - 42	9.07	8.0	13.3	19.2	Smoky operation Preliminary Test
21	42/0301/F	- do -	Ethio Briquettes (2.0)	2.70	300	3 - 53	9.9	4.5	14.6	-	Continuous Smoky
22	39/0101/W	Ethio Briquettes (Mark - I)	Ethio Briquettes (1.0)	3.0	300	1 - 0	8.8	12.9	17.0	-	Preliminary test Smoky when fresh Briquettes are added

No.	Code	Stove Type	Fuel (kg)	Water (kg)	Pan (gm)	Duration Hr - Min	Heat Transfer Rate kcal/Min		Efficiencies Percentage		Remarks
							For Boiling	Boiling	(1)	(2)	
23	41/0201/Th	- do -	- do - (0.675)	2.20	275	0 - 42	18.0	9.8	14.6	21.2	Smoky when fresh briquettes are added
24	43/0301/F	- do -	- do - (2.0)	2.7	300	3 - 26	11.5	6.8	18.7	-	CV Briquettes = 4000 kcal/kg
25	47/0901/Th	- do -	Eucalyptus Wood (1.0)	2.7	300	1 - 40	10.2	6.6	16.4	-	Satisfactory operation CV Wood = 4500 kcal/kg
26	48/1001/F	- do -	- do - (1.5)	3.225	270	2 - 22	17.3	13.0	28.2	-	- do -
27	52/1501/W	Ethio Briquette (Mark-II)	Ethio Briquettes (2.0)	3.16	300	2 - 54	10.0	8.6	16.25		Satisfactory operation
28	53/1601/Th	- do -	Eucalyptus Wood (1.5)	3.225	270	2 - 55	17.3	8.9	24.8		Good operation

Annexure - V Contd.

No.	Code	Stove Type	Fuel (kg)	Water (kg)	Pan (gm)	Duration Hr - Min	Heat Transfer Rates kcal/Min		Efficiencies Percentage		Remarks
							For Boiling	Boiling	(1)	(2)	
29	54/1601/Th	Ethio Briquettes (Mark-II)	Ethio Briquettes (1.5)	3.225	270	3 - 09	9.55	9.19	29.1	-	Ash Content = 6%
30	58/1701/F	- do -	Charcoal (0.8)	3.0	300	3 - 15	6.94	4.3	21.5	-	Ash Content = 6.2%
31	59/1801/Sa	- do -	Ethio Briquettes (1.5)	3.0	[illegible]	3 - 53	9.8	7.0	26.37		
32	61/1901/Sa	Ethio Briquettes (Mark III)	Ethio Briquettes (1.5)	3.0	500	3 - 05	10.9	5.1	22.2		Pan 22 cm ∅ top 19 cm ∅ bottom x 13 cm height at 3 I open - windy atmosphere
33	62/2001/M	Ethio Briquette (Mark I)	Corn Cobs Charcoal (0.8)	3.0	300	3 - 29	4.0	3.35	18.5		CV 5000 kcal/kg Ash = 6.25%
34	63/2001/M	Ethio Briquettes (Mark III)	Eucalyptus Wood (1.5)	3.225	270	1 - 55	19.7	12.5	24.0	-	Ash = 2%
35	64/2001/M	- do -	Ethio Briquettes (1.5)	3.0	270	3 - 37	20.44	7.0	28.9	-	Good Performance

Annexure - V Contd.

No.	Code	Stove Type	Fuel (kg)	Water (kg)	Pan (gm)	Duration Hr - Min	Heat Transfer Rates kcal/Min		Efficiencies Percentage		Remarks
							For Boiling	Boiling	(1)	(2)	
36	67/2101/T	- do -	Charcoal (0.8)	3.0	270	3 - 33	5.8	5.9	28.9	-	- do -
37	70/2201/W	Jiko-260	Charcoal (0.8)	3.71	270	2 - 13	16.1	1.43	44.8	-	Not reliable data
38	72/2301/Th	- do -	Charcoal (0.8)	3.91	270	3 - 28	12.7	7.0	36.6	-	Good Performance
39	76/2401/F	- do -	Charcoal (0.8)	3.88	540	N A	N A	N A	32.5	-	- do -
40	78/2501/Sa	- do -	Charcoal (0.8)	4.0	520	2 - 58	6.15	9.0	34.4	-	- do -
41	81/2701/M	Jiko-310	Charcoal (0.8)	3.0	1460	3 - 20	4.2	8.0	24.6	27.1	Charcoal left = 0.075
42	83/2801/T	- do -	Corn Cobs Charcoal (1.5)	9.53	1460	3 - 50	19.2	16.9	57.5	58.48	CV = 5000 kcal/kg Charcoal left = 0.025kg
43	87/2801/T	Jiko-260	Eucalyptus Wood (1.5)	4.0	520	1 - 55	16.7	15.7	28.7	-	CV = 4251 kcal/kg

Annexure - V Contd.

No.	Code	Stove Type	Fuel (kg)	Water (kg)	Pan (gm)	Duration Hr - Min	Heat Transfer Rates kcal/Min		Efficiencies Percentage		Remarks
							For Boiling	Boiling	(1)	(2)	
44	90/2901/W	Jiko-310	Charcoal (0.8)	3.0	540	3 - 05	5.3	5.8	24.3	28.6	
45	71/2301/Th	Local Tin Charcoal	Charcoal 0.5	3.0	270	2 - 51	7.7	5.1	35.0	44.9	Preliminary Test
46	74/2401/F	- do -	Charcoal (0.5)	3.0	270	2 - 08	4.8	6.0	26.1	40.3	-
47	75/2401/F	- do -	Charcoal (0.5)	3.0	540	2 - 05	6.5	2.4	16.5	39.3	Charcoal did not burn properly
48	80/2701/W	Local Iron Charcoal	Charcoal (0.5)	3.0	540	1 - 36	6.0	3.5	19.0	26.4	
49	86/2801/T	- do -	Charcoal (0.5)	3.0	270	1 - 49	9.8	3.7	20.7	24.1	
50	89/2901/W	Local Clay	Charcoal (0.5)	3.0	540	4 - 25	2.5	1.7	19.9	24.8	Very slow bruning

Calculated Results

Briquetting Of Biomass Char

No.	Code	Char Material (kg)	Binders And Additives (1) kg	(2) kg	(3) kg	Briquetting Method	Specification Of Briquettes: Wet Density	Dry Density	% ash	% moisture	Remarks
1	08/0512/Th	C.Husk (–)	Starch (–)	Clay (–)	–	~~Flow and~~ single pipe mould	–	–	–	–	Preliminary Test
2	10/0712/Sa	C.Husk (2.0)	Starch (0.1)	Clay (0.23)	Lime (0.10)	Single pipe mould	1.33 1.35	1.0	–	35	Good Strength
3	24/1912/Th	Teff Straw (0.50)	Starch (0.05)	Lime (0.05)	Water (2.08)	Pipe mould	0.64	0.32	–	72.0	Light Briquettes
4	28/2312/W	C.Husk (1.36)	Starch (0.05)	Lime (0.05)	Water (0.87)	Pipe mould	–	–	–	40.2	Strong briquettes
5	60/1801/Sa	Eucalyptus Twigs (2.48)	Black Cotton Soil (0.250)	Lime (0.025)	Water (2.35)	Pipe mould	1.21	0.65	11.75	44.0	Size = 5 cm dia x 5.5 cm
6	77/2501/Sa	C.Husk (5.0)	Starch (0.1)	Lime (0.1)	Black Cotton Soil (0.5)	mould	1.1–1.2	0.67–0.73	–	39	Strong Briquettes
7	60A/1801/Sa	– do – (1.10)	– do – (0.11)	(0.2)	(1.50)	– do –	1.1	0.57		51.0	
8	88/2901/W	– do – (5.0)	Bentonite Clay (0.5)	~~Water~~	Water (6.5)	mould	1.14	0.48		54.0	Size of Briquette 6 x 6 x 6 cms
9	90/0502 /W	C.Husk (5.0)	Bentonite Clay (0.5)	–	(5.0)	mould	1.05	0.58	–	47.6	0.5 kg Bentonite Soaked in 2kg water

Annexure-VII

ቀጥር MES/56
Ref. No.

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Addis Ababa 4/27/1986

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THE PROVISIONAL MILITARY GOVERNMENT OF SOCIALIST ETHIOPIA
MINISTRY OF MINES & ENERGY
ETHIOPIAN NATIONAL ENERGY COMMITTEE

The Officer Incharge
UNIDO Office
c/o United Nations Development Programme
P.O. Box 5580
Addis Ababa.

Subject: RP/RAF/85/627 Demonstration Programme on the use of Indiginous Biomass Resources.

This is to inform you that Professor P.D. Grover, UNIDO Consultant and Expert in Biofuels and Thermochemical Conversion Technology, has been with us from November 23, 1985 to February 11, 1986 to carry out his duties as per Terms of Reference prepared by UNIDO and which he has done to our satisfaction.

In addition, after discussions with us, he has prepared a tentative programme of further Biofuels Demonstration, Evaluation and Dissemination Programme to be carried out within a period of 3-4 years.

In principle we agree with the programme, which is an update of the one prepared in 1984. It is however understood that a project document has to be prepared and approved by the appropriate organs of UNIDO and the Ethiopian Government before implementation of the programme starts.

Sincerely yours,

Provisional Military Government of Socialist Ethiopia ... Ministry of Mines and ...

Eng. Gebru Woldeghiorghis
Executive Secretary

c.c. Office Of The National Committee
For Central Planning

Professor P.D. Grover
Addis Ababa.

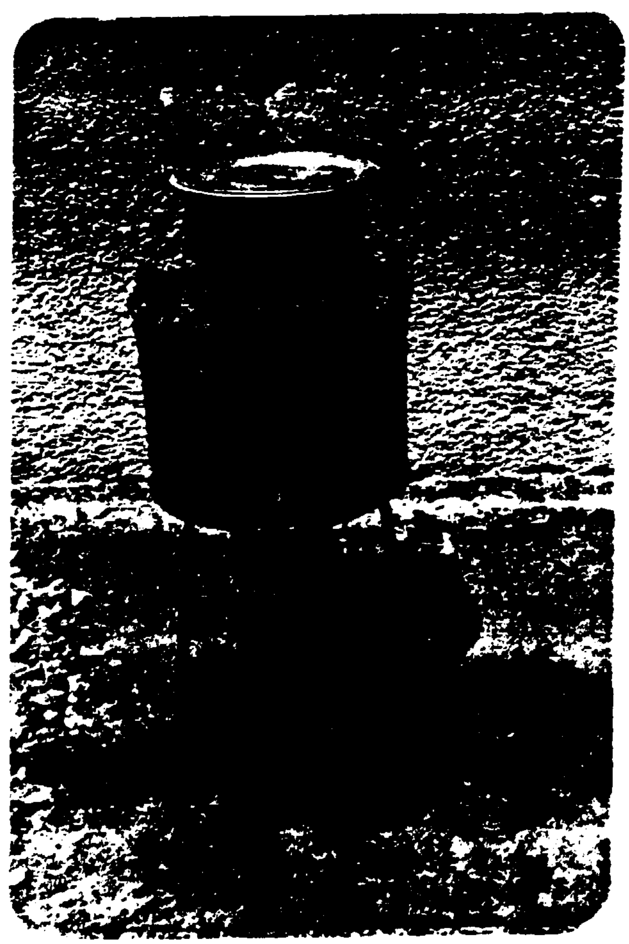
ANNEXURE-VIII: ADDITIONAL STOVES AND PHOTOGRAPHS

(A) ILO STOVE ADDIS-II

(B) ILO STOVE ADDIS-II

Additional Stoves

(C) SOME STOVE

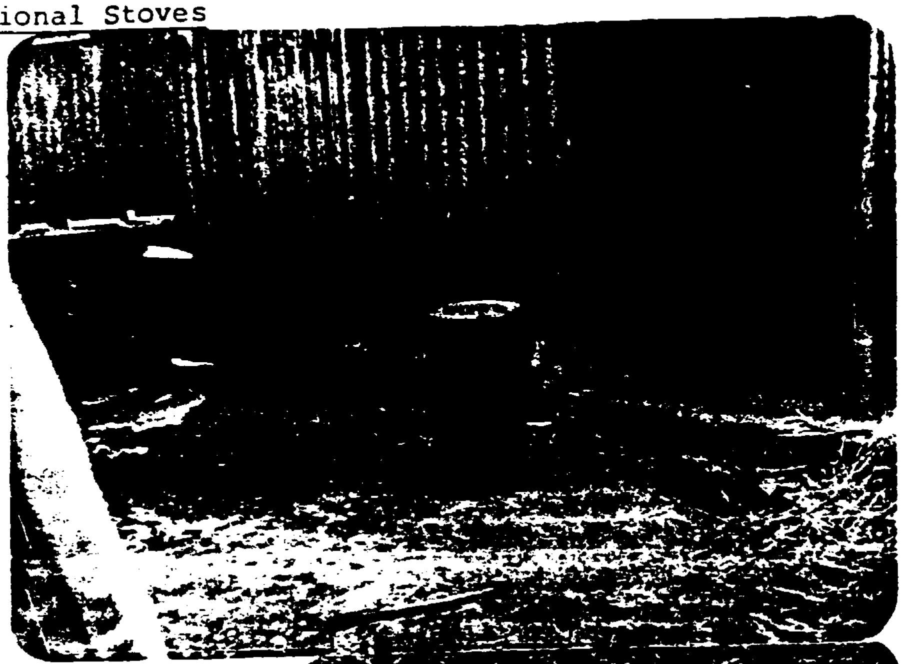


PARU 300 Ø STOVE

Additional Stove

(L) ILO STOVE MARK-II WITH CHARCOAL POT

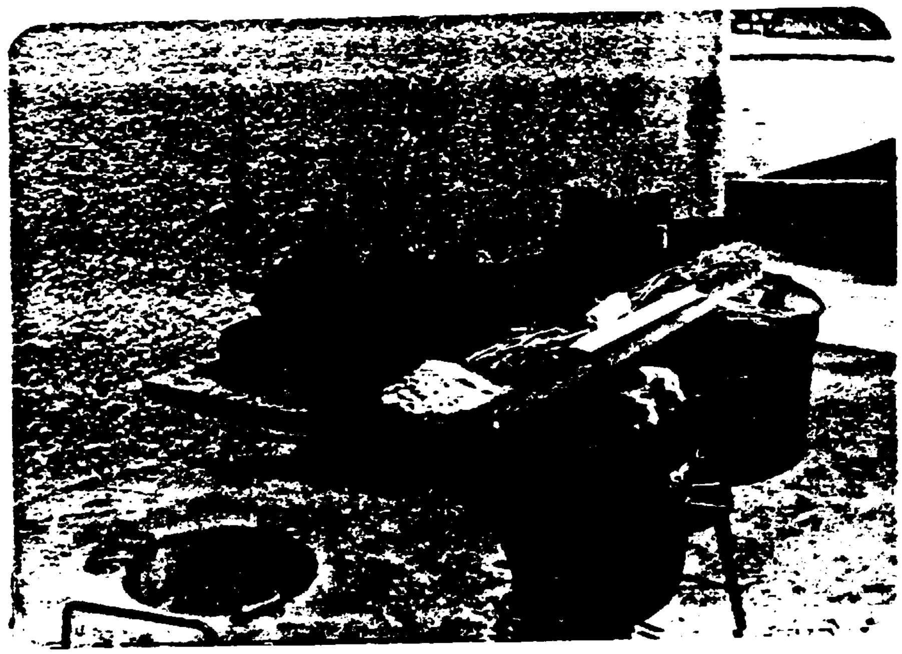
Additional Stoves



E) SAW DUST/COFFEE HUSK STOVE

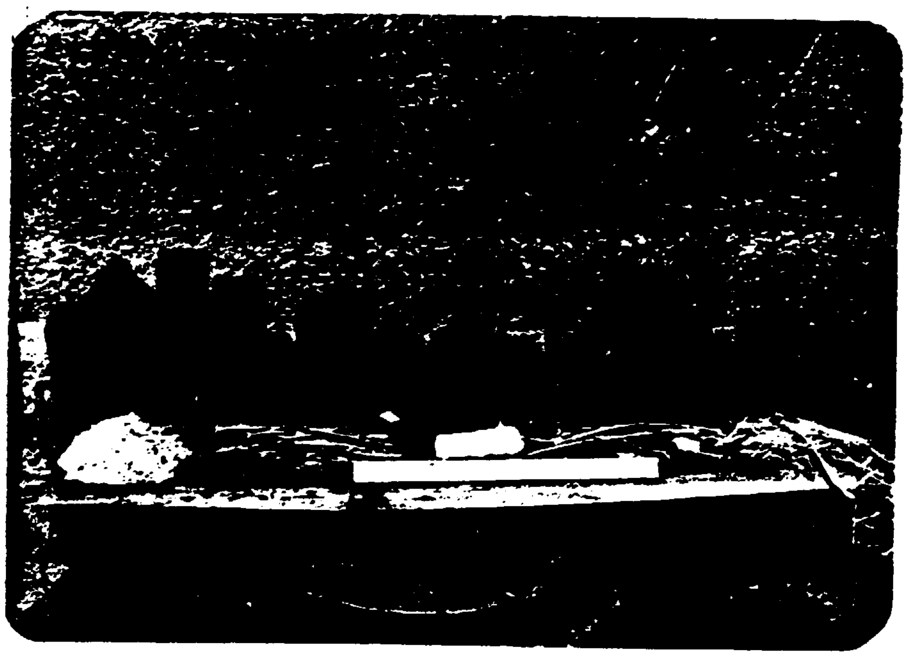
F) WITH AND WITHOUT LOGS FOR BRIQUETTING-EMPTY-TIN

(G) •PARU Fuel Briquettes Made From



L-R Coffee husk, Eucalyptus twigs corn cobs, twigs and Teff Straw in fore ground BENTONITE TRAY in Stones

(H) 'PARU' FUEL BRIQUETTES MADE FROM



L-R Coffee, husk, Eucalyptus twigs, Corn cobs, Twigs and Teff Straw

(J) FAREWELL TO CONSULTANT

Dr. K. VENCATACHELLUM, UNIDO

GHEBRU ENEC

GROVER I.I.T. Delhi