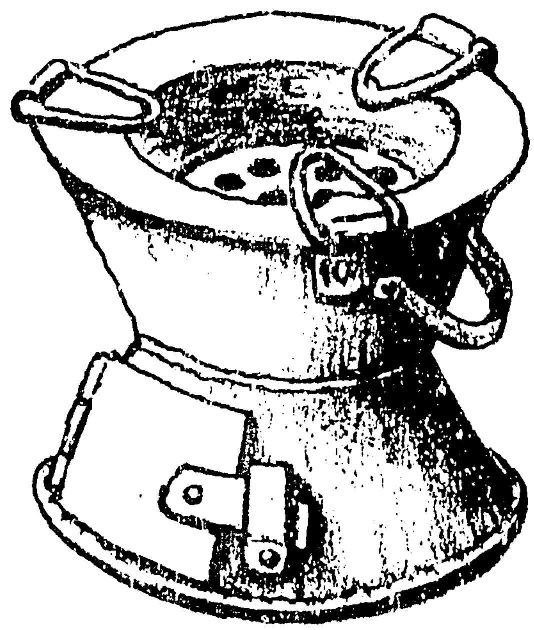
KENYA RENEWABLE ENERGY PROJECT

Ministry of Energy



How to make the Kenyan Ceramic Jiko

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Many other people, especially the jiko artisans at Shauri Moyo, contributed ideas, information and skills that fostered the development of the jiko.

The responsibility for any errors or omissions, however, rests solely with the authors.

June 1983,
Nairobi.

How to make the Kenyan Ceramic Jiko

Contents

I. INTRODUCTION

1.1. Background

The Kenyan ceramic jiko for charcoal is an adaptation of the Thai bucket (see fig. 1) to Kenyan cooking practices. The decision to attempt a widespread dissemination of this charcoal stove was made after a needs assessment survey indicated, among other things, that:

a) Given a looming fuelwood crisis and escalating charcoal prices, Kenyan charcoal consumers now need improved stoves that will use less charcoal and reduce cooking fuel costs.

b) The greatest wastage in fuelwood utilisation results through use as charcoal,* and improvements in fuel efficiency of charocal stoves would make a significant contribution to afforestation efforts.

c) The main target population for charocal stoves is urban and peri-urban households, many of whom, unlike open fire users, are already accustomed to purchasing their stoves.

d) There exists an efficient and effective informal sector network for the production and distribution of charcoal stoves throughout Kenya which could be used in disseminating improved stoves and their production techniques.

e) Charcoal will increasingly be demanded (especially for household and institutional use) given its user convenience and rising costs of imported fuels.

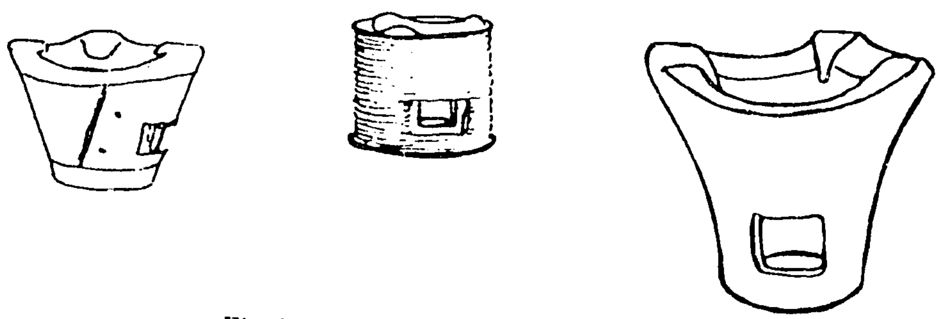


Fig. 1 Versions of the Thai Bucket Stove.

**For example, an estimated 5.4 million tonnes of firewood were used to produce 630,000 tonnes of charcoal in 1982. This gives a wood-charcoal conversion ratio of 8:1. The overall energy losses in using charcoal as the energy carrier for wood amount to 85% (given the average 15% kiln efficiency and 20% stove efficiency).*

The Thai Bucket stove is well known to be a highly efficient charcoal stove. The ceramic liner and insulation accounts for an average heat utilisation of 30%. The stove has been adapted to the vigorous stirring required in Kenyan cooking practices by maintaining the heavy metal pot rests and the stability of a wide base that come with the traditional Kenyan charcoal jiko.

Following a study tour of the Thai ceramic stove industries, the Thai production technology is successfully being transferred to Kenyan stove artisans who have access to the required materials. Several of these are now making and marketing the stoves in Nairobi with technical assistance from the Ministry of Energy. Plans are under way to establish production units throughout the country.

1.2. Test results

Tests done by ITDG at Reading indicated that the Thai Bucket stove was a design that might meet Kenya's need for more efficient charcoal stoves. Further tests comparing the Kenya-made ceramic stove with several other prototypes were carried out at Kenyatta University College by an ITDG/Ministry of Energy team.

In comparison with the widely used all-metal Kenyan charcoal jiko, the ceramic-lined model showed a potential to cut down fuel consumption per meal by up to 50%, depending on operator skill. The ceramic jiko requires less attendance (e.g. recharging with fuel) during cooking. It also poses less dangers of serious burns. Average cooking time is slightly less on the ceramic stove and the level of carbon monoxide emission is lower than that of the traditional metal stove.

These tests showed that the stove has an average heat transfer efficiency of 30% over a wide range of operating conditions. This means a potential to save up to 50% of the charcoal needed in the unimproved stove to cook a similar meal.

Preliminary field test results indicate that this savings is closely replicated under actual cooking conditions. The ceramic jiko has been tested in 451 Kenyan households. Field test results indicate that a 25% to 50% fuel savings is being obtained by test households. The stove is generally socially acceptable and the majority of users find it suitable for cooking their routine meals.

With the air inlet door open, the jiko consumes approximately 5 grams of charcoal per minute. In the standard size jiko, it takes 500 grams of charcoal 12 minutes to raise 2000 grams of water to boiling point from 22°C. This same charge will simmer the pot contents for 1½ hours with the airvent open, or for 2 hours with the airvent closed.

The cost for an unimproved jiko ranges from Ksh. 22 – 45, depending on the quality of metal used. The installation of a ceramic liner adds approximately Ksh. 30, and a c/v liner about Ksh. 10. The all-ceramic version costs Ksh. 15.

1.3. Socio-economic context

Before a decision is made to adopt this type of stove elsewhere, an assessment of its social suitability and acceptability should be done. This involves a survey of cooking patterns, of target populations, types of fuels available, materials and skills that can be utilised, etc.

The Kenyan ceramic jiko is suited to cooking patterns where:

a) Charcoal, wood chips, maize cobs, or coconut shells are fuels;

b) One pot is cooked at a time (clay or metal pots);

c) High and low power outputs are required;

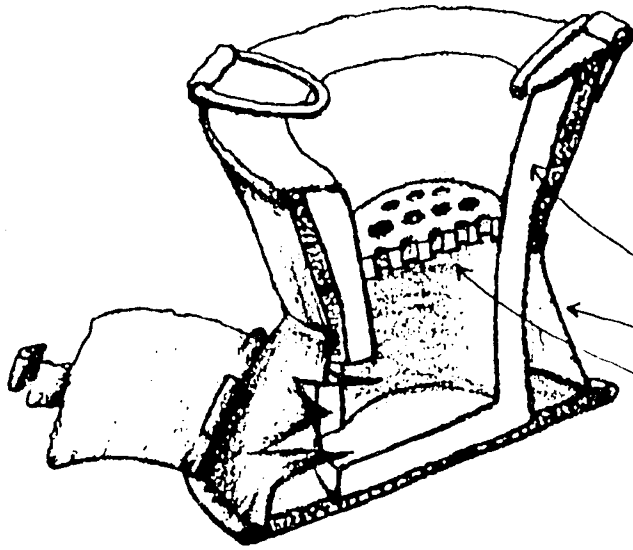
d) Space heating is not undesirable;

e) Stove portability is essential.

The improved Kenyan jiko can be made several different ways to take advantage of the availability of local materials and skills. Where there is no clay or pottery industry, the cement/vermiculite (c/v) lining may be best. Where metal is expensive and potteries are abundant, as in Western Kenya, an inexpensive all-ceramic version is made. It probably has a shorter life and less efficiency without the c/v insulation and metal cladding.

The jiko's estimated lifetime under normal household use is 8 – 12 months for the ceramic liner and 2 – 3 years for the metal cladding. The cement/vermiculite liner lasts 3 to 6 months.

1.4. Components and dimensions



The stove has three main components:

a) A fired pottery liner
b) The metal cladding
c) The metal or pottery grate

The pottery liner is anchored inside the metal cladding with a mixture of cement (one part) and vermiculite or ash (three parts). The cladding protects the liner and supports the weight of the pot.

The standard household model weighs 5 kg and has the following dimensions:

Bottom and top diameter of cladding	31	cm
Overall height	23	cm
Top inside diameter of liner	22	cm
Basal diameter of liner	16	cm
Firebox depth	10	cm
Grate diameter	16	cm
Grate thickness	1.5	cm
Grate hole diameter	1.5	cm
Inlet air door	650	cm^2
Thickness of ceramic liner	2.5	cm

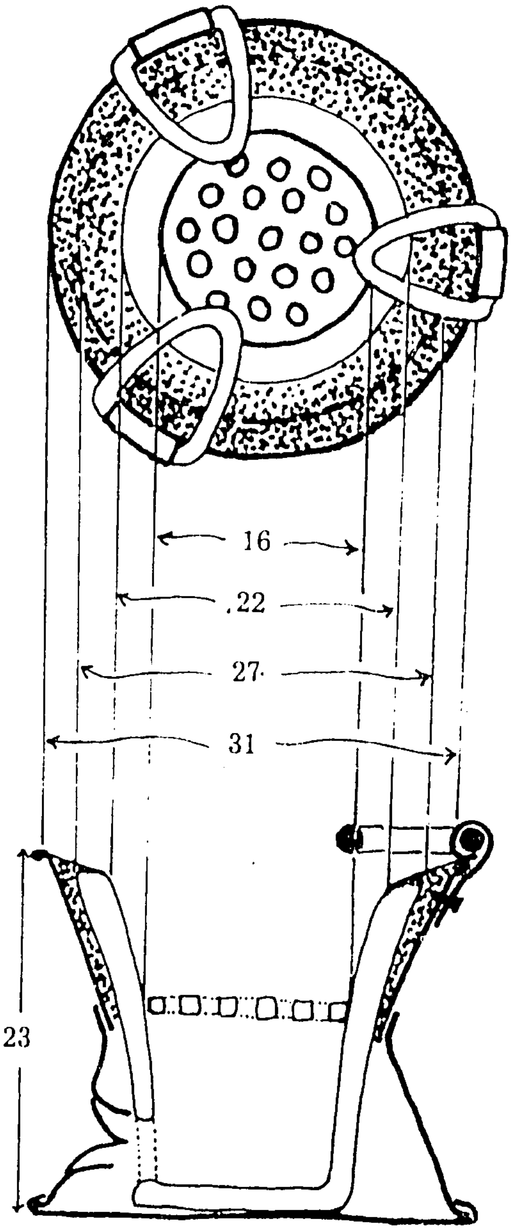


Fig. 2 The Kenyan Ceramic Jiko

II. MAKING THE METAL CLADDING

2.1. Tools and materials

The metal cladding is commonly made by the informal sector stove makers who have recently been taught to fabricate them to certain specifications.

The tools required are the usual blacksmithing tools including:

a) Ball pein hammers, 1 – 3 kg

b) Cold chisels

c) Six-foot length of rail

d) Tinsnips

e) Rivet snups

f) A pair of dividers/calipers

g) Blacksmith's square and tape.

Fig. 3

Shauri Moyo fundi cutting sheet metal with tinsnips.

2.2. Production process

The cladding for a standard jiko takes a skilled artisan about 2 – 3 hours to produce using the following method:

a) A piece of sheet metal is prepared for rolling. This requires measuring out, flattening and straightening the sheet with a leaf spring tool on the rail. The sheet is cut to size and the air inlet vent marked and cut out.

b) On the edge of the rail the sheet is shaped into a cylindrical form using a hammer. If the "bell bottom" shape is desired, then 2 semicircles are shaped into funnels and joined together.

c) The bottom is then covered with another scrap using a simple round joint.

d) Three pieces of round bar are measured and shaped into pot rests.

e) The pot rests are fixed into the top of the cladding using rivets and a hinge made out of flat bar or 1.5 mm sheet metal.

f) Handles and legs are riveted to the sides of the cladding.

To produce a standard cladding according to specifications, some artisans have been taught to use an assembly line method. Each artisan specialises in the production of a particular part (see next page) and works on improving the finished quality and rate of output. The parts are then assembled by other artisans for sale.

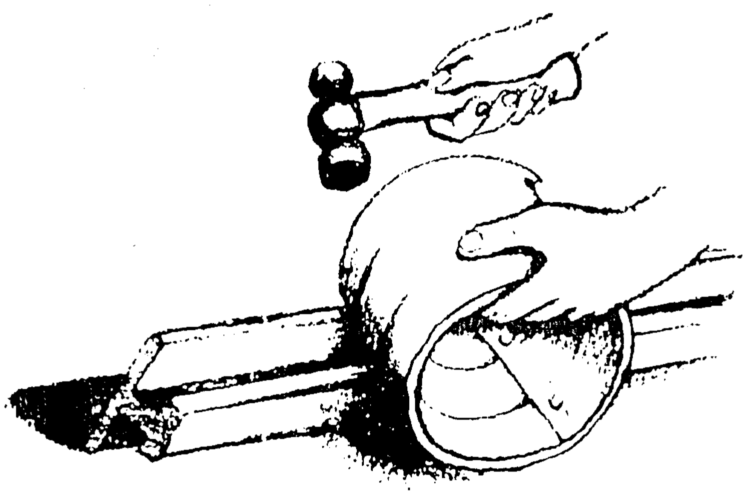
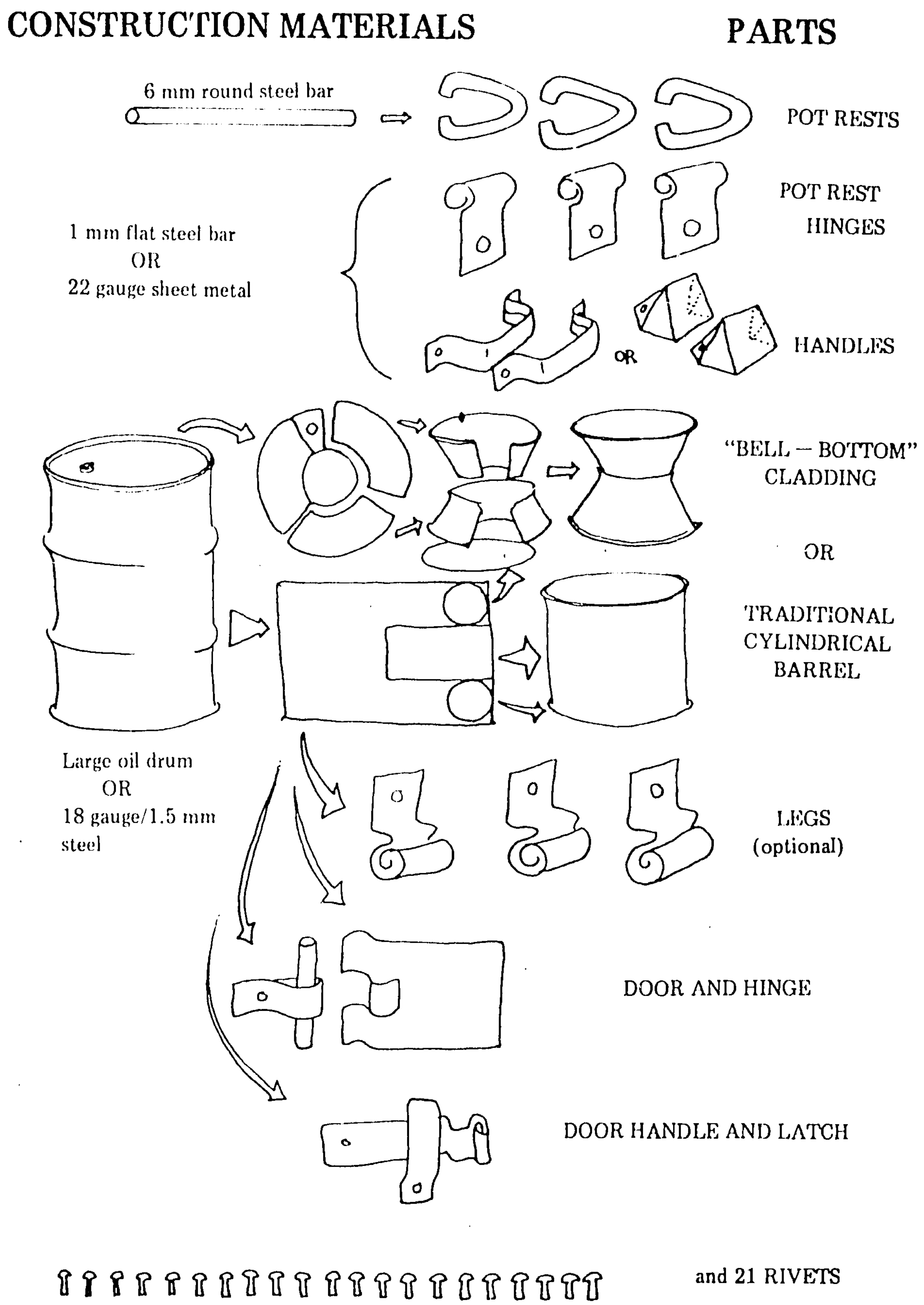


Fig. 4

Folding the edge so that the cylinder can receive a round joint. The edges of the bottom will be hammered around this bend to lock the bottom in place.

Metal Parts for the Jiko Cladding



III. MAKING THE CERAMIC LINER

3.1. Materials and tools

Materials needed for making the ceramic liner and grate are clay and fuel for firing. The section entitled "Formulating a clay body" gives details on choosing clays. Fuels that may be used include firewood cut in sticks smaller than 5 cm diameter, rice husks, coffee husks (or other agricultural wastes,) sawdust, wood-chips, bamboo, gas, electricity and oil.

Fig. 5a Pounding stick

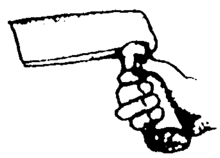


Fig. 5c Knife used in Thailand for carving the tops of liners.

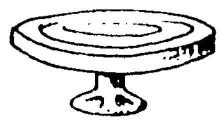


Fig. 5d Turntable

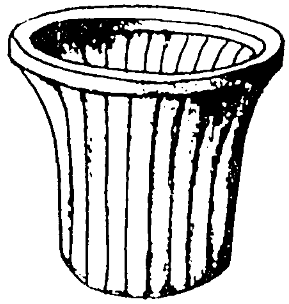
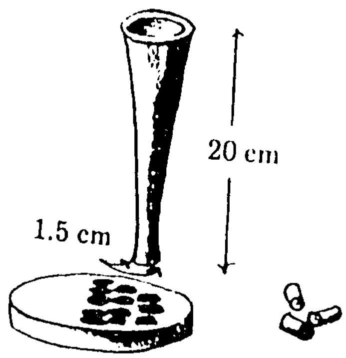


Fig. 5b The mould can be made from wood (shown), cement, or fired clay. It has no bottom.

Fig. 5e Grate hole punch. Pellets from the grate holes come out of the top.



Tools may be simple or sophisticated. For mixing, a pounding stick (fig. 5a) or a pugmill (a motorised mixing and deairing machine) is utilised. Forming tools consist of a mould (fig. 5b), cutting knives (fig. 5c), a turntable (fig. 5d), and a grate hole punch (fig. 5e).

3.2. Production process

It is important to realise that the ceramic liner can crack or break down due to mistakes in any part of the production process: a bad clay mix, unnecessary stress in the forming, transport, drying, or under/over-firing. Careful attention must be given to every step.

3.2.1. Formulating a clay body

The ceramic liner requires an earthenware clay body capable of withstanding the considerable thermal stress of a heating/cooling cycle that reaches 800° C at the inside walls. Clay, properly formulated and mixed, should be semi-plastic to plastic (a coil should bend without cracking) and have a wet-to-dry shrinkage range of 5 – 10% (see fig. 6). In formulating a clay body, the logical place to start is with clays that produce the strongest cooking pots in a given area, but it will be necessary to experiment with additives to achieve the best thermal resistance. Check with potters, brickmakers, farmers, and dam and roadbuilders about sources of clays. Only large sources of clays should be considered, enough to provide several years' worth of material.

Plasticity, the ability to bend without cracking, is evidence of a balanced distribution of particle size and a homogeneous dispersion of water. Finer clay particles have more surface area per mass than larger ones; therefore attracting and holding more water. As the water evaporates, a vacuum is created and the particles are pulled together – and where there was more water, there will be more shrinkage. Clays of different particle size distribution and/or moisture content will have different shrinkage rates and percentages.

Shrinkage can be measured by making a little test plate of working wetness clay, 6 cm x 15 cm x 2 cm.

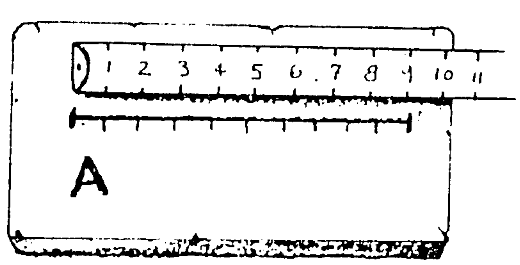


Fig. 6 Shrinkage test. This clay has shrunk 9%.

Mark a 10 cm line into the surface. Measure the line after drying and again after firing (see fig. 6). It is necessary to know the shrinkage expected in your clay to calculate the size the liner should be made wet, and will be the right size after firing.

Following are three case histories of claybodies that work. Each varies in content but arrives at a formula that provides wet and dry strength, fired strength, and high porosity. Whatever method is used, it is important that the clay be as smooth as possible, well mixed, and without rocks or organic matter.

a) Potters throughout the world mix their clay body from different types of clays to achieve desired plasticity, shrinkage, and strength for a specific firing temperature. Ilesi Pottery, in Kakamega, Western Kenya uses four types of soils:

1) A dark riverine highly plastic (sticky) clay for mouldability and wet/dry strength.

2) A grey/white kaolin (kaolinite) clay that shrinks less and gives hardness after firing. Too little of it and the ceramic crumbles on the surface.

3) A sandy soil (decomposing granitic sand with clay in it) that reduces shrinkage and enables fast, even drying by nature of having a larger grain size.

4) A prize secret ingredient clay that lets the liner dry immediately in the sun without cracking.

b) In Thailand, and at Jerri International, Nairobi, grey riverine plastic sandy clay is mixed with 40% black rice husk ash, a ratio of 3:2 by volume. Grasses have a high silica content: bamboo or cornstalk ash could be substituted for rice husk ash. The black ash is only partially combusted so that the carbon granules add porosity to the clay body as they burn away in the kiln.

c) It is common practice throughout the world to add either sand or grog to the clay. Grog is low-fired crushed ceramic, usually from broken pottery shards of the same clay. A 20 – 30% grog content in a claybody will increase strength and porosity of the clay, decrease shrinkage, and facilitate even drying. A similar addition of sand, however, will decrease shrinkage, facilitate even drying, and increase significantly the thermal resistance capacity of the finished piece. Tests done at ITDG show no proof that an addition of grog alone will increase resistance to thermal shock. Materials recommended for improving thermal stress resistance are: fine silica sand;
mica or micaceous clay;
soapstone powder; and
rice husk ash (as mentioned previously).

3.2.2. Mixing and storing the clay

It is desirable to arrive at a method that produces consistent results with the least work.

a) Ilesi Pottery digs their clays damp and mixes them on a large (6 foot diameter) flat stone in the shade. Two parts by volume of the dark plastic clay is pounded out with a heavy-bottomed pole (see fig. 5a). Two parts of the kaolin (described as "limey") clay is laid on top and pounded in. The clay is shoveled into the center, and pounded out again. One-half part of the sandy soil is sprinkled on top, and pounded in until clay is well mixed. Clay ready for moulding is stored under plastic bags or wet fibers.

b) In Thailand, the riverine clay is dug and heaped in the sun for at least several days. It is then put in pits, saturated 100% with water, and left to soak for several days. The ash is added in the soaking or wedged in (by hand or with a pug mill) as the clay is prepared for moulding. In a pit of 2 cubic meters, the clay may be covered with black ash to a depth of 25 cm.

All 16 Thai Bucket industries in southern Thailand visited by the MOE team in 1982 had pugmills for mixing and deairing clay. In northern Thailand, where industries are smaller, a buffalo is harnessed to a center post to tread in circles in the clay pit. It may also be mixed by human feet. Clay ready for moulding is stored in mounds under damp hessian bags.

Similarly, at Ruthigiti Village (clay/hay mudstove) Jiko Workshop in Central Kenya, dry lumps of clay are covered with water in a large circular sheet metal trough and left to soften. Excess water is boiled out in the mornings and the clay is mixed with poles and a pitchfork. Clay is kept damp by covering with water overnight or "mulching" with damp hay.

c) It is common in the United States and Britain, where clay and other ceramic materials are mined and exported on a large scale, to mix precise quantities of dry powdered ingredients and then add water. There is some advantage in consistency of measurement using dry weight, but formulas are more critical when glaze technology and higher temperatures are involved. Mixing is done by hand or foot, by pug mills, electric lay mixers or electric dough mixers designed for bakeries. When potter's clay is made by mixing dry powders, enough water should be added so that the clay feels slightly soft. Clay is kept damp in plastic bags or bins and left to age, to give time for the water to disperse between all the particles and for organic activity to break them down even farther. Three days' wait is minimal; one to six months is highly recommended. This aging process is sped up by the addition of a small amount of urine or sugar.

In India, potters dig and mix only the clay they will use that day. In China, potters dig, mix, and store clay for their grandchildren.

3.2.3. Moulding and grate making

The clay liner is moulded inside a single wall mould using the potter's hand. See fig. 7 for moulding sequence.

1) The mould's linner walls are sprayed with water and then coated with white ashes from the kiln to prevent clay from sticking.

2) The potter takes about 6 kg of the clay mixture and rolls it into a ram's head shape. The mixture is shoved into the bottom of the mould and pressed firmly with an open palm.

3) A fist is sunk through the center.

4) The clay is drawn up the inner walls of the mould with the edge of the hand formed like a scoop.

5) The ash box and firebox are carved out.

6) The top rim is reinforced with extra thickness of clay and then compressed.

7) The thumb is tucked in and

8, 9, 10) Swipes of the wet hand compress the floor and walls.

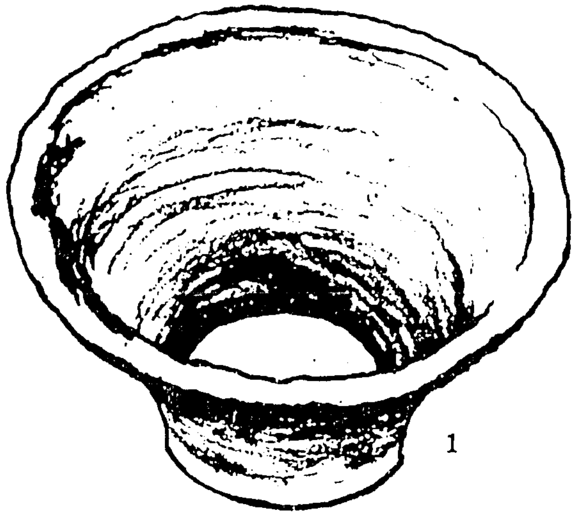
When the proper inner form has been obtained, the moulded liner is removed by turning the mould upside down, resting the liner on its rim, and pulling the mould off upwards. This process takes a skilled potter three minutes per liner.

A half-liner uses 4 kg of clay and a smaller mould the same dimensions as the top half of the full liner mould.

A pottery grate is made by flattening the same clay mixture into a circular disc of 1.5 cm thickness. Grate holes of 1.5 cm diameter are made with a punch (fig. 5e).

A 15 cm diameter grate has 19 of these holes punched, in rows of 3, 4, 5, 4, 3 holes each. Twenty five to thrity percent of the surface area should be perforated for a charcoal grate.

Moulding



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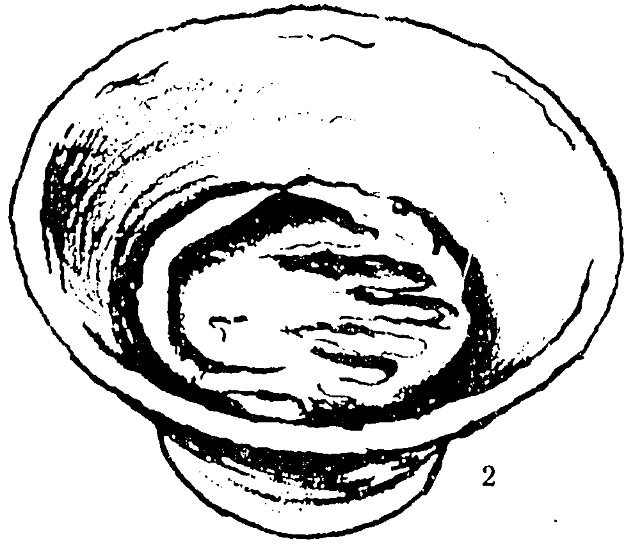

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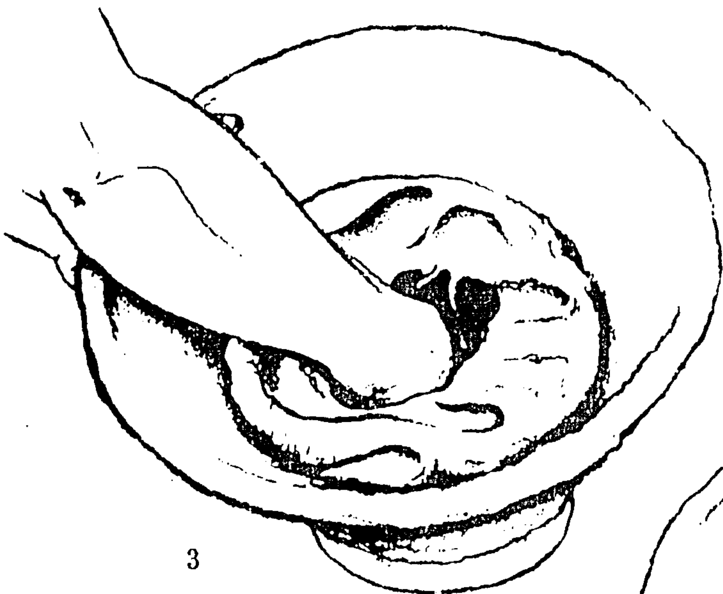

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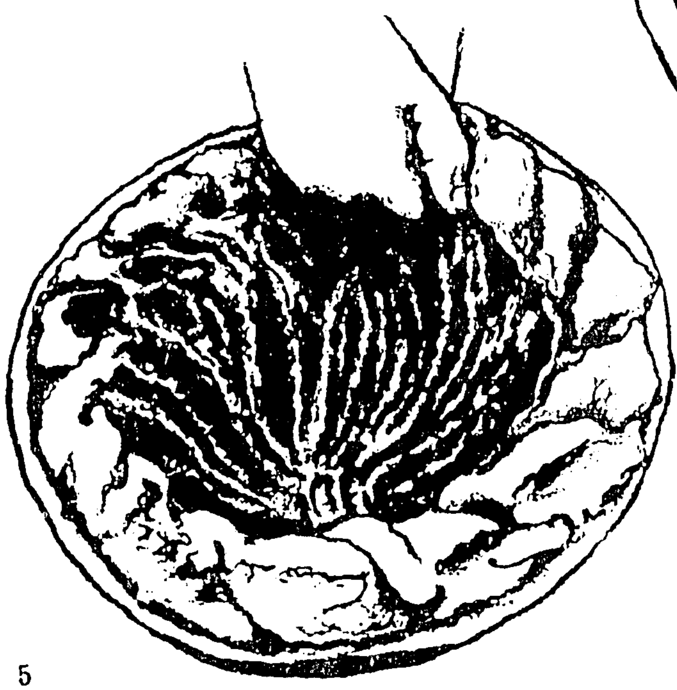

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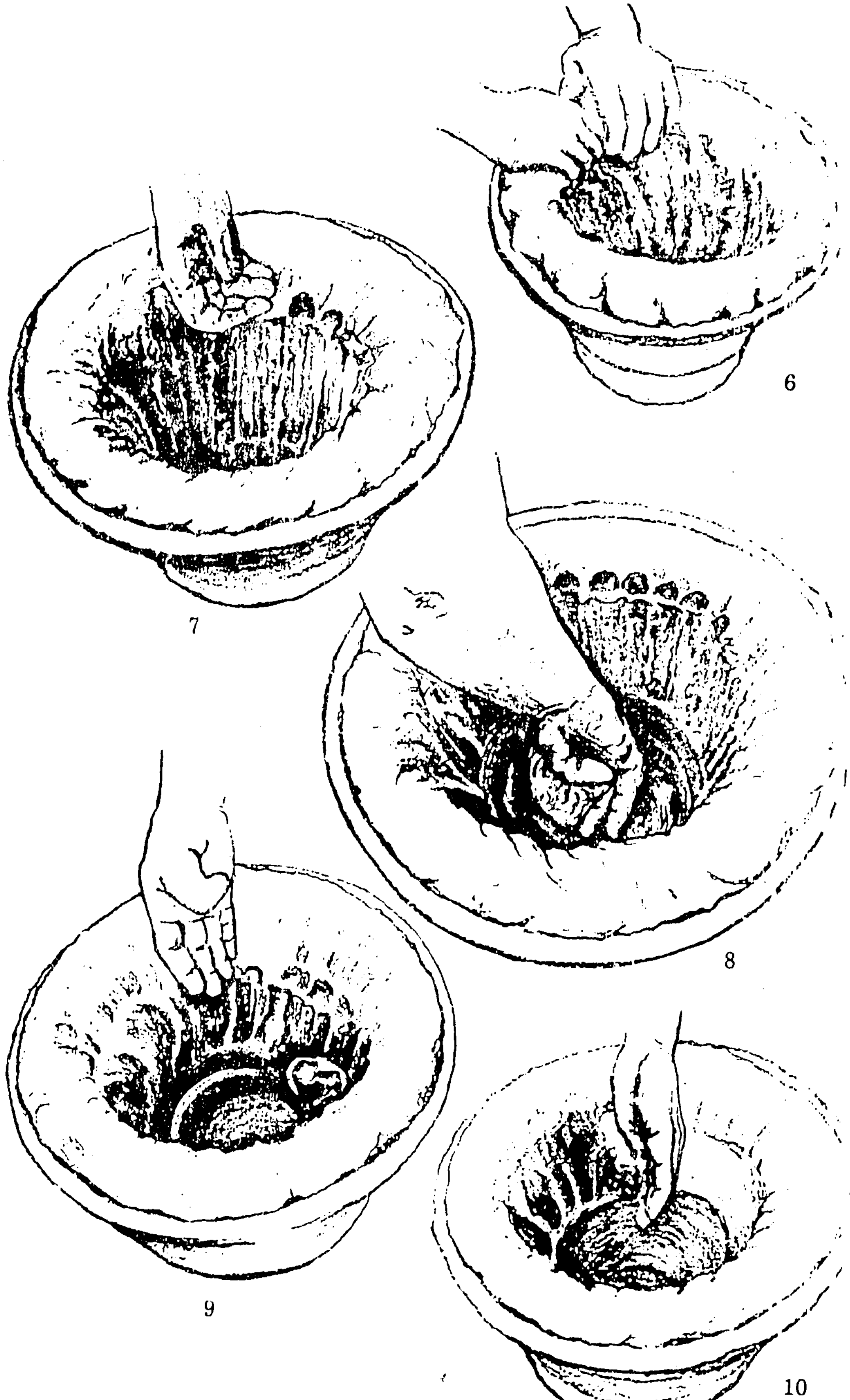


Fig. 7

A thicker grate will last longer. Ceramic pieces in Thai Bucket stoves for industrial use are over an inch thick.

3.2.4. Drying and cutting

Both the grate and the liner should be slow-dried in a shaded place, protected from strong breezes. They should be disturbed as little as possible in the early stages of drying. When approaching a damp-but-stiff leather-hard state, they can be turned over. This is when the ashbox door/air inlet is cut and the top trimmed evenly to size. The drying of the liners can be slowed by covering with damp fibers, cloth or plastic. Depending on air temperature and humidity, the liners will take 7 – 12 days to dry properly. To check for dryness, press the clay moisture in it. Final drying can be done in the sun several hours before placing them in the kiln.

against the hollow of your cheek. If it feels cool, it has...

3.2.5. Firing

The best firing temperature is 900°C. Well-fired stoves are porous for resistance to thermal shock but have good structural strength. Stoves fired too low will be quite porous and have a tendency to crumble on the surface. Stoves fired too high will start to vitrify on the surface, which will then expand and contract upon heating at a different rate than the inside, causing chips to flake off.

Porosity can be tested by rubbing a few drops of saliva or water on the (cool) surface. A material of high porosity will absorb it immediately. The more vitrified (glass-like) a surface is, the longer it will remain shiny-wet. This indication of porosity is a good way to test for consistency of firing temperature, both in different placements in the same kiln firing and from fire to fire, provided the same claybody is tested.

The simplest kiln is an open-air arrangement used by traditional potters all over the world. Here rocks or broken potte are arranged to make a kiln floor. The rocks are covered with closely spaced fuelwood sticks on which the clay pieces are assembled in a carefully arranged heap to a height of 1.5 meters (see fig. 8a). The heap is then covered with wood or dry grass and fired for 1 – 2 hours. Woodchips, twigs, bamboo, rice husks, coffee husks, and sawdust also make good firing fuels with this method. They can penetrate into the spaces between the pots and provide more uniform temperatures in the kiln. Fuel is added as required at the top during firing. Kakamega, Kenya potters add green grass on top as a burn-resistant ceiling. As it dries and burns it is covered with more green grass. In other parts of the world it is common to place large pot shards as a ceiling.

Stoves can also be fired in a brick pottery kiln using *thinly chopped firewood* or any of the previously mentioned fuels. Improved kilns range from simple wall enclosures with air inlets in concentration on the bottom to complex multichambered downdraft kilns of the Orient. (see figs. 8b-e.) If the kiln is properly designed and operated, these methods of firing are more fuel-efficient than the open-air kiln, and provide more consistent temperatures and results. Electric (fig. 8f) and gas-fired kilns may be easier to regulate but are often more expensive. Firing with fuelwood is preferable where this is in good supply and efficient pottery kilns exist.

A kiln should be designed around the size and shape of the highest reasonable number of stoves to be fired and the nature of the fuel available. Wood-fired kilns are stoked manually, and pellet fuels (husks, sawdust, wood chips) are packed around the pots or fed into the firebox by means of hoppers. For more information on ceramics and kilns, the authors recommend Pioneer Pottery by Michael Cardew, *Kilns* by Daniel Rhodes, and UNIDO/United Nations Development Program Technical Report No. 30, *Manual for Basic Kiln Design and Construction*, by Hans G. Felbier.

Observe and talk and work with local potters and brick and tile makers, they may be capable of producing the ceramic liner. Once skills are well established, it is possible to produce 3000-5000 units per month in a cottage industry with 10-15 employees.

A range of Kiln options

Fig. 8a Open air kiln. The rocks serve as a grate, distributing air to the center for more even combustion. Much heat is lost off the top and sides; a large number of the pots may underfire as the temperature range is 700-900° C.

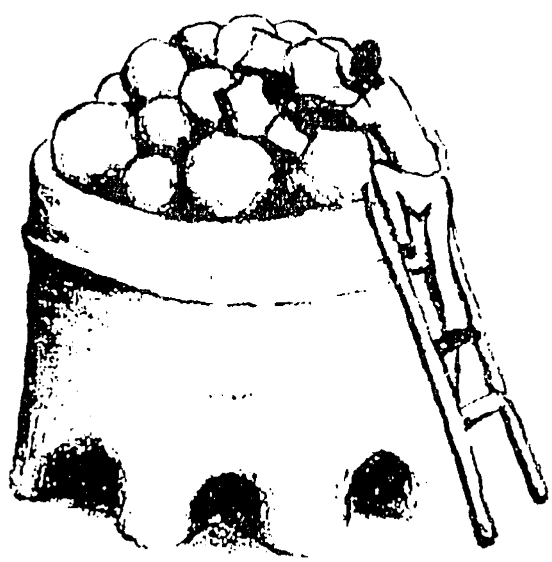
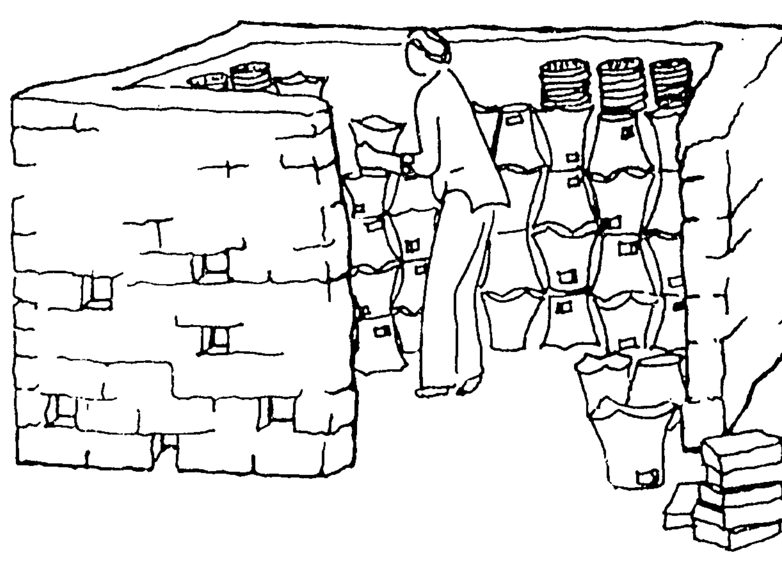


Fig. 8b Simple walled kiln in West Africa. A "ceiling" is formed with shards of broken pots. Fuel is fed from ports along the bottom.

Fig. 8c

Simple walled kiln in Thailand. Note stacking of liners. The door will be bricked in, air enters through ports on all sides. Sawdust is packed between the clay liners, ignited with a fire on top and left to smolder. More fuel is added on top as needed.



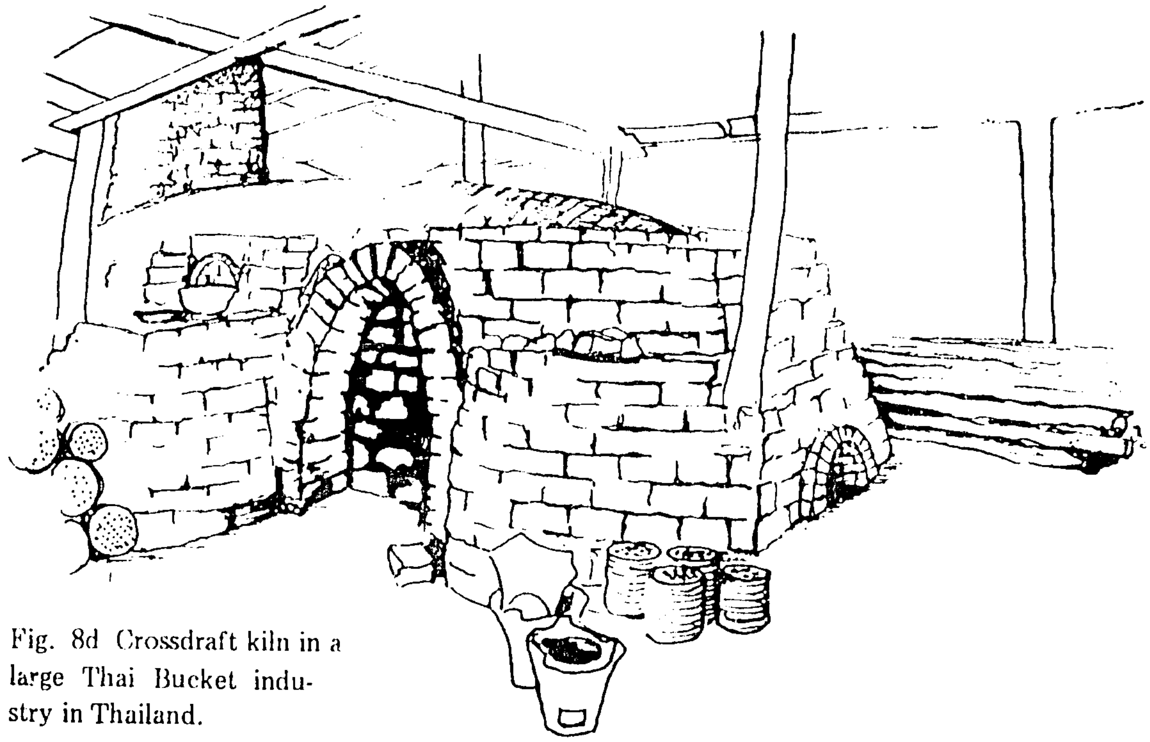
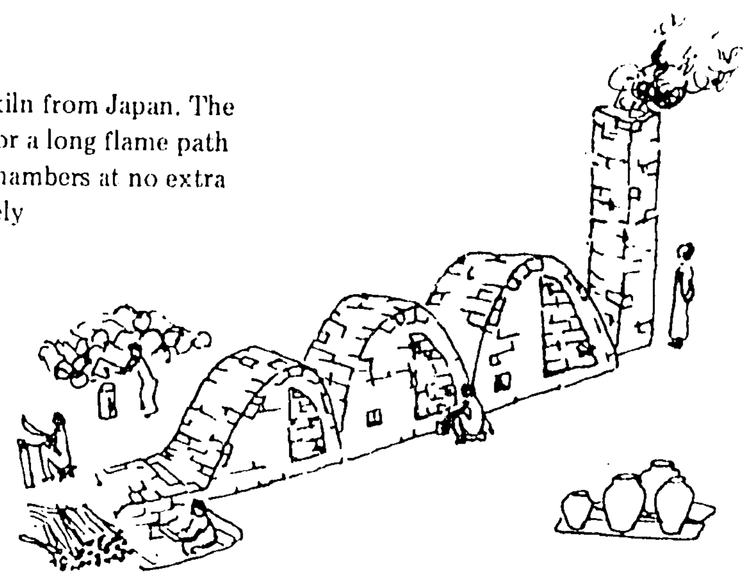


Fig. 8d Crossdraft kiln in a large Thai Bucket industry in Thailand.

Fig. 8e Climbing chamber kiln from Japan. The segmented chambers allow for a long flame path which preheats succeeding chambers at no extra cost. These kilns are extremely fuel efficient and provide the option of different firing temperatures in each chamber. Some, centuries old, are still in use.



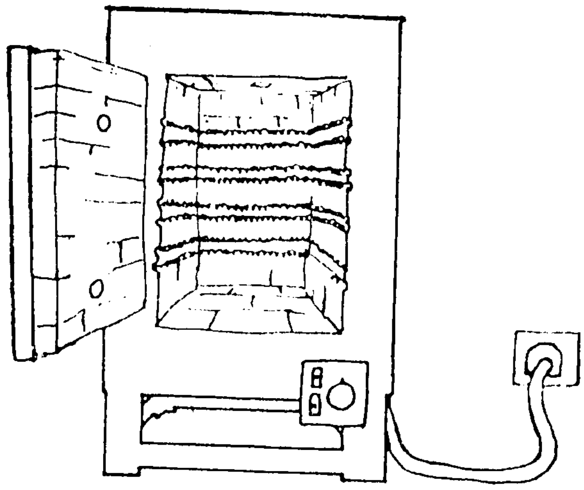
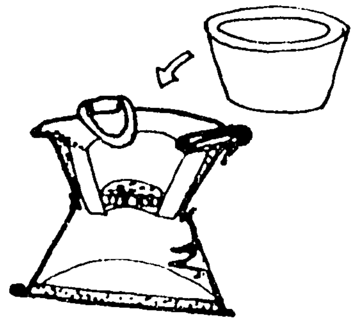


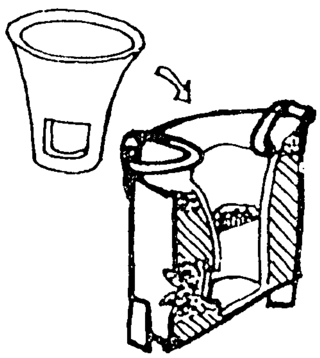
Fig. 8f Electric kiln. Lined with highly insulating, porous "soft brick," it provides even and predictable heating, but the elements are expensive, fragile and wear out regularly.

IV. ASSEMBLY AND OPTIONS

Assembly involves anchoring the ceramic liner firmly into the metal cladding. One way of doing this is to coat the outside surface of the liner with a mixture of one part cement of 3 parts vermiculite (an exfoliated rock. Diatomite may be used instead, or ash, although ash is not as efficient an insulator). The liner is then slid snugly into a "bell-bottom" metal cladding. The c/v mix provides extra and useful thermal insulation and cushions the liner from knocks.

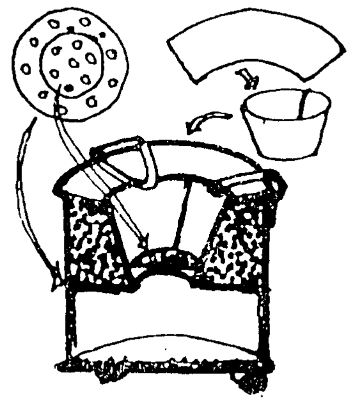
A half-liner and grate are sufficient for the "bell-bottom" cladding. Put a layer of c/v on the floor of the jiko to protect it from corrosion due to hot coals and ashes that fall. This design gives more room for air to circulate, easing ignition.





Another assembly method is to insert the full ceramic liner into a traditional metal jiko of appropriate dimensions. The space between the liner and cladding should be filled with ashes or other insulation, sealing around the air inlet and the top 3 cm of the jiko with a cement mixture.

The c/v version may be more appropriate if:
cement is available, pottery is unavailable, or a less expensive option is prefered. The jiko's efficiency can be equally improved with a wall of cement/vermiculite at about a third the cost of installing the pottery liner. Its lifetime, however, is one fourth to one half as long.



It is advisable to cement in the ceramic grate with cement or clay to keep it from breaking during post-production transportation. A ceramic grate makes a stove more efficient, but is also more fragile than a metal grate (which wears out from corrosion every 3 -- 6 months).

It is very important that cement be kept damp for the first 7 days for curing to establish a strong bond. Moisten twice a day for a week.

V. HOW TO USE THE JIKO

To light the ceramic jiko, place charcoal on the grate and ignite with paraffin or wastepaper from below in the ash chamber. A fire can also be built on the grate with twigs and then charcoal, maize cobs, or coconut shells added for cooking. The air inlet door should be kept open while igniting, and it is preferable to do this outdoors to avoid smoke in the kitchen.

Operating the stove skillfully yields the best performance in both fuel use and cooking. Proper operation involves:

a) Estimation of the time stove is to be used in order to determine the initial charge of charcoal. For short duration cooking (less than one hour), fill only half the firebox with fuel. Try to avoid having too much charcoal left after cooking as this is lost, since it is inconvenient to extinguish charcoal.

b) When pot contents come to boil, it is good practice to close the inlet door and slow the stove to low power output. The boiling/simmering process will be sustained even with the air door closed. Closing the air inlet door results in lower fuel consumption rate, less water evaporation in the pot, and reduced carbon monoxide emission. This leads to overall fuel savings.

c) When recharging the stove, add only two or three pieces of charcoal. Filling the stove completely slow down the power output as the full charge takes time to catch fire.

d) Use of flat-bottomed metal or clay pots to enhance the efficiency of heat transfer to the food.

e) Use of pot lids. This greatly reduces heat loss through evaporation, which can account for a pot *without* a lid taking *twice* as long (and twice as much fuel) to boil as a pot *with* a lid.

f) Use of stove in sheltered places. Strong draughts inhibit proper heat transfer to the pot and enhance convective heat loss around the pot.

g) Extinguishing left-over charcoal. Dump the charcoal out and cover it with a pot turned upside down or lightly sprinkle it with water. Do not pour water directly into the jiko.

The jiko should not be dropped or handled roughly as the liner is breakable. Under normal use, the liner may show small vertical cracks along the walls but it should continue to work perfectly well for months afterwards. When the liner finally breaks and falls apart, it can be replaced by jiko repairers. A jiko under regular use needs a new grate every three to six months. This could be a ceramic or metal grate.

The jiko should be stored out of the rain to prevent the metal from rusting.

VI. GENERAL NOTES

The ceramic jiko described here is in its early stages of dissemination in Kenya. Therefore, a great deal more remains to be learned from field experience. It is not yet clear what the price structure will be after more producers come into the market. Another problem is quality control. At the moment demand exceeds supply for these "new improved" jikos and consumers do not know how to discriminately choose a well-made product. Hence, hastily made jokos (such as a pottery liner in the cladding without cement/vermiculite) that are less efficient and less durable sell for 2 – 3 times what a quality stove could sell for and still earn him a healthy profit. There are ongoing efforts to assess alternative production schemes and also to evaluate the total impact of the stove on household demand for charcoal.

Although present consumers of charcoal may find their fuel needs cut in half, it is possible that the introduction of such a highly efficient stove will hasten the increasing *overall* demand for charcoal as non-renewable fuels become more expensive and these consumers switch to charcoal. Extensive tree-planting for this purpose and efficient charcoal conversion methods (such as gasifiers yielding producer gas as well as charcoal) will enable fuel needs to be met.

It is envisaged that mass acceptance of this stove will help generate employment oppportunities within the urban and rural stove making industries in Kenya. The economics of setting production units for *stoves only* has not yet been determined. Experience shows that stove production can easily be combined with other pottery or hardware production, especially as a new product where the financial risk is less to the artisan. If possible, it is more economical to combine the ceramic production activity with metal cladding and assembly work under one plant.

Stoves can also be fired in a brick pottery kiln using *thinly chopped firewood* or any of the previosly mentioned fuels. Improved kilns range to complex multichambered downdraft kilns of the Orient. (See figs. 8b-e.) If the kiln is properly designed and operated, these methods of firing are more fuel-efficient than the open-air kiln, and provide more consistent temperatures and results. Electric (fig. 8f) and gas-fired kilns may be easier to regulate but are often more expensive. Firing with fuelwood is preferable where this is in good supply and efficient pottery kilns exist.

A kiln should be designed around the size and shape of the highest reasonable number of stoves to be fired and the nature of the fuel available. Wood-fired kilns are stoked manually, and pellet fuels (husks, sawdust, wood chips) are packed around the pots or fed into the the firebox by means of hoppers. For more information on ceramics and kilns, the authors recommend *Pioneer Pottery* by Michael Cardew, *Kilns* by Daniel Rodes, and UNIDO/United Nations Development Program Technical Report No. 30, *Manual for Basic Kiln Design and Construction*, by Hans G. Felbier.

Observe and talk and work with local potters and brick and tile makers, they may be capable of producing the ceramic liner. Once skills are well established, it is possible to produce 3000 – 5000 units per month in a cottage industry with 10 – 15 employees.

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