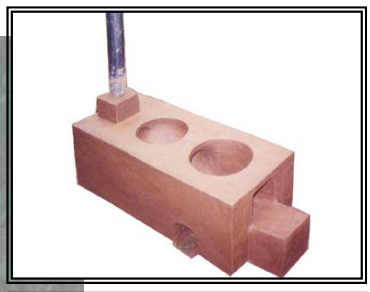
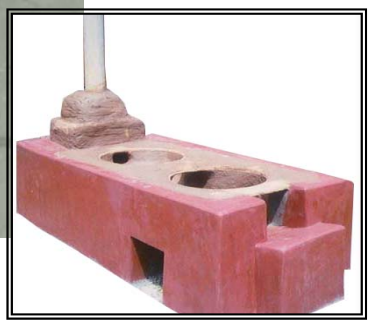
A Technical Manual of Improved Cooking Stoves





MARCH TOWARDS REDUCING INDOOR AIR POLLUTION(IAP)

2008

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LIST OF ACRONYMS

ARI	–	Acute Respiratory Infection
ARECOP	–	Asia Regional Cookstove Program
BCSIR	–	Bangladesh Council for Scientific and Industrial Research
BRDB	–	Bangladesh Rural Development Board
BRAC	–	Bangladesh Rural Advancement Committee
CEA	–	Country Environmental Analysis
CCT	–	Control Cooking Test
COPD	–	Chronic Obstructive Pulmonary Disease
DPHE	–	Department of Public Health Engineering
GDP	–	Gross Domestic Product
GHG	–	Greenhouse Gas
GOB	–	Government of Bangladesh
GTZ	–	German Technical Assistance
HEDON	–	Household Energy Network
ICS	–	Improved Cooking Stove
IAP	–	Indoor Air Pollution
IAQ	–	Indoor Air Quality
ICDDR,B	–	International Center for Diarrheal Diseases Research, Bangladesh
IFRD	–	Institute of Fuel Research & Development
KPT	–	Kitchen Performance Test
LGED	–	Local Government Engineering Department
M&E	–	Monitoring and Evaluation
MDG	–	Millennium Development Goal
M.S. Sheet	–	Mild Steel Sheet
NGO	–	Non-Governmental Organization
PRA	–	Participatory Rural Appraisal
PCIA	–	Partnership for Clean Indoor Air
PPM	–	Parts Per Million
REIN	–	Renewable Energy Information Network
IDCOL	–	Infrastructure Development Company Limited
VDP	–	Village Defense Party
VERC	–	Village Education Resource Center
WB	–	The World Bank
WHO	–	World Health Organization
WSG	–	Woodburing Stove Group

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Prologue

Under the World Bank project 'Bangladesh: Addressing Indoor Air Pollution (IAP)', an attempt has been made to develop a technical manual of Improved Cooking Stove technology to be used in a pilot project 'Mitigation of IAP in the rural area of Bangladesh' and for those who are interested. Seven models of ICSs have been selected for delineation in this technical manual. Participants from a number of organizations working on propagation of ICSs in Bangladesh brainstormed and selected the ICS models for discussion in the manual.

This manual briefly and precisely describes the kitchen systems, general designs and construction principles of the seven suitable ICS models with detailed drawings, pictures of components, raw materials required and step by step construction procedures.

The selected improved stoves suitable for domestic cooking to semi-industrial purposes were developed by Dr. A. M. Hasan Rashid Khan, Ex Director, BCSIR, a pioneer in the field and his colleagues at the Institute of Fuel Research and Development (IFRD), Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, Bangladesh. Dr. Hasan is currently working as the Project Manager of VERC-World Bank IAP Project. All the models discussed were developed through consulting users and basing on their opinions.

The dissemination of the ICS technology has been mainly progressing in the country through conducting training courses in construction, maintenance, repair and installation of improved stoves in the user's kitchen. Over a hundred large, medium and small NGOs and some donor agencies are engaged in dissemination of the ICS technology in the country. But due to lack of people's participation, proper coordination, leadership and suitable funding mechanisms, the quality control and actual quantities of ICSs disseminated in the country to date have not been possible to ascertain at this stage.

While constructing different models of ICSs, technicians/ICS experts are expected to keenly consider the procedures described in details in the manual. After completion of the construction of a particular stove, its dimensions should be checked with those of the corresponding model as mentioned in the manual. The manual also describes how to use, repair, maintain and manage troubleshooting of ICS models. Additionally, popular ICS models from South Asia, Latin America and Africa are also described herein with a view to familiarizing the Bangladeshi promoters and users of ICS technology with those of other countries across the world.

To say the least, this manual should be quite beneficial and useful for all the people involved in designing, making and dissemination of the ICS technology at all levels and especially for the users at the grass-roots level.

I take this opportunity to proffer thanks to Priti Kumar, Senior Environmental Specialist, Dr. M. Khaliquzzaman, Consultant and Jonathan Rouse, Consultant of the World Bank for supporting this initiative meaningfully. Thanks are specially due to Dr. A. M. Hasan Rashid Khan, the Project Manager, VERC-World Bank IAP Project and his team members for producing this technical manual.

I appreciate the constant guidance and supervision provided by Mr Yakub Hossain, Deputy Executive Director, VERC in making the implementation of this crucial undertaking possible.

Shaikh Abdul Halim
Executive Director
VERC.

13 May 2008
Savar, Dhaka

1. Introduction

More than one-third of the world's population living predominantly in the rural areas of developing countries use wood as a primary source of energy. It is the oldest type of fuel which man used for centuries to cook food, light and heat his home, manufacture metallic objects and generate mechanical power.

In Bangladesh, about 90% families use traditional fuels viz, fuel wood, charcoal, twigs and leaves, agricultural residues, viz. plant residues, paddy husk and bran, bagasse, jute sticks and dried animal dung for cooking and other heating purposes. The total annual consumption of these fuels stands at about 40 million tonnes [study1] which constitutes about 67.97% of the total energy consumption of the country. The remaining 32.03% energy is supplied from sources which may be described as commercial fuels, such as, gas, oil, electricity, LPG, coal etc. Of the traditional fuels, agricultural residues, tree branches, dry leaves, cow dung etc contribute to the tune of 33.71% of the total national figure, while woody fuels contribute about 34.26%.

In Bangladesh, a meagre 9% of the total land area is covered by Government managed forest and this is alarmingly decreasing because of the population growth and the mushrooming not too well planned industries. All these anthropogenic factors and some natural degeneration processes lead to fast depletion of forest resources, which, consequently effect adverse changes in the ecosystem leading to the erosion of the long prevalent climate regimes, eventually bringing about drastic changes in the climatic patterns of the country.

Only till some two or three decades back, farmers in this country used to leave a sizeable portion of the crop plants in the field after harvesting different agricultural crops. Those residues used to be left in the in the fields, which along with the cow dung generated there from the grazing cattle would decompose and mix naturally with the topsoil providing valuable organic manure to the farmland, readying it for tilling and farming throuth the ensuing season. But what's happening today is, the farmers do not leave any crop residues in the fields any more, they are used to cutting the ripened crop plants totally, without caring for fertilizing the soils naturally and traditionally, as both the agricultural residues and cow dung are used as cooking fuels in the rural areas and many are engaged in their trades. As a result, the agricultural lands are deprived of the essential natural fertilization in the process and therefore, solely depend on artificial, that is, chemical fertilizers for boosting production of crops. Thus the constitutions of the soils have been gradually changing, affecting the soils adversely to a considerable extent.

The common devices used for cooking and other heating purposes in the country are the three stone stoves, popularly known as traditional stoves. But efficiency of these stoves are

low (5-15%) compared with the volumes of fuels they use up, that is. As a result, huge amounts of traditional fuels are being consumed every year. Apart from low efficiency, such stoves also emit smoke which contain several poisonous elements viz. in particular, carbon monoxide, formaldehyde etc. which, due to incomplete combustion of fuels cause indoor air pollution (IAP) in the kitchen environment. In some studies [2-4], indoor air pollution levels of particulates in rural houses using biomass fueled cook stoves have been found to be as high as 10,000 µg/m^3, which is 50 times higher than the world health organization recommended permissible level of exposure Women and children are thus continuously exposed to high levels of harmful smoke which lead to serious health hazards. A number of scientific studies have reported higher incidences of chronic obstructive pulmonary diseases (COPD) and acute respiratory infection (ARI), low birth weight babies and cataract among women and children who are exposed to IAP of traditional fuels.

In the Institute of Fuel Research and Development (IFRD), BCSIR, a number of improved stoves have been developed to meet requirements in respect of biomass fuel types, shape of cooking utensils and cooking habits. The improvement was made by proper dimensioning of combustion chambers with a view to effecting maximum heat transfer to the utensils. All the models were developed through consulting users and basing on their opinions. After a particular model of ICS was developed in the laboratory, it was immediately installed in the user's kitchen. After a stipulated period considered adequate for obtaining significant feedback, user's opinions about the efficacy and efficiency of the particular model of stove were obtained, applied for modifying the existing model as necessary or, if necessary, newer models were developed subsequently [study 5].

The above mentioned models may be grouped into three categories:

I. IMPROVED COOKING STOVE WITH OUT CHIMNEY FOR DOMESTIC COOKING PURPOSES.
II. IMPROVED COOKING STOVE WITH CHIMNEY FOR BOTH DOMESTIC, LARGE SCALE COOKING AND SEMI INDUSTRIAL PURPOSES.
III. IMPROVED COOKING STOVE WITH WASTE HEAT UTILIZATION.

The ICS models have been found to be saving up to 50-60% fuels as compared with the traditional ones; they save cooking time too [6&7]. ICS with chimney have been found to be reducing IAP in the kitchen environment considerably.

If one learns the techniques of making ICS, he/she can build the stove without spending any money.

This manual describes seven specific ICS models with detailed drawings, components, materials used and the construction procedures. The manual will be quite useful for the

people involved in dissemination of ICS at different levels, supervisors, technicians, extension workers and of course, the users at the grass root level.

2. The Kitchen System

2.1 Traditional Stoves

Traditional stoves in Bangladesh are usually a mud-built cylinder with three raised upper ends on which cooking utensils rest. One of the three spaces in between these raised points is used as fuel gases feed hole and the other two for flue gases exits. These stoves may be built underground or over ground. In some cases, two stoves are joined together laterally using a single fuel feeding hole. These stoves cause unnecessary loss of heat for the following reasons:

a) These stoves are too deep, their depths ranging from 12 inches to 18 inches. Because of the large distance between the pot and fuel bed, heat transfer to the cooking pot is considerably reduced resulting in low efficiency.

b) Because of large size of the flue gases exits between the cooking pots and the stove, much of the flue gases get out of the stove without coming in contact with the cooking pot and thus lower convective heat transfer.

c) Since air cannot reach the bottom of the stove, considerable amount of cooking fuel accumulate at the bottom as charcoal. The efficiencies of these stoves vary from 5-15% depending on the depth of the stove and size of the flue gases exits.

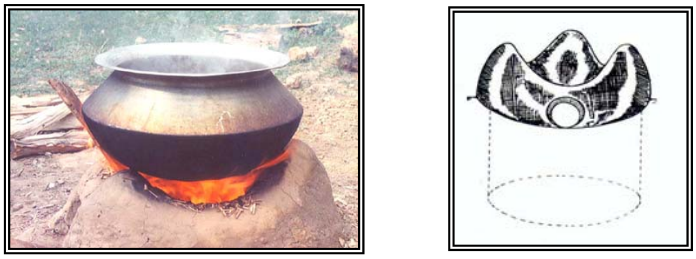


Fig. No.-1 : Traditional stove commonly used in the country.

2.2 Traditional Fuels:

Different types of fuels, which are generally used in the traditional stoves are: fuel wood, twigs, leaves, straw, rice husk, cow dung in the form of dry cakes, jute stick, bagasse and agricultural residues.

2.3 Utensils:

There are two types of cooking utensils used viz. flat bottomed and round bottomed ones. Round bottom utensils are more efficient than flat bottom utensils because a greater part of the utensil's bottom remains in direct contact with the flame. As a result, more of the

content is heated at a time. Round bottom utensils are popularly used for domestic cooking. But in hostels, hotels, camps, where large amounts of food stuffs have to be cooked, the flat bottom utensils are commonly used. In the villages, the poorer section of people generally used utensils made of burnt clay.

2.4 Cooking Process:

The majority of the people of Bangladesh eat rice, fish, pulse (dal), potato, vegetables, meat, chicken etc. All these food stuffs are cooked in water by boiling. Apart from these foods, wheat is also taken as a food by making chapati, paratha, luchi etc using wheat flour. During the winter season, most of the women in villages cook their food outside their houses i.e in the open place in their yard using straw, leaves and agricultural residues as fuels which are abundantly available at the time. They make the stove by simply digging a hole in the ground. While cooking, women generally sit in front of the stove on a block of wood called "pirhi", holding a staff in their hand, which is used for pushing the leaves, straw etc. into the stove. During the rest of the year, they cook their food inside the house. The rich people always cook their food in a kitchen and they mainly use fuel wood, bamboo, cow dung dry cake, rice husk etc. as fuel.

3. Improved Cooking Stoves (ICS)

3.1 What is ICS?

ICSs are those traditional stoves which upon some modification/alternation/addition yield higher efficiencies when compared with the unmodified ones.

❖ Salient Features of an ICS :

a) An ICS is an improved version of the traditional stove having higher fuel efficiency compared with the traditional ones.
b) An ICS has a grate in the middle of its combustion chamber and fuel burns on it.
c) There is entry of primary air in an ICS below the grate which helps burning of charcoal formed during burning of fuel wood.
d) The three raised ends of a chimneyless ICS are much smaller than those of the traditional stoves.
e) In case of multiple mouth ICSs with chimneys, cooking in the first mouth is done by direct flame produced from fuel, while cooking in the other mouths are done by hot flue gases coming out from the first mouth and the spent flue gases are led out of the kitchen through a chimney

3.2 Benefits of ICSs:

1. Reduce indoor air pollution (IAP) and thereby check health hazards of the users.
2. Save 50-60% of the traditional fuels used.
3. Reduce CO_2 emission in the atmosphere and thereby reduce the green house effects.
4. Maintain proper nutritive values of the cooked food.
5. Cause less blacking of utensils.
6. Reduce cooking time as compared with the traditional ones.
7. Cause less fire hazards.
8. Help conserve the forest resources of the country.

3.3 Scope for use of ICSs:

- An ICS is suitable for both domestic cooking and large scale cooking in hostels, hotels, hospital, army camp, orphanages etc.
- An ICS can be easily designed to suit the needs of any type of semi industrial setup where fuel wood/other traditional fuels are used for heating purposes.

3.4 Raw Materials for Construction of ICS:

The main raw materials for making an ICS are as follows:

I. Mud/clay (Adhesive):

Fine potter's clay is most suitable for construction of ICSs. With too much clay used, the stove body shrinks unevenly and develops cracks as it dries. In such cases, it is necessary to add small portions of sand. Clay binds the sand grains tightly together and sand also prevents the clay from shrinking during drying. Organic matter viz leaves, twigs, other sandy things create problems. Therefore, it is better to collect subsoil from a pit which may be dug down to 12-18 inches beneath the surface. First by removing the top soil, required amount of clay has to be collected, required amount of water added to the clay, cow dung/rice husk mixed with the clay lump and thus a paste prepared, which should be pliable enough to be easily spread with a shovel, and at the same time, hard enough to stay erect and not slither limply.

2) Pieces of pottery / "U" shaped iron rods:

- Pieces of pottery are necessary for making the hedge in the ICS, which will hold the grate.
- Six inches long iron rods bent into a "U" shaped implement. 3-4 of these "U" shaped iron rods are embedded into the inner wall of the stove for holding the grate.

3) Pieces of Bamboo:

Some pieces of bamboo, 6-8 inches long and of 1inch width are necessary for making hedges in the different parts in an ICS. Iron rods also can be used instead of bamboo pieces.

3.5 Tools/Equipment required for construction of ICSs:

During construction of an ICS, the following tools and equipment are required and should therefore be kept at hand:

1. Dice/ Mold
2. Scale/Measuring tape
3. Spade
4. Knife
5. Mason's tools etc

Dice/ Mold:

This is necessary for construction of an ICS body for domestic purposes. It is round shaped having 9 inches diameter and 18 inches height. Both top and bottom portions of it are open. The dice has two rings at the top. Banana trees can also be alternatively used for making such dices.

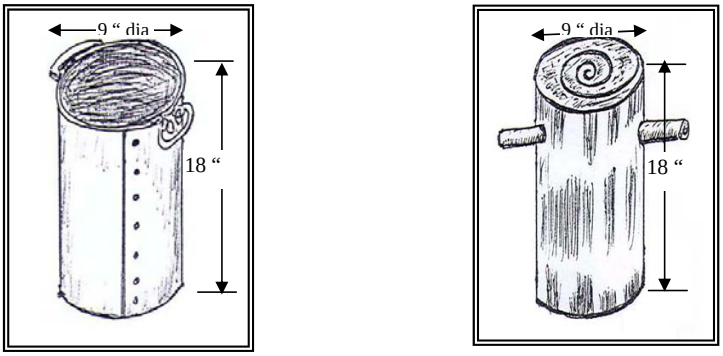


Fig.No. 2 a) Dice made of M.S. sheet b) Dice made of banana tree

3.6 Different parts of an ICS :

An ICS consists of different parts, which are as follows:

1. Structure
2. Grate
3. Chimney
4. Cap

1. Structure:

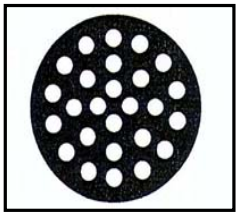
The construction procedures of structures of different models of ICS are given in details in the section "Design construction procedure of different models of ICS" page No 15 of this manual.

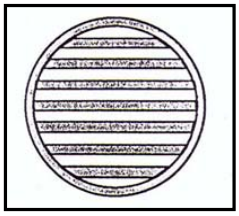
2. Grate:

The traditional fuels commonly burn on the grate. But the main reasons for using the grate are as follows:

- It maintains the optimum distance required for rightly training the flame to heat the bottom of the utensil.
- It allows primary air through its hole at the bottom to facilitate burning the charcoal formed because of burning of fuel.
- The ash generated fall down through holes of the grate.

The grate is circular in shape. It is generally made from cast iron and iron rod. The diameter of the grate is one inch less than the diameter of the mouth of the ICS.





a. Grate made of cast iron /M.S. sheet dia of hole is 0.5 inch and distance between two holes is 0.5 inch	b. Grate made of iron rods and distance between two rods is 0.5 inch

Fig.No.3 Grate used in ICS.

3. Chimney:

The chimney provides necessary draught to draw the air into the combustion chamber and to overcome the various flow resistances in the stove and finally lead out the spent flue gases out of the kitchen.

The chimney should be taken out through the roof, up to at least 2-3 feet above the roof which is very essential in case of thatched roofed cookhouses. So the height of the chimney is variable, depending on the height of the kitchen roof.

Proper insulation should be ensured between the chimney and the roof, specially when it is thatched. This can be done by placing another cylindrical piece of tin or clay of larger

diameter around the chimney and by filling the gap between the two with clay and other insulating materials.

Bends in chimney should be avoided because it creates a pressure loss and some time flame and hot flue gases come out through the feed hole. However, in unavoidable conditions, a bend may be given but it should be made as smooth as possible.

In case of a thatched roof cooking corner, it is wise to fixed the chimney outside the kitchen by making a hole in the wall. Make a chimney holder on a platform outside the kitchen and then instal the chimney on it. The chimney can be supported by posting a bamboo pole next to the chimney, as convenient.

There are three types of chimneys, which can be used in an ICS. They are as follows:

1. Chimney made of mud
2. Chimney made by potters
3. Chimney made of cement, sand and iron ring.

1. Chimney made of mud:

A bamboo staff measuring 5-6 ft in height and 3 inches diameter has to be posted next to the chimney holder of ICS. Now, rinse an M. S. sheet pipe/bamboo staff of 3.5 inches diameter and 3 ft height with water and place it in the chimney holder. Next, pack mud around the smaller piece of M. S. sheet pipe/bamboo staff and make a mud chimney of about one feet height. Now, mould the chimney wall uniformly around the pipe and after a while, the pipe will have to be removed by slightly twisting it loose out of the mud chimney.

Wait till a day has passed and the next day should see you placing the M. S. pipe on the top of the mud chimney and making another one feet chimney in the same manner as done on the previous day. In this manner, within a time span of 5-6 days, a mud chimney of the desired, that is, required height can be made.

2. Chimney made by potters:

Chimneys may be made by potters too. In this case, a chimney will consist of 2-3 parts. When in use, one part of the chimney has to be connected with another part and supported by a fixing bamboo pole posted next to the chimney.

3. Chimney made of cement, sand and iron ring:

For longer durability, chimneys may also be made using cement, sand and iron rings. There are some entrepreneurs across the country who have developed designs of chimneys

which can be manufactured using different components of sanitary latrine. In some areas, where ICS technology is under implementation, the local entrepreneurs are also producing chimneys made of cement and components of sanitary latrine.

4. Cap:

A cap is provided at the top of the chimney to stop rainwater entering it. It may be made with a metal sheet and the cap has three metal strips to fix it on the top of the chimney. The cap has to be fixed on to the top of the chimney in such a way that there should be enough space between the cap and the chimney top so that the smoke doesn't get trapped within the chimney and can easily exit.

5. The Lid for Ash outlets:

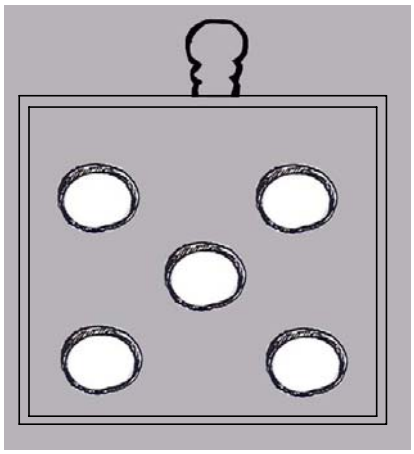


Fig.No.4 Lid used for ICS:

The ash outlet lid can be a square mud plate of one inch thickness. On this plate, 5-6 holes of one inch diameter have to be made which should be slightly bigger than the hole of the ash outlet. A holder has to attached at the top of the plate. When food being cooked in an ICS reaches boiling point, the ash outlet/outlets are covered with this perforated lid. This will control the entry of primary air in the combustion chamber of the stove and the fuel will be burnt for a longer period, as necessary. This lid can be also made using M. S. sheet.

3.7 Efficiency and Fuel Saving Measurements

- **Efficiency Measurements:**

The efficiency of the stove is defined as the ratio of the nett amount of heat absorbed by the water in the utensil and the amount of sensible heat supplied by the fuel [11].

The efficiency of a cooking stove is generally determined by the water evaporation method. It is measured by heating a certain amount of water in a utensil using specific amount of fuel wood. The standard equation followed for this purpose is as follows:

$$\eta = \frac{m_w C (Tb-Ti)+m_s L}{m_f H} \times 100\% \quad \text{..... (i)}$$

Where,

η	= efficiency (*thermal*)	%
m_w	= mass of water in the utensil at the start of an experiment	(kg)
m_s	= mass of water evaporated from the utensil during an experiment	(kg)
m_f	= total mass of fuel consumed during an experiment	(kg)
C	= specific heat of water	(kJ/ kg.K)
T_i	= temperature of water of the utensil at the start of an experiment.	(^{0}C)
T_b	= boiling point of water	(^{0}C)
L	= **heat** of vaporization of water at atmospheric pressure and at 100^{o}C.	(kJ / kg)
H	= nett calorific value of fuel	(kJ/ kg)

In calculating the efficiency, the following numerical values were used:

C	=	4.19	: kJ / kg.K
L	=	2,257	: kJ / kg
H	=	17,447 (*Mango tree*)	: kJ / kg

Example: Efficiency calculation of Improved Double Mouth Cooking Stove with Chimney (*on the floor*)

- Take 3 kg of water in each of two identical utensils and place them on the stove.
- Next, burn 1.5kg of fuel wood in the stove and evaporate some water from the utensils.
- After the experiment in over, put the necessary data in the equation and then calculate the efficiency of the stove.

- **Fuel Saving Measurement (*CCT*):**

It provides the user with an excellent visual appreciation of an ICS as compared with a traditional stove.

Example: Cooking Test in Improved Double Mouth Cooking Stove with Chimney (*on the floor*).

- Four samples of rice, each containing 704 gms of rice and 3 kgs of water are to be put into four identical utensils.
- Now, rice has cooked in two utensils on a traditional stove, one after another.
- The other two samples of rice will have to be cooked in two other utensils on the improved double mouth stove at a time.

- Measure the amount fuel consumed and time required for cooking rice in traditional and improved stoves.
- Now calculate the fuel and time saved while cooking on the improved stove and compare with the same results recorded while cooking using the traditional stove and the benefits of using the ICS will be strikingly clear.

3.8. Rationale for Selection of ICS Models:

The entire cooking system viz traditional stoves, fuels, utensils and the cooking processes including cooking habits of the women folk of the country have been discussed in section no. 2.0 of this manual.

To identify the most acceptable ICS models which are now being used in the community, a sharing meeting was held on February 20, 2008 at VERC Office, Savar, Dhaka.

About 25 participants from different organizations viz. BCSIR, LGED, ICDDR B, GTZ, Grameen Shakti, Practical Action Bangladesh, Shwanirvar Bangladesh, BRAC, Concern World Wide, Winrock International, VERC, Private Entrepreneurs etc. attended the sharing meeting.

All participants explained their experiences in dissemination of the ICS technology in the country. After brain storming discussion the following models of ICSs have been selected for the technical manual largely based on consumer preference as perceived by the participants [13]

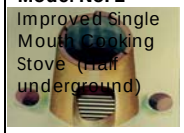
Table No. 1: Selection of ICS Models for Technical Manual

SL.NO	Name of the ICS Models	Reasons for Users Preference
1.	Model No.1 Improved Single Mouth Cooking Stove (*Portable)*	• Portable • Saves fuel • Can be used indoor-outdoor • Low cost
2.	Model No.2 Improved Single Mouth Cooking Stove (*Half underground*)	• All types of traditional fuels can be used • Save fuels • Low cost
3.	Model No.3 Improved Double Mouth Cooking Stove with Chimney (*on the floor*)	• Most suitable for rich and middle class families who use fuel wood, briquettes etc. solid fuels • Saves fuels • Saves cooking time • Reduces IAP in the kitchen environment
4.	Model No.4 Improved Double Mouth Cooking Stove with Chimney (*Half underground*)	• All types of traditional fuels can be used • Saves fuels • Saves cooking time • Reduces IAP in the kitchen environment
5.	Model No.5 Improved Single Mouth Cooking Stove with Chimney(*Portable*)	• Portable • Saves fuel • Can be used indoor/outdoor • Low cost • Reduces IAP at cooking place partially

SL.NO	Name of the ICS Models	Reasons for Users Preference
6	Model No.6 Improved Double Mouth Cooking Stove Couple with Single Mouth Cooking Stove having one common Chimney	• Most suitable for rich and middle class families who use fuel wood, briquettes etc. solid fuels • Saves fuels • Saves cooking time • Reduces IAP in the kitchen environment • In times of need, either of the stoves can be used
7	Model No.7 Improved Double Mouth Cooking Stove with Chimney for Large Scale Cooking and Semi Industrial Purposes	• Most suitable for cooking in hotels, restaurants, hostels etc. • Saves fuels • Saves cooking time • Reduces IAP in the kitchen environment

These models have gained popularity among the users in different parts of the country because, they save fuel and cooking time, reduce IAP in the kitchen environment, easy and comfortable to use and the construction costs of different models are reasonable. The advantages and disadvantages of different types of ICS models are given in *Table No: 2.*

3.9 Table No-1: Advantages & Disadvantages of Different Types of ICS Models

SL No	Name of the ICS Models	ADVANTAGES								DISADVANT-AGES
		Features of ICS Models	Types of Traditional fuels used	Ease of Construction	Raw Materials Used & Life Time	Socio-Cultural Practices	Role IAP	Fuel Saving (%)	Cost of ICS Models (TK.)	
1	2	3	4	5	6	7	8	9	10	11
1.	**Model No. 1** Improved Single Mouth Cooking Stove (Portable) 	▪ Portable ▪ Suitable for 8 member family ▪ Suitable for use during natural calamities viz floods, in camp/ boat etc	- Fuel wood, branches, cow dung cake, briquettes etc. solid fuels	▪ can be easily built ▪ low cost	▪ Clay ▪ Pieces of pottery or ▪ Metal grate *Locally available raw materials* 2 years	▪ Can be used indoor and out door according to the cooking habits of the users	▪ Slightly reduced IAP in the kitchen	50	200.00	▪ All types of traditional fuels can not be used ▪ During transportation from one place to another it may break ▪ Emits smaller amount of smoke and heat inside the kitchen
2.	**Model No. 2** Improved Single Mouth Cooking Stove (Half underground) 	▪ Fixed ▪ Suitable for 8 members family	- All types of trad. fuels including agricultural residues by changing the grate	▪ can be easily built ▪ low cost	▪ Clay ▪ Pieces of pottery or ▪ Metal grate *Locally available raw materials* 1 years	▪ Can be used where it was built according to the cooking habits of the users	▪ Slightly reduced IAP in the kitchen	45-50	200.00	▪ It is a fixed stove ▪ During cooking constant caring is needed ▪ Emits smaller amount of smoke and heat inside the kitchen
3.	**Model No. 3** Improved Double Mouth Cooking Stove with Chimney (on the floor) 	▪ Fixed ▪ Suitable for 8 members family ▪ Can be built on a raised platform for cooking by standing	- Fuel wood, branches , cow dung cake, briquettes etc. solid fuels	▪ Should be built by skill technicians ▪ Feed hole can be built either side or in the front side of the combustion chamber	▪ Clay ▪ Pieces of pottery or ▪ "U" shaped iron rods. ▪ 8 inches long bamboo pieces ▪ Metal grate ▪ Chimney ▪ Cap *Locally available raw materials* 2-3 years	▪ Can be used where it was built according to the cooking habits of the users	▪ Greatly reduced IAP in the kitchen	60	600.00	▪ It is a fixed stove ▪ All type of traditional fuels can not be used ▪ Require regular maintenances, at least once in a month ▪ Every dimensions of stove should be strictly maintained
4.	**Model No. 5** Improved Single Mouth Cooking Stove with Chimney (Portable) 	▪ Portable ▪ Suitable for 8 member family ▪ can be built fixed or half under graund	▪ Fuel wood, branches , cow dung cake , briquettes etc. solid fuels	▪ Should be built by skill technicians	▪ Clay ▪ Pieces of pottery or ▪ "U" shaped iron rods ▪ 8 inches long bamboo pieces ▪ Metal grate ▪ Chimney ▪ Cap	▪ Can be used indoor & out door according to the cooking habits the users	▪ Greatly reduced IAP in the cooking environment	50-55	400.00	▪ All types trad. fuels ca not be use ▪ During transportation from one place to another may break & chimney should be disconnected from the stove ▪ Still emits smaller amount of smoke & heat inside the kitchen

... [1]

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SL No	Name of the ICS Models	ADVANTAGES								DISADVANT-AGES
		Features of ICS Models	Types of Traditional fuels used	Ease of Construction	Raw Materials Used & Life Time	Socio-Cultural Practices	Role IAP	Fuel Saving (%)	Cost of ICS Models (TK.)	
1	2	3	4	5	6	7	8	9	10	11
					Locally available raw materials 2 years					
5.	**Model No. 6** Improved Double Mouth Cooking Stove Coupled with Single Mouth Cooking Stove having one Common Chimney common chimney 	▪ Fixed ▪ Suitable for (7-8) member family ▪ Can be built half under ground	- Fuel wood, branches , cow dung cake, briquettes etc. solid fuels	▪ Should be built by skill technicians ▪ Feed hole can be built either side or in the front of the combustion chamber	▪ Clay ▪ Pieces of pottery or ▪ U shaped iron rods ▪ 8 inches long bamboo pieces ▪ Metal grate ▪ Chimney ▪ Cap *Locally available raw materials* 2-3 years	▪ Can be used where it was built according to the cooking habits of the users	▪ Greatly reduced IAP in the kitchen		750.00	▪ It is fixed stove ▪ All type of trad. fuels can not be used ▪ Require regular maintenance at least once in a month ▪ Every dimensions of stove should be strictly maintained ▪ Require more space for installation of the stove in the kitchen ▪ when both the stove are functioning require constant caring for charging of fuel
6.	**Model No. 7** Improved Double Mouth Cooking Stove with Chimney Suitable for Large Scale Cooking and Semi Industrial Purposes 	▪ Fixed ▪ Suitable for 50 members in hostels, hotels etc.	Fuel wood, branches , cow dung cake, briquettes etc. solid fuel	▪ Should be built by skill technicians ▪ Feed hole can be built either side or in the front of the combustion chamber	▪ Clay ▪ Bricks, cement and sand ▪ U shaped iron rods, rods & Iron ring ▪ Metal grate ▪ Chimney ▪ Cap ▪ Red oxide 3-4 years	▪ Cooking can be done by standing	▪ Greatly reduced IAP in the kitchen	60	4500.00 - 5000.00	▪ It is fixed stove ▪ Agricultural residues and other fluffy fuels can not be used ▪ Require regular maintenance at least once in a month ▪ Every dimensions of stove should be strictly maintained

4. Design and Construction Procedures of Different Models of ICS [5-16]

4.1 Site and ICS Model Selection:

There are different types of ICS models. The users will select the models according to their needs. The proper selection of place inside the kitchen for installation of the stove is also very important. Therefore, the womenfolk who spend most of their time in the kitchen should be fully consulted for selection of the most suitable ICS model and the right place inside the kitchen for installation of stove. Both tasks depend upon the arrangements inside the kitchen, type of fuel used, way of cooking etc. Before finalizing the selection of ICS model and place for its installation, please make sure:

1. To determine the type of traditional fuel the particular beneficiary uses.
2. That the user's sitting position will be easy and comfortable for cooking. Some users sit in front of the stove when cooking, while others do so by sitting on a side.
3. That the cook will be able to reach for all required cooking utensils and other necessary things while cooking.
4. During winter, other family members may prefer to sit around the stove. So there should be some space around the stove.
5. After selecting the place for stove installation, it will be easily possible to install the chimney either by making a hole through the roof or alternatively, by putting it up outside and connecting it to the stove through a hole in the wall.

ICS Layout:

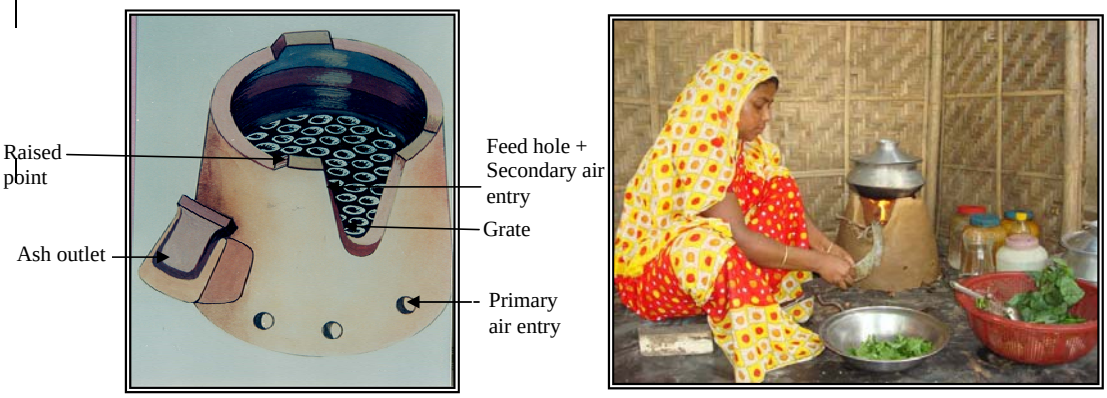
Before ICS construction and installation begin, the overall dimensions, utensil shapes and sizes and other design features must be laid out. A plan of the ICS model can be drawn out on the floor where installation will take place.

Attention!

The dimensions of all the ICS models were standardized by the scientists at BCSIR who are pursuing R & D activities on both renewable and non renewable sources of energy and allied fields. During construction of ICS, their dimensions should not be changed without consulting the ICS

4.2 Model No.1: Improved Single Mouth Cooking Stove (*Portable*)

- **MODEL DEVELOPED BY** : BCSIR, DECEMBER 1982
- **TYPE OF FUEL USED** : Suitable for burning fuel wood, branches, cow dung cake, briquettes etc.
- **PRICE** : TK.200.00
- **FUEL SAVING** : 50% as compared with traditional stove.
- **EFFICIENCY** : 25%
- **SEASONALITY** : Round the year



A. Model **B. Model on use**

Fig.No.5: Improved Single Mouth Cooking Stove (*Portable*)

1) Different Parts of the model:

a) Structure
b) Grate
c) Lid for covering the ash outlet.

2) Dimensions of the model:

a) Mouth diameter : 9 inches
b) Feed hole : U type,4.6X4.0 inches
c) Distance between grate and raised points : 6 inches
d) Height of the raised points : 0.5 inches
e) Ash outlet : 3X3 inches
f) Entry of primary air hole diameter : 0.5 inches (7-8 nos. holes)
g) Height of the stove : 12 inches

3) Procedure for construction:

a) A circular mud plate having 13 inches diameter and one inch height is made on the floor of a suitable corner of the cookhouse or cooking place. A dice rinsed with water has to be placed next on the circular mud plate.

b) Now, a structure having 13 inches height and 0.75 inch thickness is to be made by packing and moulding mud around the dice. Make sure that the thickness of the mud wall is about 0.75 inch around the dice.

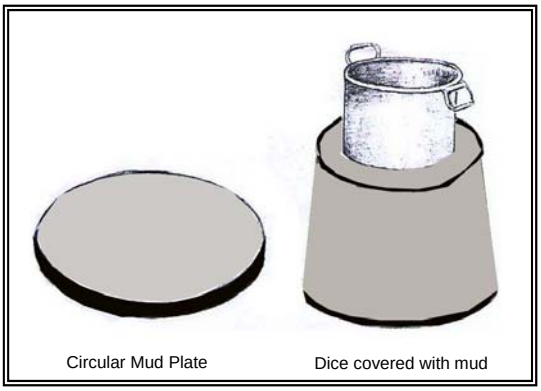


Fig.No: 6 First Stage: Construction of Improved Single Mouth Cooking Stove (Portable)

c) After a while, the dice is to be removed by slightly twisting it free out of the circular mud plate. Leave the structure for 1-2 days to allow it to drying up to an extent.

d) After drying, a hedge is to be made at 6.5 inches below from the top of the mouth to hold the grate. The hedge is made by inserting broken pieces of earthen pot in the inner wall of the mouth and it is then covered with mud.

e) On the top of the structure on one side, a fuel feed hole for fuel having (4.5 x 4.0) inches has now to be made by cutting the mud wall, as required. Extend the feed hole about two inches towards outside by inserting pieces of pottery and then cover it with mud for holding the fuel.

f) Now, make the three raised points each measuring 1.75 inches in length and 0.5 inch in height at the top of the structure for supporting the cooking utensil.

g) An ash outlet measuring 3X3 inches and 7-8 nos. holes of half inch diameter have to be made in the wall of the stove just below the grate for entry of primary air for better burning of the fuel. After smoothening the stove with wet mud, leave it for 5-6 days for drying. When the stove dries up completely, it will be then be ready for use.

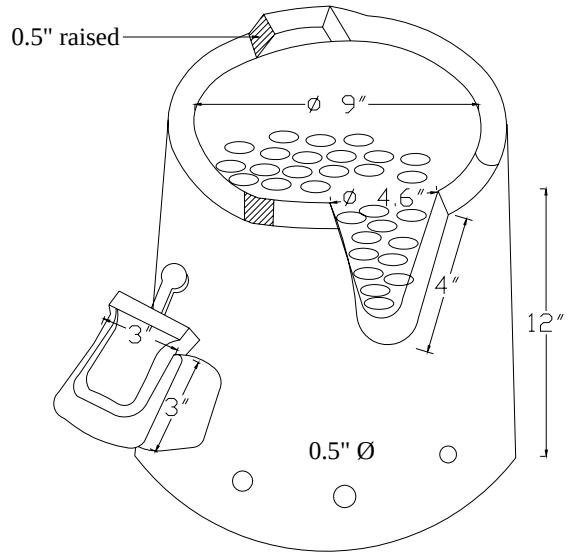


Fig.No.7. Improved Single Mouth Cooking Stove (*Portable*) showing its different dimensions

This Model is slightly modified by Practical Action and ICS Technicians:

Modification:

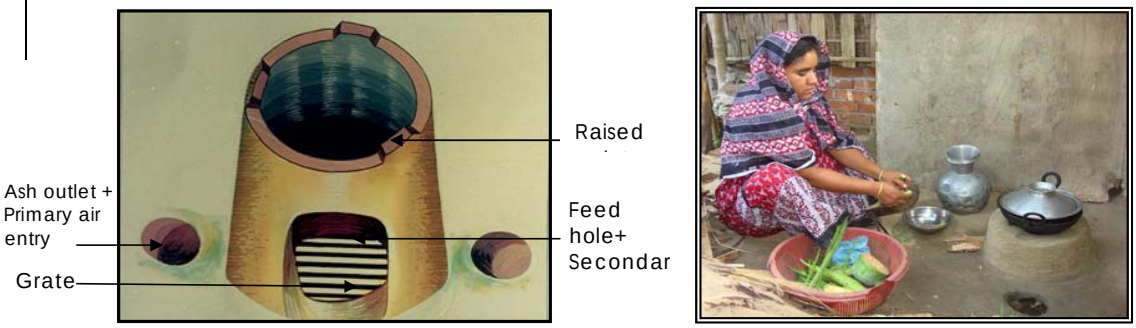
- *Instead of one ash outlet and 7-8 holes for entry of primary air, they added two ash outlets on both sides of the stoves having same dimensions. But the efficiency is the same.*

Reason for modification:

- *It is easy to carry the stove from one place to another by holding it by its two ash outlets.*
- *During maintenance by smoothening with mud, the size of holes became smaller, which reduced the entry of primary air in the combustion chamber*

4.3 Model No.2: Improved Single Mouth Cooking Stove (*Half underground*)

- **MODEL DEVELOPED BY** : BCSIR 1983
- **TYPE OF FUEL USED** : Suitable for burning fuel wood, branches, cow dung, briquettes and fluffy fuel viz, straw, leaves, bagasse etc.
- **PRICE** : TK.200.00
- **FUEL SAVING** : 45-50% as compared with traditional stoves.
- **EFFICIENCY** : 22%
- **SEASONALITY** for use : If the model is installed outside, then also it is suitable only in the dry season
- **LIFE TIME** : 1 years



A. Model **B. Model on use**

Fig.No.8. Improved Single Mouth Cooking Stove (*Half underground*)

1) Different parts of the model:

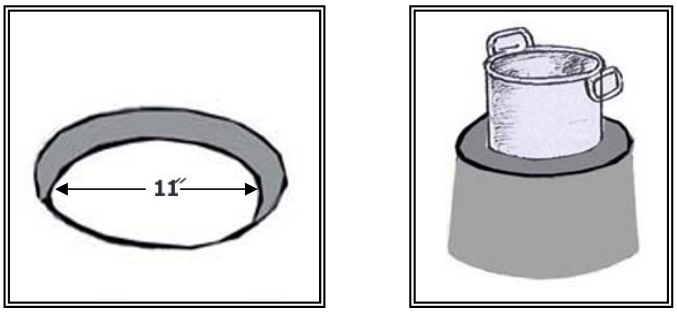
d) Structure
e) Grate
f) Two perforated lids for covering the ash outlets.

2) Dimension of the model:

a) Mouth diameter : 9 inches
b) Feed hole : 5X5 inches
c) Distance between grate and raised points : 9.5 inches
d) Height of the raised points : 0.5 inch
e) Ash outlet and primary air entry way : 5 inches
f) Height of the stove from the G.L : 9 inches

3) Procedure for Construction:

a) A hole measuring 11 inches diameter and 9 inches depth is to be made by digging the ground at a suitable place where the stove will be installed. Wet the hole with water. A dice rinsed in water is then placed in the hole. The side of the lower portion of the dice is then packed with wet mud. Now the dice will have to be lifted up to 5 inches by slowly and carefully twisting it upwards.



a b

Fig.No.9.Improved Single Mouth Cooking Stove (*Half underground*)
a. 1st stage b. 2nd stage during constriction

b) A structure measuring 9 inches in height is then made by putting mud around the dice. The thickness of the mud wall will have to be about 0.75 inch around the dice. Now leave the structure for 1-2 days for drying up partially.

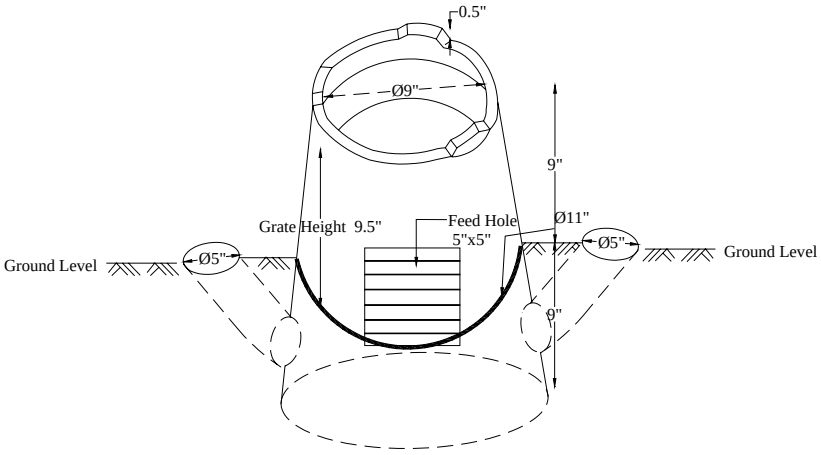


Fig.No.10.Improved Single Mouth Cooking Stove (*Half underground*) showing different dimensions of the Stove.

c) After partial drying of the structure, a hedge is made at 10 inches down from the top of the mouth, which will hold the grate. The hedge is made by inserting pieces of pottery in the inner wall of the mouth and then it has to be covered with mud.

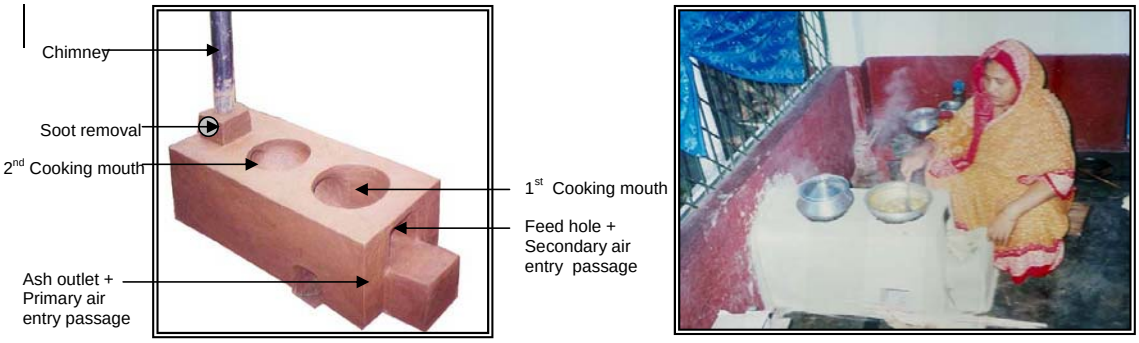
d) On the bottom of the structure, a 5 inches X 5 inches feed hole has to be made for fuel charging by cutting the mud wall on one side.

e) Three raised points each measuring 0.75 inch in length and 0.5 inch in height have to be made at the top of the structure, which will support the cooking pot or utensil.

f) Two ash outlets, each measuring 5 inches in diameter are made on the two sides of the feed holes with slopes and passing below the grate. These holes will also act as passages for entry of primary air into the stove. Finally, the stove surface is smoothened with mud and left for 5-6 days allowing it to dry up completely. When the stove is dried up perfectly, it is then ready for use.

4.4 Model No. 3: Improved Double Mouth Cooking Stove with Chimney *(on the floor)*

- **MODEL DEVELOPED BY** : BCSIR 1984
- **TYPE OF FUEL USED** : Suitable for burning fuel wood, branches, cow dung cake, briquettes etc.
- **PRICE** : TK.600.00
- **FUEL SAVING** : 60% as compared with traditional stove.
- **EFFICIENCY** : 28-30%
- **SEASONALITY** : Round the year
- **LIFE TIME** : 2-3 years



A. Model **B. Model on use**

Figure No: 11 Double Mouth Cooking Stove with Chimney (on the floor)

1) Different parts of the model

a) Structure
b) Grate
c) Chimney
d) Cap
e) Lid for covering the ash outlet.

2) Dimension of the model:

a) Mouths (diameter) : First mouth: 9 inches and second mouth: 8 inches.

b) Distance between two mouths : 3 inches

c) Feed hole : Length 5 inches x width 5 inches

d) Distance between grate and the top of the mouth : 8.5 inches

e) Ash outlets/primary air entry passage : Length 5 inches x width 5 inches

f) Entry way from first mouth to second mouth : 7.0X4.5 inches

g) Open space left after placing the utensil on the second mouth : 2.5 inches

h) Diameter of the flue gases exit in the second mouth : 2 inches

i) Tunnel from second mouth to chimney holder : Length 6.0 inches x width 3 inches x height 3 inches

j) Chimney holder : Length 5 inches x width 5 inches x height 10 inches

k) Height and diameter of the chimney : 6-9 feet and 3 inches

l) The distance between the chimney and cap : 4 inches

m) Soot removal outlet at the bottom of the chimney : Length 3 inches x width 3 inches

n) Height of the stove : 15 inches

iii) Procedure for construction

a) Two dices of 9 and 8 inches diameter are placed one after another, where the ICS will be installed. The distance between the two dices should be 3 inches. Before placing the dices, they should be rinsed in water.

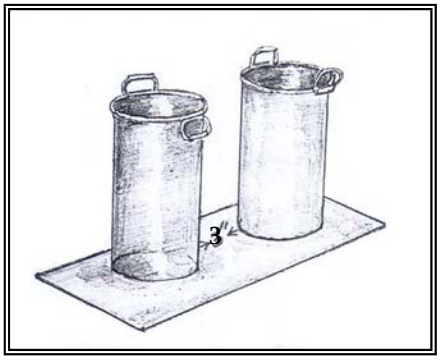


Figure No: 12 1st Stage: Construction of Double Mouth Cooking Stove (on the floor)

b) A rectangular mud platform measuring 36 inches long x 17 inches wide x 15 inches high is made by putting mud around the two dice.

Figure No: 13 2nd Stage: Construction of Double Mouth Cooking Stove (on the floor)

c) After a while, both dices are removed from the mud platform by slowly and carefully twisting them from right to left.

d) It is then allowed to dry for 1-2 days. After partial drying, a hedge is made down into the first mouth at 9.0 inches below from the top, which will hold the grate. The hedge is made by inserting pieces of pottery in the inner wall of the first mouth and then covered the same with mud.

e) A feed hole for fuel charging measuring 5x5 inches is made 1.5 inches below from top of the first mouth as in Fig.14. Then just below the grate on the both sides of the first mouth, two ash outlets/primary air entry passages measuring 5x5 inches are made.

f) Then an entry way for flame and hot gases from the first mouth to the second measuring 7.0X4.5 inches is made just above the grate on the common or partition wall of the two mouths. After that, the second mouth is partially filled up with mud and a slant is made from the grate to the second mouth. A flue gases exit of 2.0 inches diameter is made at a point just one inch below from the top of the second mouth.

g) A flue gases tunnel measuring 6 inches in length x 3 inches in width x 3 inches in height is made to reach from the second mouth up to the chimney holder.

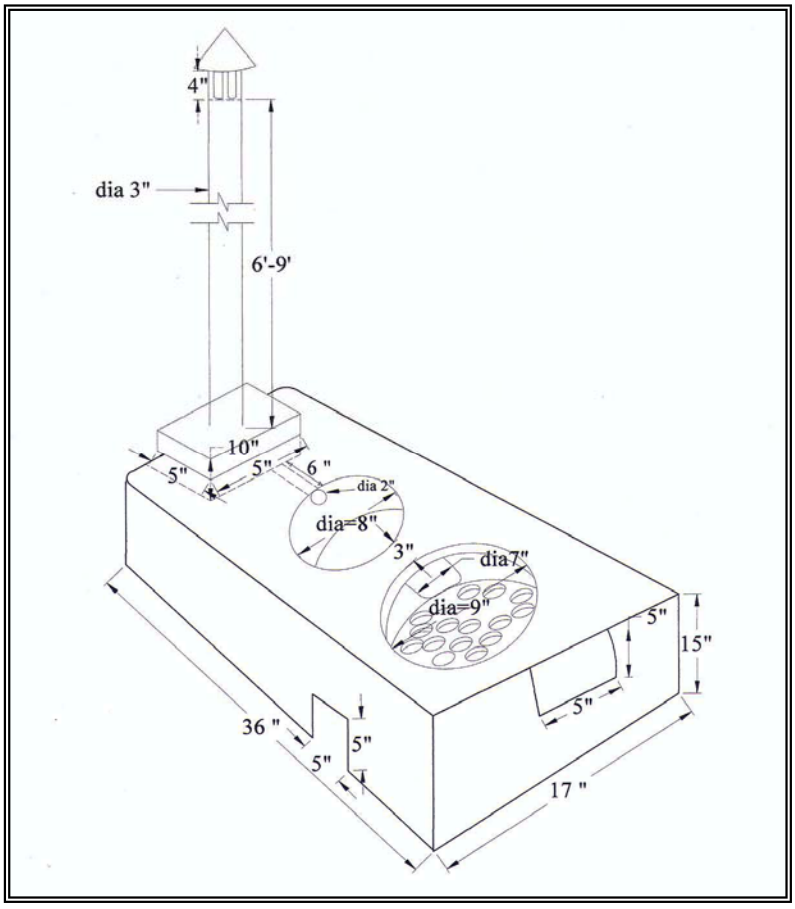


Figure No: 14 Double Mouth Cooking Stove with Chimney (*on the floor*) showing different dimensions of the stove

h) For placement of the chimney at the end of the second mouth, a space measuring 5 inches long x 5 inches wide x 10 inches high is made. At the top of the space, two equal sized bricks are so placed that there is a gap of 3 inches left between the bricks. On top of the two bricks, a chimney of 6-9 feet in length and 3 inches diameter is placed. The bottom of the chimney is then covered with mud.

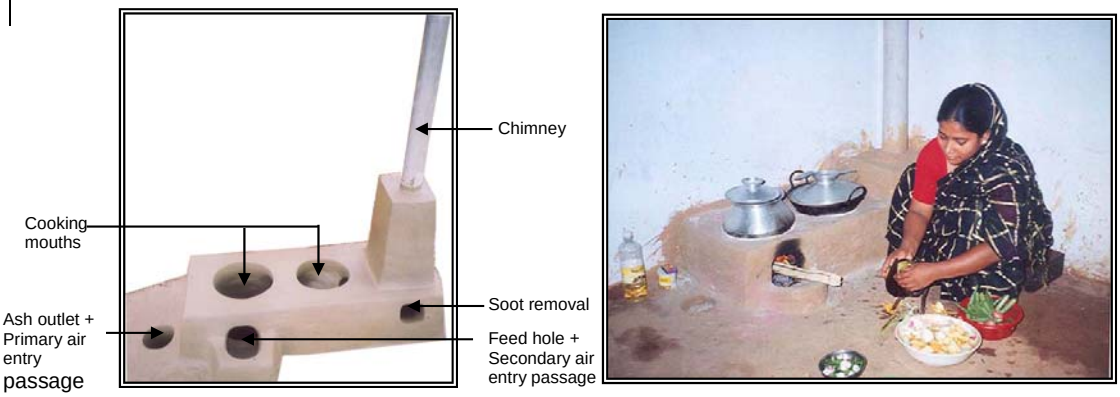
i) A cap of appropriate size is then placed on the top of the chimney. The space between the cap and the chimney should be 3-4 inches for releasing the smoke and all.

j) After completion of the installation of an ICS, it is plastered and smoothened with mud and left for 5-7 days to dry. After drying it up perfectly, the stove can be used for cooking or other heating purposes.

k) For durability and good looks, the entire structure of the stove can be covered with a layer of brickwork, plastered and finally paint covered (red oxide).

4.5. Model No.4 Improved Double Mouth Cooking Stove with Chimney (*Half underground*)

- **MODEL DEVELOPED BY** : BCSIR 1984
- **TYPE OF FUEL USED** : Suitable for burning fuel wood, branches, cow dung cake, briquettes and fluffy fuel viz, straw, leaves, bagasse etc.
- **PRICE** : TK.600.00
- **FUEL SAVING** : 55-60% as compared with traditional stoves.
- **EFFICIENCY** : 22-25%
- **SEASONALITY** : Round the year



A. Model B. Model on Use

Fig.No.15. Improved Double Mouth Cooking Stove with Chimney (*Half underground*)

1) Different parts of the model

a) Structure
b) Grate
c) Chimney
d) Cap
e) Lid for covering the ash outlet.

2) Dimensions of the model:

a) Mouths diameters : First mouth: 9 inches and second mouth: 8 inches.

b) Distance between two mouths : 3 inches

c) Feed hole : Length 5 inches x width 5 inches

d) Distance between the grate and the top of the mouth : 9.5 inches

e) Ash outlets/primary air entry passage : Length 5 inches x width 5 inches

f) Entry way from first mouth to the second : (7.0X4.5) inches

g) Open space left after placing the utensil in the second mouth : 2 inches

h) Diameter of the flue gases exit in the second mouth : 2.0 inches

i) Tunnel from second mouth to the chimney holder : Length 6 inches x width 3 inches x height 3 inches

j) Chimney holder : Length 5 inches x width 5 inches x height 10 inches

k) Height and diameter of the chimney : 6-9 feet and 3 inches

l) Distance between the chimney and its cap : 4 inches

m) Soot removal outlet at the bottom of the chimney : Length 3 inches x width 3 inches

n) Height of the stove from G.L : 9 inches

3) Procedure for construction:

a) At a suitable place where the stove will be installed, a hole measuring 11 inches diameter and 9 inches deep is made by digging the ground. The hole is then wet with water. A dice rinsed in water is then placed into the hole. The surroundings of the lower

portion of the dice is then filled with wet mud. After that another dice rinsed in water is placed just 3 inches away from the first dice.

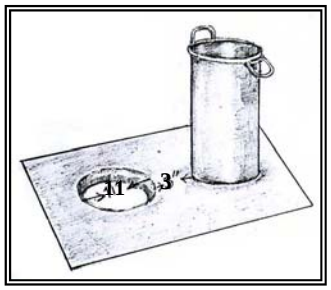


Fig.No.16. 1st Stage: Construction of Improved Double Mouth Cooking Stove with Chimney *(Half underground*)

b) A rectangular mud platform measuring 36 inches long x 17 inches wide x 9 inches high is made by putting mud around the two dice as in **Fig no 17**.

c) After a while, both the dices are removed by carefully twisting them out of the mud platform.

d) It is then allowed to dry for 1-2 days. After partial drying, a hedge is made in the first mouth at a point 10 inches below from the top, which will hold the grate. The hedge is made by inserting pieces of pottery into the inner wall of the first mouth and it is then covered with mud.

e) A 5 inches X 5 inches feed hole for fuel charging is made at a point 1.5 inches below from top of the first mouth as in Fig.No.17. Then two ash outlets/primary air entry passages measuring 5 inches x 5 inches are made just below the grate on both sides of the first mouth.

f) Next, an entry way for flame and hot gases from the first mouth to second mouth measuring 7.0 inches X 4.5 inches diameter is made just above the grate on the common wall of the two mouths. After that, the second mouth is partially filled up with mud and a slant is made from the grate reaching up to the second mouth. A flue gases exit of 2 inches diameter is made at a point just one inch below from the top of the second mouth.

g) A flue gases tunnel measuring 6 inches in length x 3 inches in width x 3 inches in height is made from the second mouth, reaching up to the chimney holder.

h) For placement of chimney at the end of the second mouth, a 5 inches long x 5 inches wide x 10 inches high space is readied. At the top of the space, two equal sized bricks are so placed that there is a gap of 3 inches left between the bricks. Then on top of the

two bricks, a chimney of 6-9 feet length and 3 inches diameter is placed. The bottom of the chimney is then covered with mud.

i) A cap of appropriate size is then placed on the top of the chimney. The space available between the cap and the chimney should be 3-4 inches to let out the smoke and excess heat, if any.

j) After completion of installation of the ICS, the stove surface is smoothened with mud and left for 5-7 days for drying. After proper drying, the stove can be used for cooking or other heating purposes.

k) For longer life and better looks and finish, the entire structure of the stove can be laid with bricks, plastered and given a coat of paint finally.

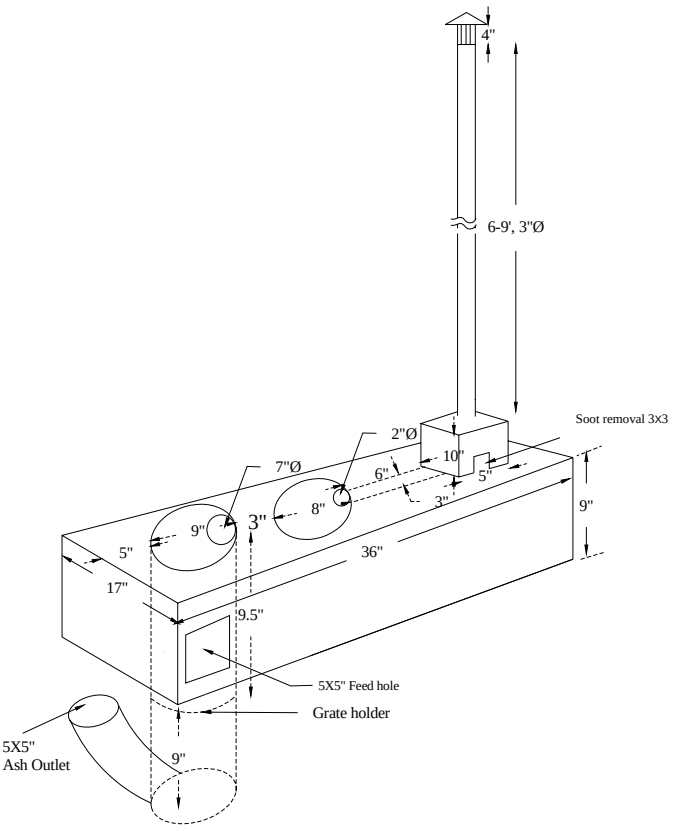


Figure No: 17. Double Mouth Cooking Stove with Chimney (*Half underground*) showing different dimensions of the stove

4.6 Model No.5 Improved Single Mouth Cooking Stove with Chimney (*Portable*)

- **MODEL DEVELOPED BY** : BCSIR 1984
- **TYPE OF FUEL USED** : Suitable for burning fuel wood branches, cow dung cake, briquettes etc.
- **PRICE** : TK.400.00
- **FUEL SAVING** : 60% as compared with traditional stoves.
- **EFFICIENCY** : 28-30%
- **SEASONALITY** : Round the year

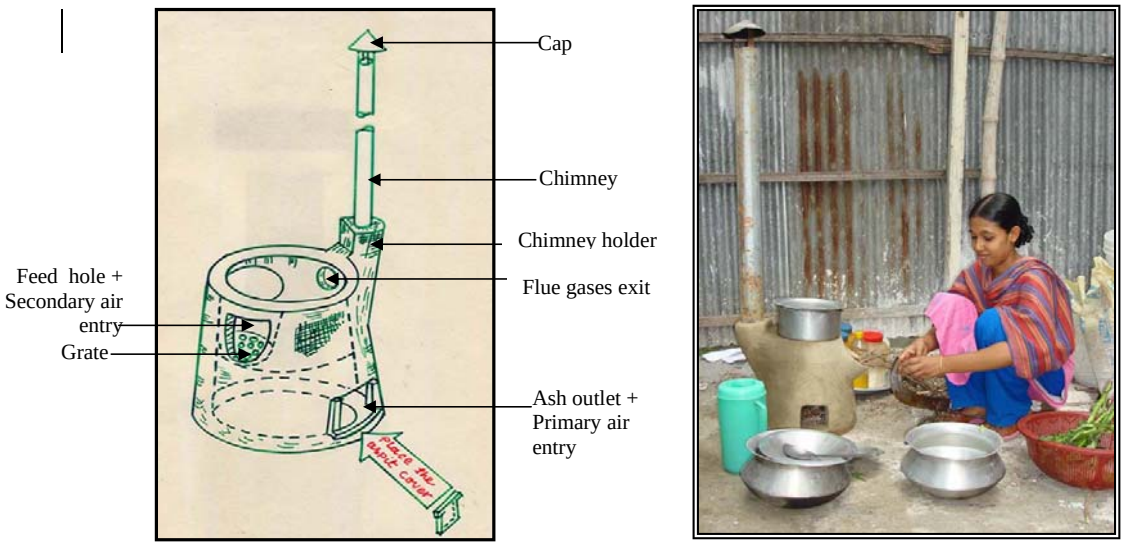


Fig.No.18. Improved Single Mouth Cooking Stove with Chimney (*Portable*)

1) Different parts of the model

a) Structure
b) Grate
c) Chimney
d) Cap
e) Lid for covering the ash outlet.

2) Dimension of the model:

a) Mouth diameter : 9 inches
b) Feed hole : (4.5X4.5)inches
c) Distance between the grate and the top of the mouth : 8.0 inches
d) Exit for flue gases : 1.5 inches (diameter)

e) Chimney height and its diameter : 3 feet and 2 inches respectively

f) Distance between the top of the chimney and the cap : 4 inches

g) Ash outlet and entry of primary air : 3 inches X 3 inches

h) Chimney holder : 2.5 inches diameter X 2.5 inches height

i) Height of the stove : 13 inches

3) Procedure for construction:

a) A circular mud plate of 13 inches diameter and one inch height is made on the floor of the selected suitable place. A dice rinsed in water, is then placed on the circular mud plate.

b) A structure of 9 inches diameter and 14 inches height is made by packing mud around the dice.

c) After a while, the dice is removed by carefully loosening and twisting it out of the structure.

d) It is then allowed to dry for 1-2 days. After partial drying, a hedge is made at a point 8.5 inches below from the top of the mouth, which will hold the grate. The hedge is made by inserting pieces of pottery into the inner wall of the stove and it is then covered with mud.

e) A feed hole for fuel charging measuring 4.5 inches X 4.5 inches is made by cutting the mud wall at a point just an inch below the top of the structure on one side. Extend the feed hole through about two inches towards the outside by inserting pieces of pottery and then cover the same with mud. It will hold the fuel.

f) On the opposite side of the feed hole, a chimney holder of 2.5 inches diameter and 2.5 inches height has to be made. This is made by inserting pieces of pottery into the wall of the stove and then covering the same with mud.

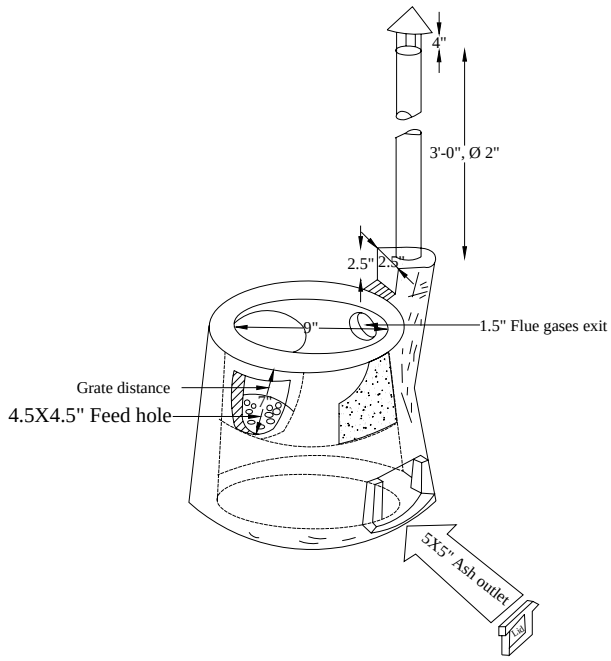
g) A flue gases exit having a 1.5 inches diameter is made just 0.5 inch below the top of the mouth, which leads to the chimney holder.

h) Then a grate is placed on the hedge, keeping two-thirds of the grate free and the remainder one-third is made to be slanting upwards up to the flue gases exit covered with mud.

i) Two ash outlets and entry way of primary air measuring 5 inches x 5 inches are made on both sides of the stove and just below the grate.

j) Next, a chimney of 3 feet height & 2.0 inches diameter with a cap on top of it is placed on the chimney holder.

k) After completion of the construction, the stove is smoothened with mud and left for 5-7 days for drying. After drying, the stove can be used for cooking or other heating purposes.



Fg.No.19. Improved Single Mouth Cooking Stove (*portable*) showing different dimensions of the stove.

This stove can easily be made half under ground as follows:

a) At a suitable place selected for installation of the ICS, a hole measuring 11 inches in diameter and 9 inches deep is made by digging into the ground. The hole is then moistened with water. A dice rinsed in water is then placed in the hole. The surroundings of the lower portion of the dice is then filled with mud. Now the dice has to be lifted upwards up to 5 inches by carefully twisting and turning it.

b) A structure of 9 inches height is then made by packing mud around the dice. Make the mud wall about 0.75 inch thick around the dice. After a while, the dice is to be removed by twisting it free by moving it carefully in the right to left movements. Then leave the structure alone for 1-2 days, allowing it to dry up partially.

c) Then follow the same procedure for construction of improved single mouth cooking stove with chimney (*Portable*) discussed already.

4.7 Model No.6 Improved Double Mouth Cooking Stove Coupled with Single Mouth Cooking Stove having a common chimney.

- **MODEL DEVELOPED BY** : BCSIR (Supervisors of ICS Project, Phase-II 1998)
- **TYPE OF FUEL USED** : Suitable for burning fuel wood, branches, cow dung cake, briquettes and fluffy fuel viz, straw-leaves bagasse etc
- **PRICE** : TK.750.00
- **FUEL SAVING** : As per models 3 and 5.
- **EFFICIENCY** : Do
- **SEASONALITY** : Round the year
- **LIFE TIME** : 2-3 years

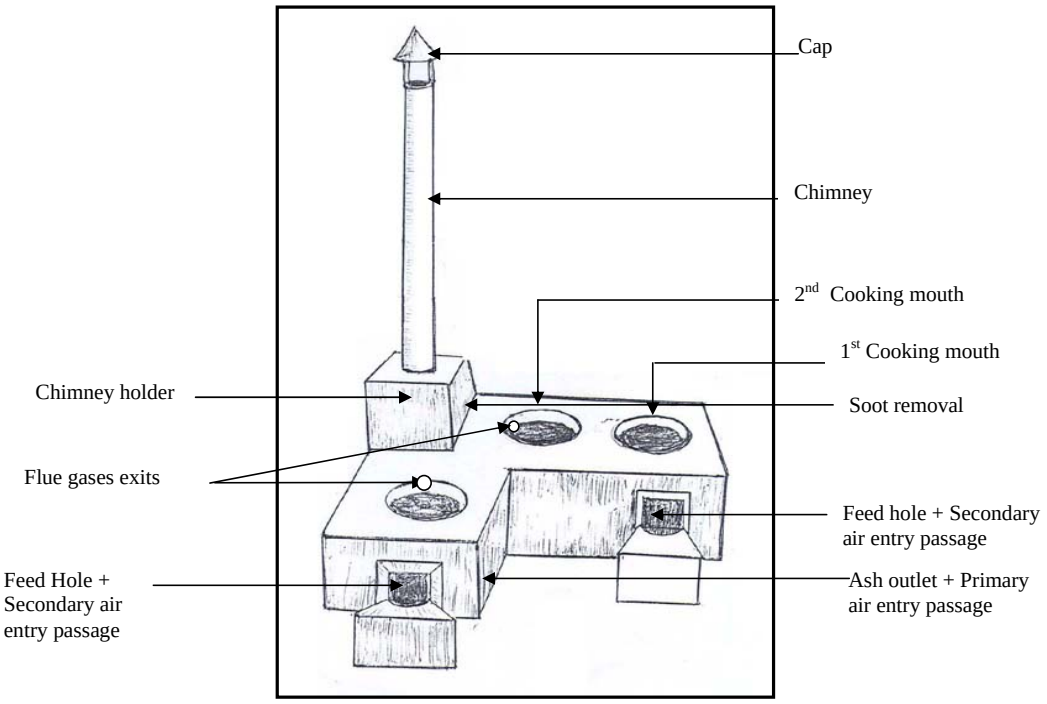


Fig.No.20. Improved Double Mouth Cooking Stove Coupled with Single Mouth Cooking Stove having a common chimney.

1) Different parts of the model

a) Structure
b) Grate
c) Chimney
d) Cap
e) Lid for covering the ash outlet.

A. Model No. 6: on Use

B. Improved Single Mouth cooking Stove with Chimney (*Fixed on the floor*) on use

Fig No : 21 Cooking with ICSs

2) Dimension of the model:

- **Double Mouth Cooking Stove:**

a) Mouths diameters : First mouth: 9 inches and second mouth: 8 inches.

b) Distance between two mouths : 3 inches

c) Feed hole : Length 5 inches x width 5 inches

d) Distance between the grate and the top of the mouth : 8.5 inches

e) Ash outlets/primary air entry passage : Length 5 inches x width 5 inches

f) Entry passage from the first mouth to the second : 7.0 inches X 4.5 inches

g) Open space left after placing the utensil on the second mouth : 2.5 inches

h) Diameter of the flue gases exit on the second mouth : 2 inches

i) Tunnel from the second mouth to the chimney holder : Length 6 inches x width 3 inches x height 3 inches

j) Damper : 4 inches X 4 inches

k) Height of the stove : 15 inches

- **Single Mouth Cooking Stove**

a) Mouth diameter : 9 inches

b) Feed hole : 4.5 inches X 4.5 inches

c) Distance between the grate to

d) the top of the mouth : 8.5 inches

e) Flue gases exit diameter : 1.5 inches

f) Ash outlets/primary air entry passage : Length 3X width 3 inches

- **Common Chimney:**

a) Chimney holder : Length 5 inches x width 5 inches x height 10 inches

b) Height and diameter of the chimney : 6-9 feet and 3 inches

c) Distance between the chimney and cap : 4 inches

d) Soot removal outlet at the bottom of the chimney : Length 3 inches x width 3 inches

e) Damper : 4 inches X 4 inches

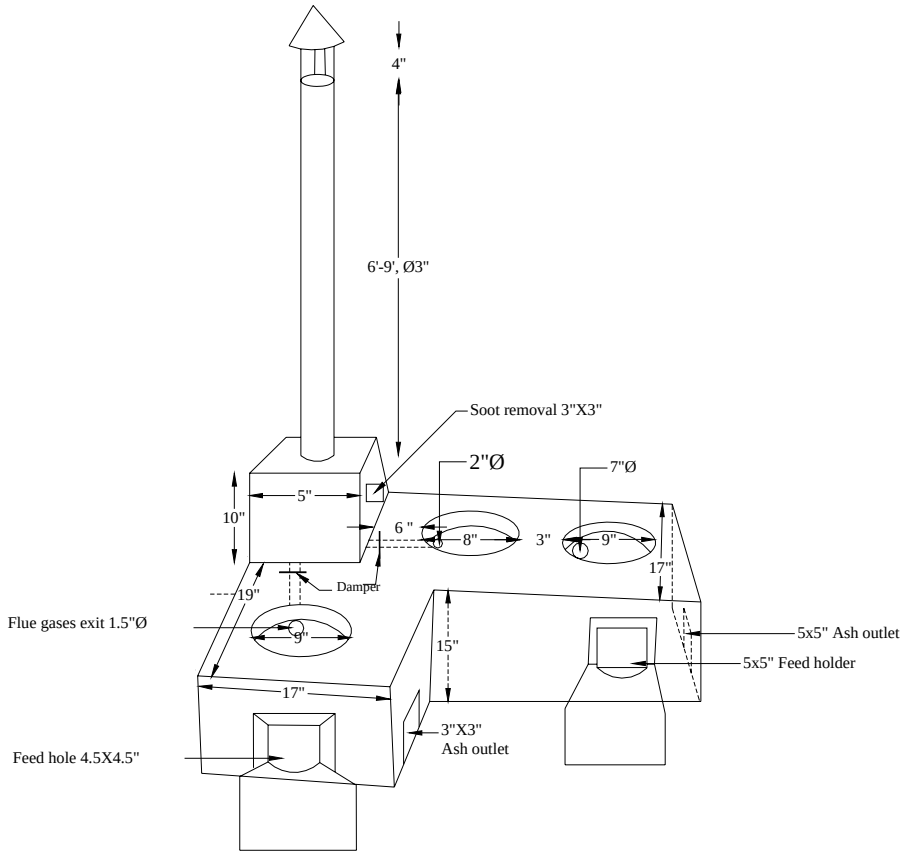


Fig.No.22. Improved Double Mouth Cooking Stove Coupled with Single Mouth Cooking

Stove having a common chimney showing different dimensions of the stove.

3) Construction procedure:

Select a suitable place for installation of an improved double mouth cooking stove on the floor. Construction procedure is the same as mentioned on page 26.

After that, an improved single mouth cooking stove (on the floor) is made on one side of the chimney holder of the double mouth stove:

a. Place a moistened dice of 9 inches diameter on the floor.

b. A rectangular mud platform measuring 19 inches in length X 17 inches wide X15 inches high has to be made by packing mud around the dice.

c. After a while, the dice is removed from the mud platform by twisting it from right to left.

d. It is then allowed to dry for 1-2 days. After it is partial dryid, a hedge is made at a point 9.0 inches down from the top, which will hold the grate. The hedge is made by inserting pieces of pottery into the inner wall of the mouth and it is then covered with mud.

e. A feed hole for fuel charging measuring 4.5 inches x 4.5 inches is made 1.5 inches below the top of the first mouth as shown in Fig.21. Then two ash outlet/primary air entry passages measuring 3 inches x 3 inches are made just below the grate on the both sides of the first mouth.

f. A flue gases exit of 1.5 inches diameter is made just an inch below the tip of the cooking mouth placed opposite to the feed hole.

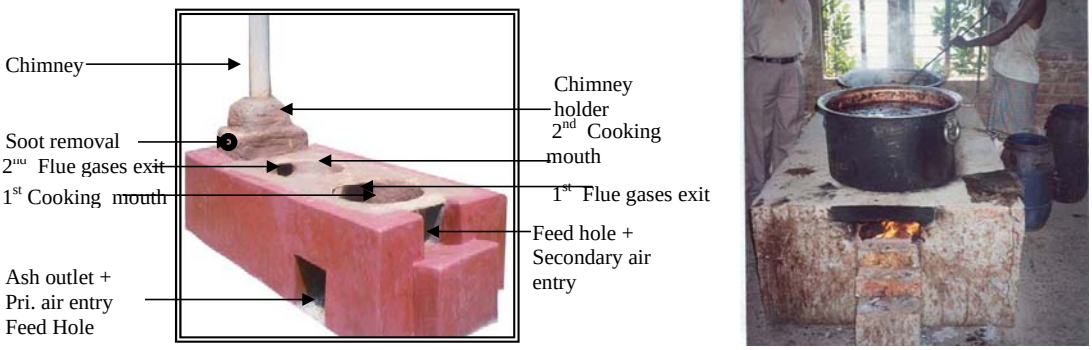
f) A tunnel measuring 6 inches in length x 3 inches in width x 3 inches in height is next made reaching from the flue gases exit up to the chimney holder.

g) For longer life and better finish, the entire structure of the stove can be covered with brickwork, wall plastered and finally painted with red oxide.

Both stoves have dampers just near the chimney. When both stoves are in use, the two dampers will be lifted up. But when one stove is used, the damper of the functioning stove will be lifted up and the damper of the other stove will be lowered down to prevent back suction of the flue gases through the feed hole. A damper can be made of M. S. sheet measuring 4 inches x 4 inches.

4.8 Model No.7 Improved Double Mouth Cooking Stove with Chimney, suitable for Large Scale Cooking and Semi Industrial Purposes.

- **MODEL DEVELOPED BY** : BCSIR 1985
- **TYPE OF FUEL USED** : Suitable for burning fuel wood, branches, cow dung cake, briquettes and fluffy fuel viz, straw, leaves, bagasse etc.
- **PRICE** : TK.2500.00 - 3000.00
- **FUEL SAVING** : 60% as compared with traditional stoves.
- **EFFICIENCY** : 29-31%
- **SEASONALITY** : Round the year



A. Model **B. Model on use**

Fig.No.23. Improved Double Mouth Cooking Stove with Chimney, Suitable for Large Scale Cooking and Semi Industrial purposes.

1) Raw materials for construction:

SL.No	Nature of the Materials	Quantity
1.	Mud/clay (adhesive)	200 kg
2.	Bricks	210
3.	0.7 inch thick ring of 18 inches diameter	2
4.	Rods 14 inches long, 0.7 inch thick	26
5.	Rods 8 inches long, 0.7 inch thick	14
6.	"U" shaped iron rods 4 inches long, 0.7 inch thick	4
7.	Cement	1 bag
8.	Sand	5 bag
9.	Red oxide	250 gm
10.	Cast iron grate: 17 inches diameter, hole diameter 0.5 inch	1
11.	Chimney, 4 inches diameter, 9-10 feet high	1
12.	Cap	1

2) Different parts of the model

a) Structure
b) Grate
c) Chimney
d) Cap
e) Lid for covering the ash outlet.

3) Dimensions of the model:

a) Mouths diameters : First mouth: 18 inches and Second mouth 17 inches
b) Distance between two mouths : 6 inches
c) Feed hole : Length 10 inches x width10 inches
d) Distance between the grate and the top of the mouth : 12 inches
e) Ash outlets/primary air entry passage : Length 10 inches x width10 inches
f) Entry passage from first mouth to the second mouth : 10 inches
g) Open space left after placing the utensil on the second mouth : 3 inches
h) Diameter of the flue gases exit in the second mouth : 4 inches
i) Flue gases tunnel reaching from the second mouth up to the chimney holder : Length 6 inches x width _5 inches x height 5 inches
j) Chimney holder : Length 10 inches x width10 inches x height 15 inches
k) Height and diameter of the chimney : 8-9 feet and 4-5 inches
l) The distance between the chimney and the cap : 4 inches
m) Soot removal outlet at the bottom of the chimney : Length 4 inches x width 4 inches
n) Height of the stove : 22 inches

3) Construction Procedure:

- Find a suitable place measuring 74 inches x 30 inches for installation of the stove and mark the required area using chalk.
- Now select 16 pieces of uniform sized bricks and bundle them into 8 pairs (2 pieces of bricks together) using lengths of rope.

    a) Place an 18 inches diameter ring, leaving 8 inches of open space in front and 6 inches space on the both sides of the ring. Mark them with chalk. Now remove the ring.

b) On the each side of the marked circle, (where there are six inches spaces) place two pairs of bricks in such a way that they are 10 inches apart. This space measuring 10 inches x 10 inches acts an ash outlet and entry passage for primary air into the stove. On both sides, make two hedges on the top of the two pairs of bricks by placing pieces of iron rods and cover them with mud. Both front and back sides of these hedges will make a platform measuring 71 inches in length x 28 inches in width x 10 inches in height as shown in Fig.No.24

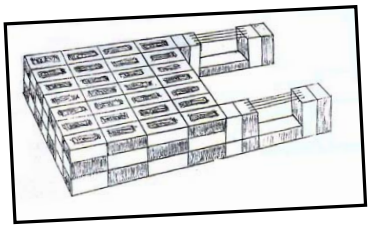


Fig.No-24: First stage: Construction of ICS for Large Scale Cooking and Semi Industrial Purposes

c) Now on the first mouth (18 inches dia) of the platform, make a feed hole by placing 4 pairs of bricks, measuring 10 inches x 10 inches and first exit measuring 10 inches in diameter for passage of flame and hot gases from the first mouth to the second mouth.

d) Make the second mouth (17 inches diameter) of the stove, which should be six inches away from the first mouth. At the end of the second mouth, on the opposite side of the feed hole, make a flue gases exit measuring 4 inches diameter by placing two bricks on the back side of the second mouth as shown in Fig.No-24

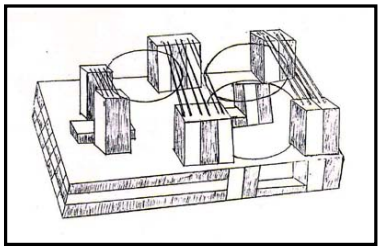


Fig.No-25: Second stage: Construction of ICS for Large Scale Cooking and Semi Industrial Purposes.

e) Make a flue gases tunnel from the exit of the second mouth to the chimney holder measuring 6 inches in length X 5 inches in width X 5 inches in height

f) Make a chimney holder at a point 6 inches away from the second mouth which should be 10 inches in length X 10 inches in width X 15 inches in height as shown in Fig No 26. On one side of this chimney holder, make an outlet measuring 4 inches X 4 inches for removal of chimney soot.

Chimney Holder: 10″x10″x15″

Fig.No-26: Third Stage: Construction of ICS for Large Scale Cooking and Semi Industrial Purposes

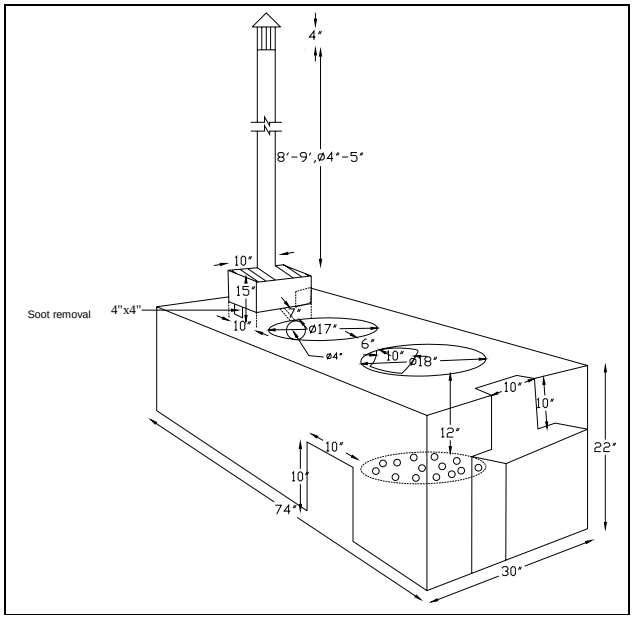


Fig.No.27. Improved Double Mouth Cooking Stove with Chimney Suitable for Large Scale Cooking and Semi Industrial Purposes showing different dimensions of the Stove.

g) The entire structure of the stove is then covered with mud.

h) Four "U" shaped iron rods measuring 4 inches in length are embedded in the inner wall of the first mouth at a distance of 12 inches from the top, where the grate will be held.

i) In the chimney holder, place a chimney made of cement, which should be of 6-9 feet height (as necessary) and 4 inches diameter. The bottom part of the chimney is now to be covered with mud.

j) Put a cap of appropriate size on the top of the chimney. The distance between the cap and the chimney should be 4 inches.

k) For longer life and better looks, the entire structure of the stove can be layered with bricks, plastered and finally given a coat of red oxide. The inner side of the stove is to be smoothened with mud.

l) After drying, the stove is made ready for use.

Indoor Air Quality

When smoke gets in your eyes:

Kitchen air quality in rural Bangladesh homes [17]

The main goal of our CO concentration measurement was to assess the level of indoor air quality (IAQ) in rural kitchens in Bangladesh. The air quality during cooking of 53 sample meals was monitored by means of a fixed carbon monoxide sensor in house hold kitchens in two villages in the rural areas of the country. Most of the measurements were taken at breathing zone height. Two types of cooking stoves were used: Traditional One Mouth Cooking Stove (TS) and Improved Double Mouth Cooking Stove with Chimney (ICS).

Mean results of carbon monoxide concentration (CO) measurements according to stove type, PPM (parts per million) were as follows:

	Traditional Stove (TS)	Improved Stove(IS)
Number of measurement	29	24
Average concentration of CO	22.6	13.0
Range of CO concentration	2.7 -95.2	1.7 - 41.6

The impact of improved stove types with a flue is quite clear. The same is true for

4.9. **Model No: 8:** High Efficiency Insulating Blanket for Improved Stoves. [18]

- INSULATING BLANKET DEVELOPED BY : BCSIR,1988
- INSULATING MATERIALS : Locally available indigenous raw materials
- PRICE : TK. 300.00
- FUEL SAVING : 45% as compared with improved double mouth cooking stoves with chimney
- SEASONALLY : Round the year

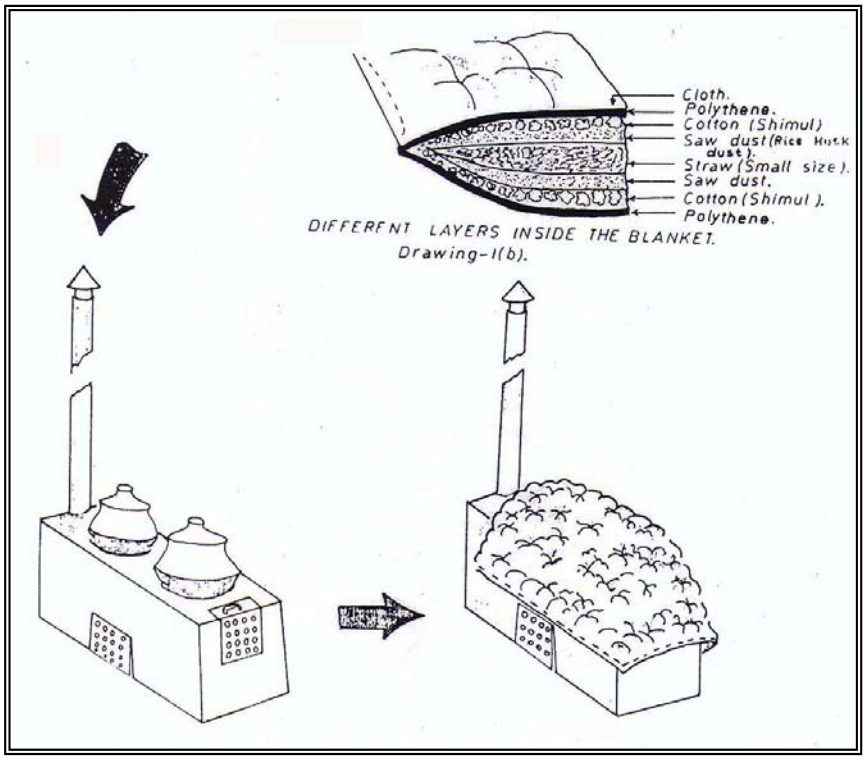


Figure No. 28 : Improved Domestic Double Mouth Cooking Stove with Insulating Blanket

The total cooking process on the stoves is divided into two stages:

1. Pre-boiling stage
2. Simmering stage

In the pre-boiling stage, foodstuff put into the water for cooking is brought from room temperature to the boiling point. In the simmering stage, the contents of the cooking utensil are allowed to boil till the food is completely cooked.

In the pre-boiling stage, fuel must be added to the stove as this stage involves raising of temperature. During the simmering stage, the temperature can not rise above the boiling point, however high the fuel-feed rate to the stove may be. The function of the stove during the simmering stage, therefore, is to keep the temperature at the boiling point and not to raise it any further. Therefore, in the simmering stage, fuel feeding may be eliminated if suitable arrangement can be made to check the fall of temperature, and thus the amount of fuel fed during this stage will be saved.

Improved Cooking Stove with Waste heat Utilization [5]

The waste hot flue gases entering the chimney are released in the atmosphere, the temperature of the gases varying in the range 175-225°C, when they enter into the bottom of the chimney

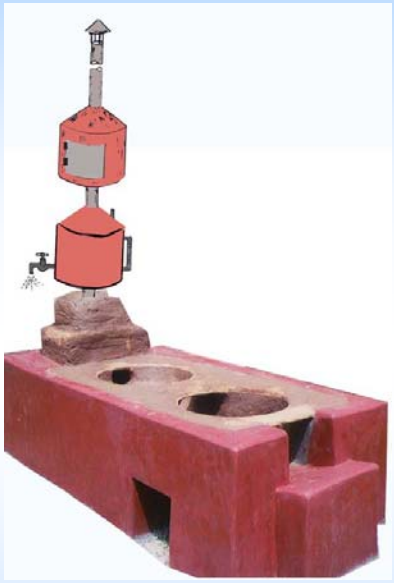


Fig No 29: Improved Double Mouth Cooking Stove with Chimney for Large Scale Cooking Coupled with Water Heater and Oven

In hotels/restaurants, double mouth cooking stoves with chimney are required to be used day and night. In such a case, a double wall water heater having a capacity of 15 litres of water and a double wall oven can be fitted at the bottom of the chimney as shown in Fig. No 28. As the stove is used continuously, within 45-55 minutes of cooking time, water in the water heater should start boiling. This hot water can be used for cooking, making tea, washing utensils etc. The temperature in the oven will be reaching up to 100-115°C within an hour. Also, using proper insulation, the oven temperature can be raised up to 160°C. This oven can be

Comparison of Different Parameters of ICS Models are given in Table No-3:

Table No-3: Comparison of Different Parameters of ICS Models

SL No	Name of the ICS Models	Efficiency (%)	Different Parameters of ICS Models											
			ICS Structure								Chimney			
			Mouth diameter		Raised Point (Inches)	Grate Height (inches)	Feed Hole (inches)	Pri.Air Entry/ Ash out let (inches)	Flue Gases Exit (inches)	Tunnel from 2nd Mouth. to Chimney holder LXWXH (inches)	Chimney Holder (length X widthX height) inch.	Chimney dia (inches)	Chimney Height (feet)	Soot Removal
			1st Mouth (Inches)	2nd Mouth (Inches)										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	Model No. 1 Improved Single Mouth Cooking Stove (Portable)	25	9.0	-	0.5	6.0	4.5X4.0	0.5 dia 7-8 holes	-	-	-	-	-	-
2.	Model No. 2 Improved Single Mouth Cooking Stove (Half underground)	22	9.0	-	0.5	9.5	5X5	5X5	-	-	-	-	-	-
3.	Model No. 3 Improved Double Mouth Cooking Stove with Chimney (on the floor)	28-30	9.0	8.0	-	8.5	5X5	5X5	2.0	6X3X3	5 X 5 X 10	3.0	6-9	3X3
4.	Model No. 4 Improved Double Mouth Cooking Stove with Chimney (Half underground)	22-25	9.0	8.0	-	9.5	5X5	5X5	2.0	6X3X3	5 X 5 X 10	3.0	6-9	3X3
5.	Model No. 5 Improved Single Mouth Cooking Stove with Chimney (Portable)	21-22	9.0	-	-	8.5	5X5	5X5	1.5	-	2.5 X 2.5 X 2.5	2.0	3.0	3X3
6.	Model No. 6													
	i. Improved Double Mouth Cooking Stove (see Model-No-3)	28-30	9.0	8.0	-	8.5	5X5	5X5	2.0	6X3X3	5X5X10	3.0	6.9	3X3
	ii. Improved. Single Mouth Cooking Stove (see Model No-5)	21-22	9.0	-	-	8.5	5X5	5X5	1.5	6X3X3				
7.	Model No. 7 Improved Double Mouth Cooking Stove with Chimney Suitable	29-31	18	17	-	12	10X10	10X10	4.0	6X3X3	10 X 10X 15	4-5	8-9	4X4

	for Large Scale Cooking and Semi Industrial Purposes													

6. Future Prospects of ICS Technology In Bangladesh

Different models of improved stoves have been known to be saving up to 50-60% traditional fuels as compared with the traditional ones. The total volume of traditional fuel consumption in the country is about 40 million tonnes annually [1]. If improved stoves can be made popular in the country and if it saves 50% of the traditional fuels, then annually about 20 million tonnes of traditional fuel will be possible to save.

The reduction of use of traditional fuels by using improved stoves, therefore, will result in lower emissions of green house gases (CO_2) in the atmosphere. It should also help conserve the remainder forest resources and eventually increase the soil fertility of agricultural land in the country. An improved stove with chimney leads the flue gases out of the kitchen efficiently and thereby reduce IAP in the kitchen environment at the same time.

In riverine Bangladesh, it will be very difficult to supply natural gas for cooking purposes to the every household in the country even if we happen to tap huge deposits of natural gas in the near future. Therefore, improved stoves have a reasonably bright future in the country. Large scale dissemination of the improved stoves in the country, thus can positively help conserve the local forest resources and green cover, changing the grass roots social life to a great extent.

ICS models developed in the country are now a widely proven technology. There are people in the country who have been using ICS models and reaping various benefits through sustained periods. Therefore, the following strategies may adopted and suitable action plans developed for large scale dissemination of ICS across the country:

1. Setting up small industries across the country for production of different ICS models and their components, so that the grass roots users will be able to buy the required components / parts suitable for meeting their needs from the local shops and assemble them in their kitchens, as required.

2. Developing skilled manpower through organizing and conducting training courses to popularize ICS technology, enabling the unemployed men and women of the country acquire the skills, who might choose to apply their knowledge and skill learnt, taking it as a profession for their livelihood.
3. Creating awareness of the efficacy, efficiency and utility of ICS through launching widespread advertisement campaigns through various medias.
4. Involving different relevant GO-NGOs for dissemination of ICS throughout the country.
5. BCSIR should be focal point for R & D and Loop Research of ICS.
6. To further increase the efficiency of ICS models by putting suitable insulation materials around the combustion chamber and other mouth of the stove.

Recent Development of ICS: Down Draft Stoves

Biomass fuels are generally used in the conventional stoves. But due to incomplete combustion of biomass fuels, appreciable quantities of pollutants viz. carbon monoxide, particulates, polycyclic organic matters etc. are released in the kitchen environment while cooking is undertaken, which resultantly cause IAP, affecting the respiratory system of the traditional stove users adversely in the process. To over come these problems, Eindhoven University of Technology, Eindhoven, The Netherlands have been pursuing research since 1980 into Clean Combustion of Wood by applying down-draft combustion principle in wood burning devices [19].

During this author's EEC post doctoral fellowship at the Eindhoven Technical University, Eindhoven, The Netharlands in 1989-90, by applying down-draft combustion principle, the researcher team (including the author) developed a biomass burning device, where fuel wood burns cleanly. Users of the device established that the temperature below the grate being about 1000-1100^{o}C, temperature of the flue gases at the top of the chimney being about 550-750^{o}C, the CO emission is about 0.0065%.

The principle of operation of the stove, in contrast to that of conventional design is that the flow of air is in the same direction as the volatiles and fuel. A chimney for the stove is essential to provide the necessary draft, which induces the liberated volatiles and air to flow downward through the fuel bed where they burn vigorously resulting in higher temperatures (1000-1100^{o}C) than during conventional burning (550-750^{o}). It has been experimentally found that this mode of burning leads to a

very good combustion process, and especially the resultant CO emission is negligible.

Later, during 1994-97, BCSIR had undertaken and conducted a four-year Joint Collaboration Research Project with Eindhoven Technical University, Eindhoven, The Netherlands sponsored by EEC to develop biomass stoves by applying the down-draft combustion principle.

Subsequently, during the project period and after the project period, IFRD by applying down-draft combustion principle developed a series of down-draft stoves suitable for domestic cooking to large scale cooking and other heating purposes. The efficiencies of the stoves are similar to that of conventional improved stoves but CO emission is negligible.

By applying this principle, a series of down-draft stoves suitable for domestic cooking to large scale cooking and other heating purposes have been developed by BCSIR. Pilot scale dissemination of these stoves has been initiated in different parts of country.

Two down draft stoves are described below:

1. BERBECUE *(KEBAB)* OVEN [19-21]:

- **MODEL DEVELOPED BY** : BCSIR 2001
  Under BCSIR –Eindhoven Technical University Joint Collaboration Research Project Sponsored By EEC
- **TYPE OF FUEL USED** : Fuel Wood (blocks)
- **PRICE** : TK. 1,500
- **CO EMISSION** : 0 . 08 %
- **CO/CO_2 Ratio** : 0 . 027
- **LIFE SPAN** : 5 years

Fig No. 30: Down-draft barbecue (Kebab) Oven

The sharp pointed skewers holding the kebab or meat pieces are placed horizontally on the top tray and it is then placed on the top of the chimney. The hot flue gases coming out of the chimney directly roast/ singe the bottom of the kebab. The temperature at the top of the chimney is around 350-400^{0}C.

The kebab cooked on the down-draft stoves happens to be tastier than those barbecued on the traditional ones. This is because in a down-draft oven, the kebab is cooked in hot gases, whereas, in case of a traditional stove, the kebab is cooked directly placing the meat skewers on the glowing charcoal. As a result, at the end of cooking, the meat gets dried up and simply get burnt at times.

2. DOWN DRAFT DRIER [19-22 :

• **MODEL DEVELOPED BY**	: BCSIR 2001 Under BCSIR –Eindhoven Technical University Joint Collaboration Research Project Sponsored By EEC
• **TYPE OF FUEL USED**	: Fuel wood (blocks)
• **PRICE**	: TK. 1,500
• **CO EMISSION**	: 0.1%
• Co/Co_2 **RATIO**	: 0.030
• **LIFE SPAN**	: 4 years

Wood blocks are charged in the combustion chamber on a grate, followed by ignition. The hot flue gases on their way out of the chimney heat up foods/other stuff placed on the drawer. The maximum temperature recorded in the process was 250^{0}C. It can be used for drying vegetables viz. potatoes, cauliflower, cabbages, bitter gourd, onions etc. It can also be used for drying fishes and other similar purposes.

Fig No. 31: Down draft drier

7. Maintenance

7.1 How to Use the ICS:

a) Fuel will burn on the grate. Do not overstuff the combustion chamber with fuel , as there must be sufficient space left for air to get in.

b) In case of using an ICS with chimney, care should be taken that there is no open space left between the utensil and stove mouth. If any open space happens to be left, then there will occur heat loss and it will also cause pollution inside the kitchen.

c) Plan whatever cooking has to be done and arrange the ingredients required in advance. After cooking one item, remove the cooking pot from the stove mouth and immediately replace the space with another utensil containing uncooked stuff. The cooking should be done continuously to save fuel, heat and time.

d) In case of the double mouth ICS with chimney, cooking on the first mouth is done by direct flame produced by the fuel and on the second mouth by hot flue gases coming out of the first mouth. As a result cooking in the first mouth is faster than second mouth. Therefore, when foodstuff put on the first mouth reaches the boiling stage, it is exchanged with the food stuff put on the second mouth. This will result in reducing fuel consumption in the cooking process.

e) When food stuff on both the stove mouths reach the boiling stage, then stop adding any more fuel in the stove. Allow the foodstuff to simmer (boiling) using minimal amount of fuel to finish cooking.

f) While cooking using a double mouth ICS with chimney, both the cooking mouths should be fitted with utensils. Do not keep any mouth uncovered during cooking.

g) For using smaller utensil compared with the stove mouths, a metal plate having a small hole can be used as an adapter in the ICS.

h) In case of firing the stove, it is better to blow air through the ash outlets/ primary air entry.

7.2 Repair of ICS

a) A newly constructed ICS can always be used, but one has to make sure that it is dry and ready for cooking. It should never be used unless it is properly dried, because a wet or partially damp stove will consume considerably larger amounts of fuel and the durability of the stove also will be compromised.

b) Repair any cracks as soon as they occur, as "A stitch in time saves nine".

c) The chimney should have a cap, because it keeps the sparks from flying out and prevents rain from entering into the chimney.

d) After using the ICS for 5-7 days, it should be thoroughly smoothened using a mixture of mud and cow-dung. Thus the durability of the ICS will be increased.

e) The chimney diameter of an ICS may be constricted or reduced after a long period of continuous use by deposition of soot on the inner wall of the chimney. This might result in causing flame and hot flue gases coming out through the feed hole during cooking instead of passing through the chimney. Therefore, the chimney should be cleaned at regular intervals, preferably once in a months or so by removing the cap and brushing it down with a bamboo pole with grass or rags tied to one end. The soot dislodged should be removed through the soot removal hole' made at the bottom of the chimney, which should be kept closed putting a lid on it while operating the stove.

7.3 Trouble Shooting Of ICS

After using the ICS continuously for a long time, the ICS users may be faced with certain operational problems. These problems may be classified into two groups:

1) **During use of the ICS, part of the flame and hot flue gases may start coming out through the feed hole of the stove. In such a case, the problem may be due to one/more of the following reasons :**

a. The connecting passage between the first and the second stove mouths may be smaller than optimized dimensions, which may very well cause part of the flame and hot flue gases pushing out through the feed hole.

b. The distance between the bottom of the utensil and the bottom of the second mouth of the ICS is less than optimized dimension or virtually there exists no space left between them.

c. The diameter of the flue gases exit passage from the second mouth of the ICS is less than the optimal dimension.

d. The empty space below the bottom of the chimney may be clogged up with shoot/other things.

e. Due to some reason, the lower portion of the chimney may be lowered down further, causing it to touch the bottom of the surface.

f. The diameter of the chimney may be constricted or reduced by deposition of soot caused by using the ICS continuously for a long time.

g. The distance between the chimney and its cap is less than the optimal prescribed distance or there is simply no space left between them.

h. If the combustion chamber, that is, the first mouth of the ICS is overstuffed with fuel and there is not sufficient space available for air to get in.

2) After using the ICS for a period, fuel consumption may seem to be increasing due to one/more of the following reasons:

a. If the grate is actually positioned at a point which is lower than where it is supposed to be, due to some reasons. Then heat transfer to the cooking utensil will be considerably reduced resulting in low efficiency and the ICS will tend to consume more fuel than it really should.

b. After using the ICS for a long time, the diameter of the hole of the grate becomes larger. As a result, small pieces of charcoal will fall down through the grate without burning.

c. If due to some reasons, the diameters of both the feed hole and the ash outlet of the ICS become larger than their optimal dimensions, then excess air will enter in to the combustion chamber and burn the fuel more quickly without allowing fruitful use of the heat produced during the cooking process.

d. If the diameter of the flue gases exit of the second mouth of the ICS becomes larger, then hot flue gases containing much heat will quickly leave the stove through the chimney.

e. After a period of use of the ICS, if the chimney of the ICS is replaced with a new one having a larger diameter and longer height than the optimal dimensions, then the draught will be increasing, which will draw excess air and the process will dilute the heat of flue gases. Draught increases with the height and the diameter of the chimney.

Therefore, if you face any problem regarding sudden increase of fuel consumption in the ICS, then carefully review the above mentioned situations which cause such problems and take appropriate action for resolving the problem. If necessary, consult any technician possessing ICS management skills in your locality.

8. Reduction of Indoor Air Pollution by Proper Ventilation in a Kitchen

The indoor air quality in a kitchen depends not only on the emission of pollutants from the traditional stoves, but also on the kitchen construction materials and its use patterns. The emission of pollutants can be controlled by modifying the stove and through introducing better choice of fuels. This, however, may not always be possible. IAP in the kitchen environment can be reduced to a considerable level by altering the construction characteristics of the kitchen itself.

The major role of ventilation is to induce outside air to dilute the polluted air in the kitchen so that its concentration is within or near permissible limits.

There are three types of ventilation [23]:

I. Mechanical Ventilation:

Mechanical ventilation uses a combination of electric fans, air inlets and controls to regulate temperature and humidity

II. Infiltration:

It is the unintentional or accidental process by which outdoor air flows into the house through opening, joints and cracks in the walls, floors and ceilings and around the windows and doors. Air can also move out of the house in this manner, a process known as ex-filtration. Houses with walls or roofing made of bamboo provide excellent ventilation by means of infiltration and ex-filtration.

III. Natural Ventilation:

Natural ventilation is often the cheapest and simplest method that can be used to provide fresh air to the rural kitchen. In natural ventilation, air moves through opened windows and doors.

Natural ventilation in the best choice to improve ventilation rate in rural kitchens.

- **Rural & Urban cooking practices in Bangladesh:**

In the rural areas of the country, most of the walls of the kitchen and dwelling rooms are made of mud or bamboo sheet and roofs are thatched. Mud walls create an effective seal that permits almost no ventilation. On the other hand, walls made of woven bamboo sheets or jute sticks and thatched roofs permit good ventilation.

Recent studies undertaken and accomplished by the World Bank in Bangladesh ([24] estimated PM_{10} concentration which is responsible for IAP, produced by burning of biomass fuels in the rural and urban areas of the country. The researchers estimated PM_{10} concentrations of 300 µg/m3 in the sample areas which is significantly higher than the benchmark case of 90µg/m^3. Such concentrations have been known to be causing serious health hazards. They also stated that pollution from cooking place quickly diffuses into the living spaces causing further health hazards to all of the household members who are indoor during the cooking period.

The rural and urban households in Bangladesh have different types of cooking arrangements. Three types of cooking facilities used are given below:

Type: 1

Some poor homes do not have a separate kitchen. They cook inside the dwelling room during the raining season and outside during dry seasons. But the location of traditional stoves may be in the following places:

a) In any corner inside the dwelling room but the most probable place is the verandah, when it is there.

b) In any corner of the dwelling room separated by two small walls made of mud or thatched walls with a small entrance.

c) Outside the dwelling room at any place as per choice of the users.

Type: 2

Kitchens having three walls, its entrance being entirely open, with or without a roof.

Type: 3

People of a little means use kitchens with four walls and roofing, but the gap between the kitchen walls and the roof is only a few inches.

Kitchen Types 2 and 3 may be attached to or separated from the dwelling houses.

- **IAP reduction by change in ventilation characteristics and behaviours:**

The cleaner fuels and the ICS can play an important role to reduce IAP. But poor families may not be in a position to access these options to enjoy significantly cleaner air in their households.

This investigation strongly suggested that within the sample areas, some simple arrangements are already producing relatively cleaner conditions even when biomass fuels are being used.

The simple changes are effected in:

1. Ventilation characteristics :

- Construction materials
- Space configuration
- Cooking locations
- Placement of doors and windows

2. Ventilation behaviours :

- Keeping doors and windows open after cooking.

These ventilation characteristics and ventilation behaviors have been known to be producing large differences in IAP. If cooking is done inside the house, the sealing effect of the mud walls of the dwelling house increases the PM_{10} concentration by 253.µg/m^3 in the baseline case. On the other hand, if cooking is done in a detached or open air location, mud walls in the house exert the same sealing effect, but the overall PM_{10} concentration is reduced by 158 µg/m^3. For other construction materials and even by just keeping the kitchen doors and windows open after cooking the midday meal, the PM_{10} concentration is reduced to a considerable level.

Optimization of different parameters on ventilation effects during cooking in traditional stoves in rural kitchen have not yet been done in Bangladesh. However, based on the findings of these World Bank studies, the following recommendations can be made:

- When the cooking is done in a separate kitchen, the kitchen should have one door, sufficient number of windows and a ventilation gap between the roof and its surrounding walls.
- The doors and windows of the kitchen are to be kept open after cooking.

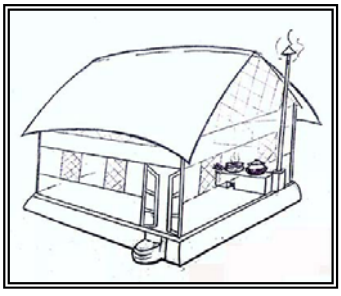


Fig.No-32: A Rural/Urban Kitchen with Proper Ventilation.

9. ICS Technology in South Asian Region, Latain America & Africa

More than half of the world's population living in the developing countries use biomass fuels while cooking using traditional stoves in poorly ventilated kitchens. It is a fact that in the poorer developing countries people roughly use three times as much fuel for cooking purposes as in the industrialized nations, but it is not widely known yet. The main reason for burning such huge volumes of biomass fuels is just the low efficiency of the traditional stoves.

South Asian countries viz Bangladesh, Bhutan, China, India, Nepal, Pakistan and Sri Lanka have been implementing ICS introduction programmes for a number of years past. Some of these programmes have been successfully implemented in some countries, while other are still doing their pilot phases. Many factors have contributed to the success of these programmes in some countries [25], which include cultural, social, ecological considerations, government policies and support, availability of skilled manpower, adequacy of infrastructural and institutional arrangements as well as the level of external support.

Some programmes, however, have encountered problems, which relate to lack of understanding of the users' needs in the kitchen and cooking practices, lack of women's participation, inadequate demonstrations/ trials of improved models in user households, poor quality of production/installation, inadequate or late feed-back/ monitoring efforts, poor after sales service etc.

However, based on local conditions, resources, available ICS technologies, skilled manpower etc. South Asian countries are still implementing the ICS programmes in their respective countries. These programmes may contribute adequately to energy and environmental conservation and in meeting overall development needs.

A few popular models of ICSs in use in the South Asian Countries are delineated below:

1) INDIA:

(i) Laxmi Improved Chulha [26]:

The model was developed in 1986 at the Technical Back up Unit, Centre for Application of Science and Technology for Rural Development (CASTFORD), Indian Institute of Education, 128/2 J.P Naik Path Kothrud, Pune-411029.

- **Efficiency : 14.7(Fuel wood)**
- **Price (Indian Currency) : Rs 70-87(1993)**

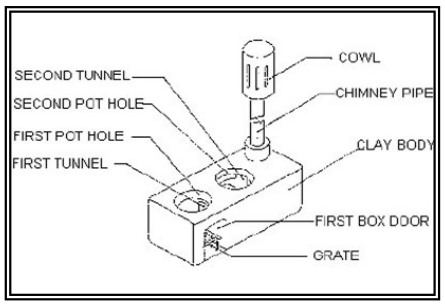


Fig.No.33: Improved double Mouth Cooking Stove with chimney.

The Laxmi, a two-pot mud stove with chimney was specifically designed for western India for cooking domestic foods. The stove can be operated using fuel wood, twigs, agricultural residues and dung cake. The stove can be constructed with clay and some ready-made parts such as a combustion chamber, connecting tunnels, chimney pipe, cowl (cap) and metal grate.

ii) Grihalaxmi (27):

Single pot chulha without a chimney, it is provided with a top grate which acts as a flame concentrator. A cast iron bottom grate is also provided.

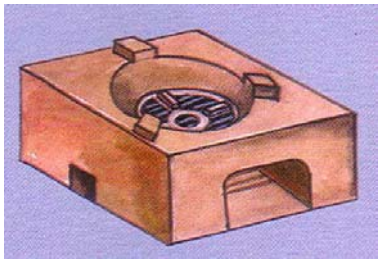


Fig.No.34: Grihalaxmi Improved Cooking Stove

- **Fuel saving: 35%**
- **Fuel used : Fuel wood, branches, cowdung cake and agricultural residues.**

2) NEPAL [28]:

Under the National ICS Programme, Improved Double Mouth Cooking Stove has been disseminated in the country. The name of the model:

(ii) Improved Double Mouth Cooking Stove with Chimney:

- **Efficiency : 15-25%**
- **Fuel wood saving as compared with the traditional ones : 30-35%**

Price (Nepalese Rupees) : 200-300.00 (2002)

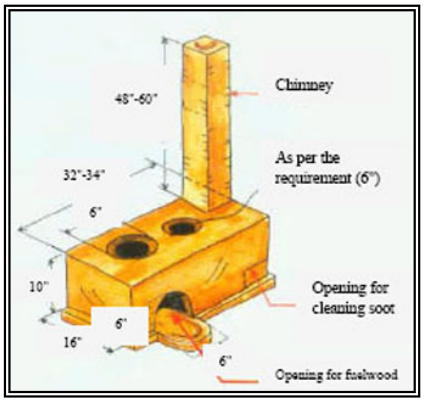


Fig.No.35: Improved Double Mouth Cooking Stove from Nepal

The ICS model is made up of 3 parts mud/earth, 2 parts straw/husk and 1 part animal dung. The ICS has two fire openings for cooking pots, one behind the other. There is no need to blow the fire. It utilizes the heat generated by burning fuel wood, more by the deflection of the flames and heated air inside it, which travels to the second opening with the help of an in-built baffle located just below the second opening, before the hot air leaves the chimney, which is made of un-burnt clay bricks that can be made in the village. The iron plates are fitted on the potholes for pots. The potholes are round in shapes; the pot bottom fits tight on them. It can be made in different sizes and capacities to suit the family size and also pot size. It can have one or more openings for pots/pans.

3) SRI LANKA [29]:

(i) Name of the ICS: "Anagi", Double Mouth Cooking Stove without Chimney.

- **Efficiency : 21%**
- **Fuel wood saving as compared with traditional ones : 30%**
- **The model was first introduced by the Ceylon Electricity Board in**
- **collaboration with the ITDG under Urban stove programmes : 1986**
- **Life-time : 3 years**
- **Fuel used : Fuel wood, other loose biomass residues such as coconut shells, fronds and leaves.**

"Anagi" is a two-pot single piece clay stove designed to meet the cooking needs of a 6-member family. The stove is made by potters.

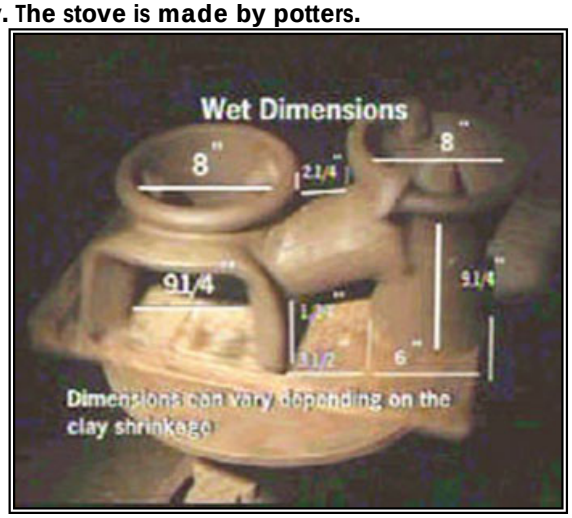


Fig.No.36: Improved Cooking Stove Anagi, Sri-Lanka

The stove has three main components as follows:

1) **Fire box**
2) **2nd pot hole and**
3) **Tunnel (which connects the fire box and the 2nd pot seat)**

The secondary components are:

- **pot rests**
- **buttresses**
- **baffle**
- **flame shield and**
- **the door**

These are made separately using modules. The three main components are thrown on the potter's wheel by a skilled potter.

The stove construction process consists of

- proper selection and preparation of clay
- throwing the main components on a potter's wheel
- moulding the secondary components
- finishing
- air drying
- packing inside the kiln and
- firing.

4) Latin American Countries: **"Lorena" Improved Stove [30]:**

Fig No: 37 Latin American Countries: **"Lorena" Improved Stove**

- **Localities:** Urban and rural areas of Latin American countries
- **Users:** Women, men, schools, restaurants etc.
- **Fuel type:** Wood.
- **Stove makers:** Women, men, building contractors and communities, bricklayers, trained artisans etc.
- **Production method:** Dig clay, crush and screen, screen sand, prepare mixture, compact, mark out hob, excavate potholes and fuels, install chimney. The work is done by both men and women.
- **Fuel saving:** 30%-60%
- **Dissemination system:** Awareness raising, building, training, talks, promotion, demonstration of methods, visit and follow-up, instruction leaflets, videos etc.
- **Specifies:** The "Lorena" improved stove originated in Guatemala in the late 1970s. Various models are in use in the countries and regions of Latin America, differing in the number of pot holes and flue system.

5) Ghana **: Ahibenso Improved Stove [30]:**

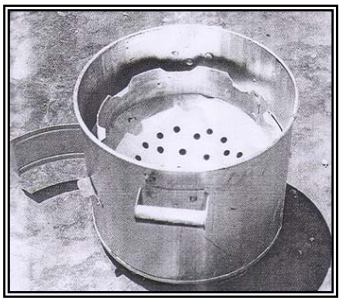


Fig No: 38 ICS in Ghana: Ahibenso Improved Stove

- **Countries, localities:** Ghana, Accra, Kumasi, Takoradi, Koforidua, Sunyani countryside, urban areas, Zambia
- **Users:** Households and commercial food sellers.
- **Fuel type:** Charcoal.
- **Materials:** Scrap metal, mild steel and galvanized steel.
- **Standard size:** 200-400 mm.
- **Stove makers:** Ghana: Alfa Manufacturing Co. Ltd, artisans trained by the project. Zambia: the informal sector.
- **Production method:** Fully mechanized process, spot welders are used, a small workshop using simple tools such as hammers and chisels does it. All producers use templates made by the project. Quality control, follow-up by project personnel.
- **Efficiency:** 39 %(GHA, Field tests): 25-30 % (ZAM)
- **Fuel saving:** 35%-40 %(GHA, Field tests): 62% (ZAM)

6) Biomass Gasifier Stove for Rural Household [27]:

Biomass gasifier stove is a highly efficient stove. The thermal efficiency of this stove is more than 49%. It is made of cast iron. Basic fuel of this stove is biomass fuel viz. crop residues, wood twigs, weeds, animal dung and other organic materials. The biomass waste generated at household, industries and agricultural fields can also be used as fuels.

Fig No: 38 Biomass Gasifier Stove for Rural Household in China

Principle of operation of biomass gasifier:

- In the gasifier stove, thermo-chemical reaction of biomass takes place: under anaerobic condition (in absence of light and air), biomass is burnt,

mixed with air(once), then thermally decomposed to a mixture of flammable gases, containing CO, CH_4,H_2 etc. which together is generally called “smoke”.

- When the smoke reaches the opening/ outlet on the top of the combustion chamber, it mixes with air again.
- As the temperature of the mixed gases rapidly reaches the flash point (about 650^{o}C), it starts burning producing a flame.
- When the chamber is warmed up, the speed of consuming gases and the speed of generating flammable gases from thermal decomposition reach an equilibrium and as a result, the stove keeps on burning at a constant rate.

The salient features of biomass gasifier stoves:

1. It can be operated using low grade biomass fuels viz. wood twigs, leaves, crop residues, weeds and animal dung.
2. It saves fuel and cooking time. For example: 1.0-1.5 kg of crop residues is enough for cooking foods for a 3-5 member family. During cooking, there is no need of watching the stove constantly.
3. It yields higher thermal power output and thermal efficiency. The thermal power output is adjustable. The flame is similar to that produced by LPG. 5 kg of water can be heated to boiling within 5-8 minutes.
4. It does not cause health hazards to the users and renders cooking environment friendly.
5. It is durable, because it is made of cast iron, which is also flame proof and anti oxidant.
6. It has a fuel feed entrance; therefore, continuous fuel feeding is possible.
7. It is portable.
8. It is most suitable for rural households.

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	Model No. 4 Improved Double Mouth Cooking Stove with Chimney (Half underground) 	Fixed Suitable for 8 member family Can be built completely under ground	-All types of trad. fuel including agricultural. residues by changing the grate	Should be built by skilled technicians Feed hole can be built either side or in the front side of the combustion chamber	Clay Pieces of pottery or U shaped iron rods 8 inches long bamboo pieces Metal grate Chimney Cap *Locally available raw materials* 2-3 years	Can be used where it was built according to the cooking habits of users	Greatly reduced IAP in the kitch