PART ONE

BASIC PRINCIPLES

A. Firewood as a fuel

Firewood was one of the first fuels to be used for cooking and heating purposes, since it was readily available and relatively easy to ignite. Even today about half of humanity, living for the most part in developing countries, depends on wood for survival. Excessive use has, however, resulted in a serious depletion of the earth's forest reserves which, besides causing considerable human suffering, has led to soil erosion on a massive scale, the silting of water reservoirs and the rapid expansion of arid and desert areas.

If we are to curb these catastrophic trends before it is too late it is vital to promote a more rational utilisation of primary and renewable energy geared to the specific needs of the people. The scope for wood saving is immense when it is considered that, in many parts of the world, up to 90% of all the wood cut is used solely for cooking and heating purposes.

Prior to the industrial revolution, problems similar to those currently facing rural populations throughout the Third World were encountered by our ancestors in Asia, Europe and North America. Their experience, gained over centuries, reveals a wealth of human ingenuity in the efficient use of wood that may be usefully applied to meeting the needs of the poor in developing countries.

Naturally, the progress made by science in determining the best methods of extracting thermal energy from various fuels should not be overlooked. Where appropriate, traditional implements may be adapted or improved in the light of modern technology.

Ultimately, it should be possible to produce designs for stoves that are simple, highly efficient, and capable of being manufactured by village craftsmen using — with the addition of some metal components coming from outside — materials that are available locally. The cost of such stoves should be low but they must, nonetheless, be of good quality and give satisfactory results. Governments may assist in this respect by means of appropriate economic measures which will not only ensure that rural communities enjoy efficient, low-cost cooking facilities, but also secure the protection of forests.

B. The essentials of efficient stoves

If fuel saving is to be achieved there are two essential principles that must be incorporated into any stove design. The first is the complete combustion of the fuel. A simple means of judging the efficiency of a stove is to observe the colour of the smoke it gives off. If this is darkish it means that part of the fuel is not being consumed and is escaping in the form of unburnt particles. A more detailed analysis of the smoke leaving a stove may be carried out with the aid of Orsat measuring equipment.

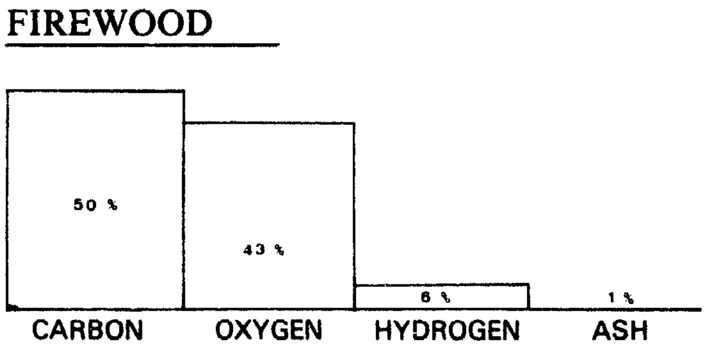
The second basic requirement of an efficient stove is that the maximum use should be made of the heat generated for the purpose intended. As far as cooking is concerned, the efficiency of a stove is measured by comparing the total volume of heat generated in the fire-box with that absorbed by the contents of the pot. This measurement is discussed briefly towards the end of this booklet.

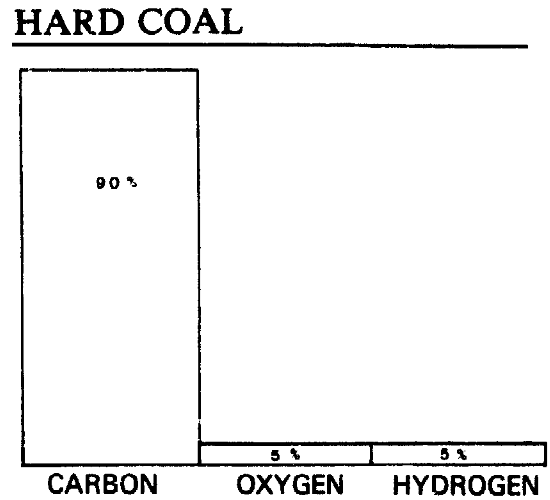
C. The main characteristics of firewood

Composition

In order to extract maximum heat it is important to understand the particular

Figure 1 *Chemical composition of firewood contrasted with that of hard coal.*





characteristics of firewood that distinguish it, especially as far as combustion is concerned, from other fuels with organic origins such as peat, lignite, hard coal or crude oil (see Figure 1).

The thermal value of firewood lies in the high proportion of combustible gases, which should be completely burnt in the stove rather than allowed to escape with the smoke. Indeed, it may be said that it is not so much wood that burns as the gases it releases! Due to its high oxygen content, firewood requires less air for combustion than most other fuels, and careful regulation of air input is thus important if turbulent, and consequently inefficient, burning is to be avoided.

Heat value

The heat value of a fuel is usually defined as the quantity of heat extracted from 1 kg of matter when it is burnt. It is usually expressed in kilo calories (kcal/kg) or kilo joules (kJ). The heat value of any given variety of wood depends on its density and water content. For example, well-seasoned hardwood with 15 to 17% moisture content has a heat value of about 3,700 kcal/kg or 15,500 kJ/kg. This figure is approximately halved with wood waste in the form of bundles or faggots.

Density

In Europe, hornbeam, beech, ash and oak, which all have high densities, are considered to be among the best varieties for firewood purposes, while soft and resinous species such as pine and spruce, with lower densities, are preferred for kindling. Unfortunately, in developing countries such a wide choice is not always available, and people have to make do with whatever species are available locally. This fact should be borne in mind by those responsible for tree planting programmes, who sometimes tend to place too much emphasis on resistance to climate and rate of growth and overlook the importance of the heat value of the trees planted.

Moisture content

Besides increasing the danger of chimney fire,[1] an unduly high moisture content — about 20% and above — slows the combustion process, lowers the temperature in the fire-box and generally renders it difficult for volatile particles to burn completely

As can be seen from the following table, it is a waste of energy to burn newly cut firewood without first reducing the moisture content through some form of drying procedure:[2]

1. By causing deposits of creosote and tar in the chimney.
2. In Europe, newly cut firewood contains about 50% moisture. Chopped, covered and dried in the open air for about two years, it still contains 15 to 17% moisture. To burn firewood containing a greater percentage of moisture is a waste of energy.

Figure 2 *The heat value of firewood in relation to moisture content.*[3]

	kcal/kg	kJ/kg
Newly cut wood	1,950	8,200
Wood well dried in open air	3,700	15,500
Wood dried in oven	4,500	18,800

Simple measures, like stacking some wood close to the stove, may further reduce moisture content and thereby increase the heat value of firewood.

D. The process of wood combustion

Basically, firewood contains two combustible substances: carbon and hydrogen. Combustion takes place when the wood is heated, causing these substances and their derivatives to escape in the form of gases and mix with oxygen from the air. This complex process is accompanied by a strong generation of heat, and a flame is produced when the wood reaches a temperature of about 250°C.

Optimal size of firewood

Wood is a good insulator, which means that heat tends to penetrate it very slowly. Thus, the thicker the wood, the longer it will take for its inner layers to gasify and generate heat. For this reason, when cooking it is recommended to use wood with a small diameter, if possible not surpassing 3 to 4 cm. Small pieces of wood release gases easily and give off a steady flame.

Air supply

To ensure proper combustion it is necessary to provide an adequate, but not excessive, supply of air. In practice, not all the air entering a stove is used in the chemical process of combustion. Some of it simply passes through and it is thus necessary to admit more air (known as excess air) than is theoretically needed. Usually, for the correct functioning of a stove the ratio of excess air[4] should be between 1.5 and 2.0. This being said, however, it is important to regulate the flow of air according to the requirements of each stage of combustion.[5]

E. The stages of wood combustion

For a better understanding, the process of wood combustion may be divided into three stages:

Stage 1

Moisture in the wood begins to evaporate and the temperature rises to about 100°C. The higher the moisture content of the wood, the more this initial stage is prolonged with consequent loss of energy.

Stage 2

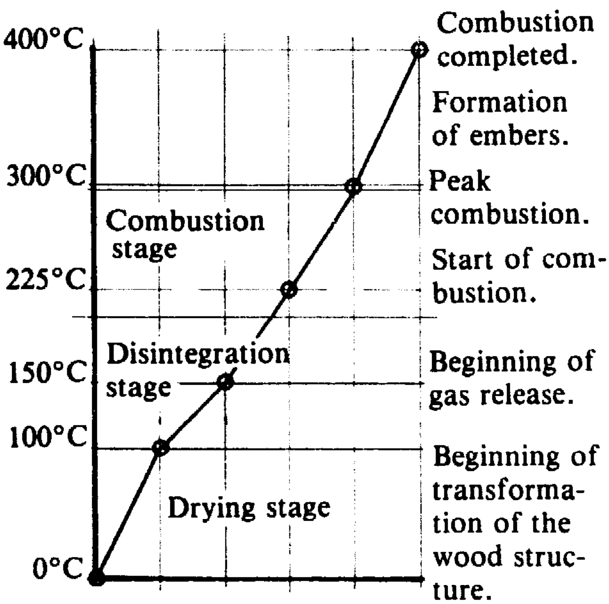
As the temperature rises, the second stage begins with decomposition of the wood. At a temperature of about 150°C, the release of gases begins and semi-liquid tar starts to appear. The wood smoulders and gives off dark smoke and a strong smell. This stage should be avoided by maintaining a steady flame from the outset of combustion as the smoke indicates that valuable particles are being lost. In addition, greasy tar accumulates in the stove and chimney and creates a danger of chimney fire.

3. Source: *Chauffage Moderne au Bois*, L'Office Forestier Central Suisse, CH-4500 Soleure.
4. Calculated by placing the volume of all air actually admitted to the stove over that theoretically required for combustion.
5. At first a liberal amount of air should be supplied. At the peak of combustion and later, towards its completion, the flow of air should be gradually reduced.

Stage 3

The third stage, termed 'full combustion', commences at around 225°C and reaches a peak at about 300°C. Above this temperature the wood is gradually transformed into glowing embers. Between 260° and 290°C there is a tendency for combustion to become over turbulent. If this occurs it should be slowed down by reducing the air supply, the draught or both. Figure 3 summarises the various stages of combustion in graph form.

Figure 3 *The stages of wood combustion.*



Source: Op. cit. *Chauffage Moderne au Bois*, p.4.

Flame temperature

The temperature of the flame given off during combustion may easily exceed 800°C. Naturally, if a pot is surrounded by flames, such intense heat will cause food to boil rapidly and result in efficient use of the wood burned. If, however, the flames touch only part of the pot's surface, the effect of heat absorption is considerably diminished. This partly explains the popularity of open-fire cooking in developing countries and why, in Europe and North America, cooking pots were always lowered into the fire-boxes of wood-burning stoves to ensure direct contact with the flames and thus economise on fuel.

Fire-lighters

The art of making a good fire lies in producing flames at the very beginning of combustion. This may easily be achieved by using chips, small twigs or faggots of particularly dry and inflammable wood. A good fire-lighter is a piece of dry, resinous,[6] round-shaped wood of about 5 cm in diameter and splintered at one end in the form of a brush. This begins by burning like a torch but then settles down to produce a steady flame. Bellows are also very useful and should form part of standard stove equipment. Where they are not available, a long metal pipe, fluted at one end so as to enable air to be blown into the fire, may be used instead.

F. Primary and secondary air

The importance of secondary air

As has been seen, it is necessary to provide stoves with air in order to ensure proper combustion. When this air is supplied from below the grate it is known as **primary** air. If only primary air is supplied, as is often the case with small wood stoves, there is a danger of inefficient use of fuel in that there may not be enough air in the upper part of the fire-box to burn all the combustible gases released from the wood. To avoid losing these valuable gases, modern stoves — irrespective of size — often provide for a supply of **secondary** air in the upper part of the fire-box.

In the interests of fuel economy the models featured in this book adopt this important innovation and provide for a supply of pre-heated secondary air.

Pre-heating the air supply

As mentioned above, combustion requires

6. In Europe, fires are often started with dry coniferous wood which rapidly develops good flames and facilitates the burning of other varieties of wood.

a temperature of approximately 250 to 300°C. It follows that if the air supplied for combustion is not pre-heated in some way before it flows into the fire-box it may do more harm than good by **cooling** the gases and preventing them from burning. In practice, the problem only arises with the secondary air supply since primary air, which comes from below, is well heated as it passes through the hot, glowing embers that accumulate on the grate during combustion. Providing for the efficient pre-heating of secondary air is a more complex matter which requires more thought. The problem is somewhat easier to resolve in metal stoves than in clay or brick models, due to the greater heat conductivity of metals.

G. Winning acceptance for new methods

Despite considerable efforts to introduce improved stoves, cooking by open fire continues to be the most popular method in developing countries.

In many instances the underlying reason for this preference is not so much attachment to tradition, or reluctance to accept change, but rather, quite simply, that many of the suggested stoves have failed to give satisfactory service. Because of this, womenfolk have tended to reject the new innovations and continue with traditional methods which, for them, present distinct advantages that must be clearly understood by stove designers if more acceptable alternatives are to be developed.

Advantages of open-fire cooking

- —no expense is involved for the rural poor.
- —the only implements needed are three stones on which to stand the pots.
- —the cooking pot may be placed directly in the flames. If the fire is well managed and protected from wind, fuel efficiency is quite good.
- —by removing some of the wood from under the pot it is simple to regulate the heat and allow for simmering.
- —the 'three stones' system is flexible and can cater for any size of pot.
- —it is easy to use several pots over one fire, which is important for family cooking.
- —no maintenance or repair is necessary.
- —the firewood need not be cut into small pieces before use.[7]
- —after use, the fire may be easily extinguished with sand or earth and the unburnt branches kept for future use.

These advantages of open-fire cooking should be contrasted with the obvious disadvantages:

Disadvantages of open-fire cooking

- —it often represents a wasteful use of firewood and is, thus, a major cause of deforestation in developing countries.
- —open-fires are difficult to use in rain or wind.
- —the cooking pots are not stable; the user must hold them in place with one hand whilst stirring the contents with the other.
- —the smoke and heat causes serious eye and respiratory complaints. To cook over an open fire represents a real hardship to women.
- —there is a risk that the fire may get out of control and spread.
- —there is a danger of accidents, particularly to children.
- —it is difficult to maintain a steady flame.

Thus, if we are to popularise new cooking methods among women in developing countries, it is essential that the alternatives proposed should not only eliminate the disadvantages of open fire cooking, but also retain the **advantages**. In particular, it is important that new models should have a higher fuel-efficiency rate than the well-

7. The fact that the rural poor usually have no saws, wedges or good axes is often overlooked.

managed open fire discussed on pages 29 to 31. To date, this has rarely been the case.[8]

In the past, these considerations have tended to be overlooked and many of the new stoves proposed have proved to be of limited practical use in the field and have, consequently, failed to win the acceptance of rural populations.

In this context, we can learn much from the experience of our ancestors in Asia, Europe and North America who, by **gradual evolution**, have already provided solutions to most of the problems involved in the changeover from open-fire cooking to more efficient methods. Much of this basic and **proven** knowledge may be usefully revised and applied to the manufacture of stoves for developing countries.

Let us then briefly examine the steps that led to the abandonment of open-fire cooking in **developed** countries.

H. The evolution from open fires to modern stoves in developed countries

There are three basic factors which contribute to wastage of heat (and consequently energy) if cooking is carried out on an open fire, using poorly designed utensils. The technical terms used to describe each of these factors (together with their meanings in the present context) are as follows:

- —**radiation**, which means loss of heat to the environment.
- —**convection**, which means loss of heat caused by the upward movement of gases.
- —**conduction**, which describes the movement of heat through solid materials.

The evolution from open-fire cooking in developed countries depended on a long, empirical study of each of these phenomena.

Diminishing heat loss through radiation

When an open fire is used it is not always possible to direct **all** the heat generated onto the pot itself. A large proportion will obviously tend to escape from the **sides** of the fire into the environment. To prevent such loss, and thus make the maximum use of the heat generated for the purpose intended (i.e. to heat the pot), the logical solution was to enclose the fire in some way. For this purpose, it was necessary to employ materials that were good insulators, and our ancestors first used stones, then clay and later bricks. Nowadays there is a tendency to use somewhat more sophisticated insulating materials for the stoves used in developed countries, but it should be remembered that these are expensive and that **they do not appreciably increase the efficiency of the stoves**. The more traditional materials, such as clay, thus remain eminently suitable for use in countries where they are readily available.

Reducing heat loss caused by convection

Heat also tends to escape from **above** the stove because hot air or gases rise and are replaced with cold air coming from outside. This problem was alleviated by enclosing the top of the stove and allowing the hot air to flow by means of ducts and chimneys. In addition, the cooking pots were carefully positioned so that as much as possible of the available heat could be absorbed by them.

8. A well-managed open fire in **field** conditions will give a rate of about 20%. Much higher percentages may be achieved under laboratory conditions, as has been shown by the research into open fires conducted by Eindhoven University (see discussion on well-managed open fires, page 29).

Increasing heat absorption by conduction

As has been seen, considerable efforts were made to prevent heat from escaping and to retain it for as long as possible in the vicinity of the cooking pot. Ultimately, however, the object of cooking is not to heat the pot itself but rather its **contents.** Thus, our ancestors were quick to realise the importance of manufacturing pots out of materials with high conductivity — such as cast-iron, copper, and, later, aluminium or steel — instead of earthenware.

A more detailed study of the evolution outlined above reveals a wealth of knowledge and experience upon which we may usefully draw when designing stoves for developing countries — especially those where the shortage of firewood is most acute.

However, if modern cooking methods are to gain acceptance, two criteria are of fundamental importance. Firstly, as has been stated earlier, the proposed alternatives to open-fire cooking must give **satisfactory results** and, secondly, they must be **within the means of the poor rural communities for which they are intended.**

Thus, the promotion of efficient stoves requires not only patient effort on the part of technicians but also, and most importantly, **the political and financial support of governments concerned in the long-term energy saving and economic interests of their respective countries.**

I. Basic components of wood-burning stoves

The fire-box

The fire-box serves as a combustion chamber and must therefore be constructed of materials capable of withstanding high temperatures. In good stoves, it is equipped with air intake as well as air-with-gas mixing arrangements, and is designed so as to direct heat towards the cooking pot. For optimal efficiency, the fire-box should be in the form of an **inverted cone**, with the base considerably smaller than the top. This shape, besides allowing the pieces of fuel-wood to fall automatically into position as required, provides ample space for the released gases — and effectively limits the size of the grate which, in wood-burning stoves, should be fairly small for optimum performance.

Figure 4 presents two cross-sections of a modern fire-box supplied with both primary and secondary air.

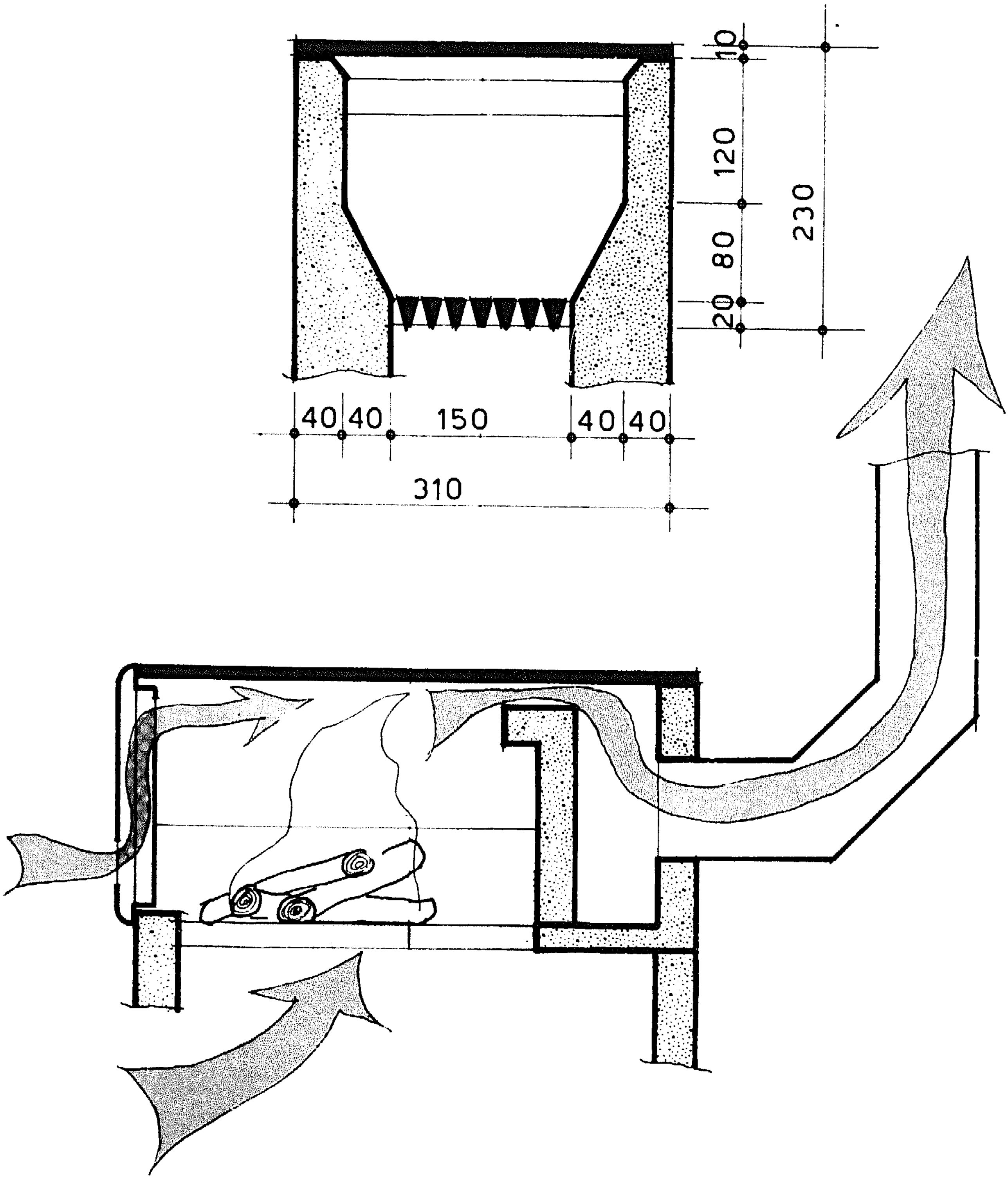
The size of the fire-box will, obviously, depend to a large extent on the use to which the stove is to be put. If it is intended (as recommended in this book) to use cooking pots which are lowered into the fire-box, the internal height should be somewhat greater and space should be left around the pots to allow for the release and combustion of gases.

The grate

A properly designed grate will improve the efficiency of a stove, **as it allows for the recovery of the energy contained in both the flames and glowing embers.** In wood burning models it should be relatively small in size, and its surface must always be less than that of the bottom of the fire-box. During combustion the grate should be completely covered with glowing embers so as to maintain a high temperature in the fire-box and facilitate the combustion of gases by pre-heating the primary air supply. If the open surface of the grate is too large, it will cause excessive burning and wood consumption. On the other hand, if it is too small it will result in defective combustion.

Wood-burning stoves require far less air input than coal, coke or peat-burning models and, consequently, the open spaces

Figure 4 *Two cross-sections of a modern fire-box supplied with both primary and secondary air.*



should represent no more than 30% of the total surface of the grate.

Experience has shown that cast-iron is the best material for manufacturing grates but, as an interim measure, until this is more widely available, local tinsmiths may make perfectly adequate substitutes out of construction or scrap iron (see designs of stoves). The main disadvantage of using these materials is that the grates will not be quite so durable as their cast-iron equivalents.

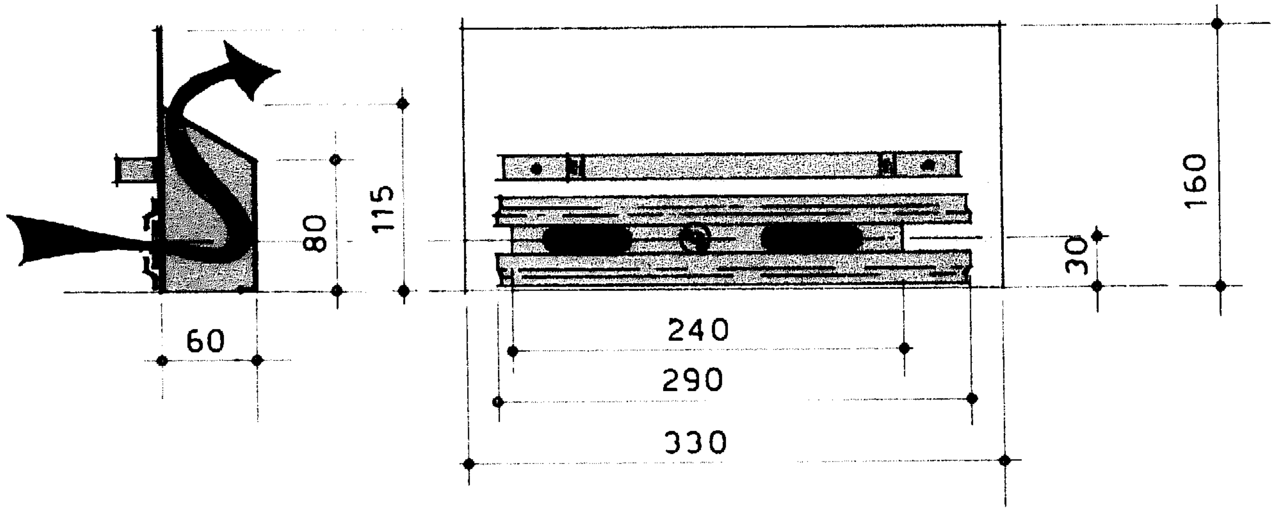
Ashes. An examination of the ashes left in the stove after use provides an excellent indication of the quality of combustion and, by extension, of the correctness of the stove's basic design proportions. Ideally, the leftover ashes should be in the form of a fine, silver-white powder. If the ashes are found to contain black particles of unburnt fuel, combustion has not been optimal and steps should be taken to improve it.

The doors

Ideally, combustion should take place within a closed fire-box — hence the importance of properly designed doors. In industrialised countries the usual practice is to fix doors to the fire-box by means of hinges. This, however, calls for additional expenditure which may be avoided. Figure 5 shows an alternative solution using doors made from scrap metal, which may be produced without difficulty by local craftsmen, and which are designed to fit **into** the stove opening. The inflow of primary air is regulated by means of an opening in the **ash-box door.** A similar opening is employed on the **fire-box door** to regulate the flow of secondary air. Here, however, a simple, inexpensive device is used to ensure that the air is correctly pre-heated.[9] A small metal box is welded or riveted to the fire-box door in such a way that it is in contact with the fire. The air passes through the regulated opening in the door, is heated as it flows through this box, and is finally ejected into the upper part of the fire-box.

Using unchopped firewood. In some regions the doors described above may not prove practicable, as they necessitate the use of **chopped** firewood. Where, due to a lack of tools, it is only possible to use **unchopped** wood, a specially small stove opening should be designed so that **the branches themselves** may be used to block the passage and thereby reduce and control the incoming air. Naturally, this solution is far from perfect and should be avoided whenever possible. A more satisfactory method is to use a block of clay or a flat stone as a makeshift door. The inflow of air may thus be regulated simply by

Figure 5 *Sheet-metal stove doors.*



9. See p.5 on the importance and difficulty of pre-heating secondary air.

pushing the block in and out of the stove opening or by pushing the stone aside (see for example the design of the Community stove).

The heating plates

One of the principal reasons for the failure of certain stove models to win widespread acceptance and establish themselves in developing countries as satisfactory alternatives to cooking by open-fire has been the fact that they have not been equipped with **efficient covers in the form of heating plates.**

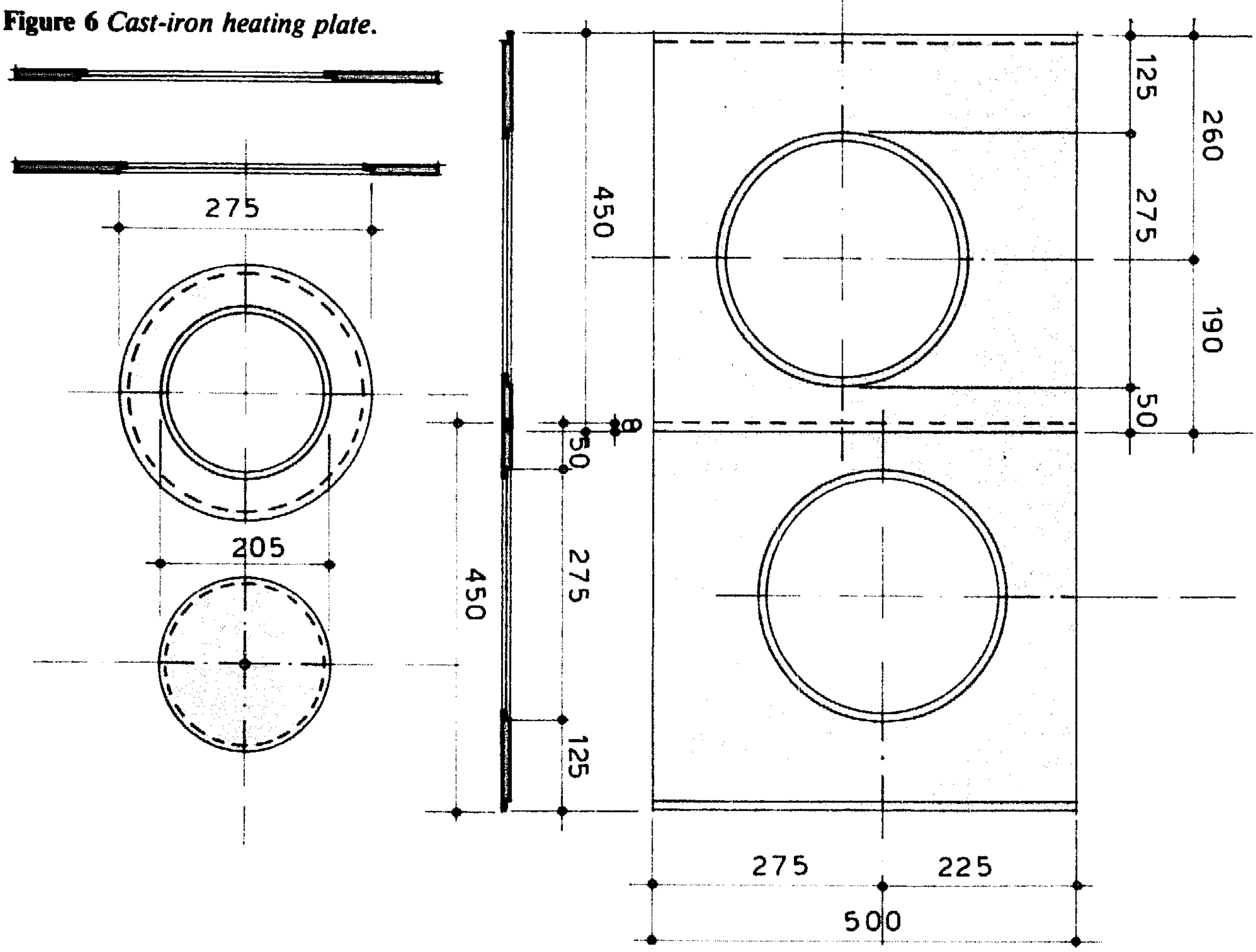
Indeed, the manufacture of these elements is one of the most critical factors in the design of an efficient stove — as was proved by the experience of our ancestors in developed countries.

The problem was in fact the object of much research in Europe during the last century and was successfully resolved with the massive, industrial production of standardised cast-iron heating plates equipped with rings to fit different sizes of pot (see Figure 6). This development constituted the **ultimate stage** in the evolution from open-fire to efficient cooking methods in developed countries. Most of the innovations that followed contributed little to improved efficiency.

Pending the local and widespread availability of cast-iron plates in developing countries, metal sheet (of 1.5 mm grade or 18 gauge) may be used to advantage by village craftsmen as a less durable but satisfactory alternative. A better solution would be to manufacture such plates in properly equipped workshops with thicker sheets — 2.0 mm or 16 gauge — and supply these to stove makers.

It cannot be stressed enough that in the design and construction of truly efficient wood stoves there is no satisfactory alternative to the use of cast-iron or sheet metal heating plates.

Figure 6 *Cast-iron heating plate.*



Dampers and baffles

Dampers. The input of air and the flow of gases through the stove may be regulated by the use of movable sheet metal plates called 'dampers' situated at the entrances to the stove and chimney. One disadvantage of this system, however, is that it is not conducive to efficient combustion of fuels as it admits ambient air directly into the firebox, which cools the gases. It also takes some time to instruct ladies in developing countries in their correct use.

Baffles. The flow of gases through a stove should be continuous and uninterrupted like a steady stream of water. However, for maximum efficiency it is important to retain the heat generated, for as long as possible, in close proximity to the cooking pots. This may be achieved by means of obstacles called 'baffles'. One particularly efficient method of deriving maximum benefit from the heat in a stove is to provoke a whirl, or vortex, of gases around the cooking pot. This is easier to achieve in stoves with more than one hole for pots. For example, if two pots are to be used it suffices to place one hole slightly to the right of centre and one slightly to the left — see Figure 6 and the description of the Pogbi stove on page 37. This allows for a heat current around each pot.

It is also important to slow down the flow of gases before they leave the stove. One way of achieving this is to direct them downwards before they enter the chimney. This method has the additional advantage of creating a space where chimney deposits may accumulate and be removed.

The chimney

Apart from allowing for the evacuation of gases into the atmosphere, the main function of the chimney is to promote a **draught,** which may be thought of as a 'motor' to facilitate combustion. In technical language a draught may be defined as the **differential between the density of the ambient air and that of the hot gases in the chimney.** In an efficient stove this differential will be neither too large nor too small.

Differential too small. The differential will be too small, and the stove will cease to function correctly, **if the temperature of the gases in the chimney is too low.** In this respect stove designers are faced with a frustrating dilemma. On the one hand it is important to retain the maximum amount of heat in the stove in order to warm the cooking pots. Any hot air which escapes to the chimney is obviously wasted for this purpose. On the other hand, however, it is necessary to sacrifice a certain amount of hot gases in order to maintain adequate draught and to avoid the accumulation of tar.[10] In small cooking stoves, the temperature of the gases emitted through the chimney at the normal rate of combustion should not fall below 100°C (measured in mid-chimney). In many developing countries, with particularly hot climates, it is necessary to maintain an even higher temperature in the chimney in order to ensure optimal draught.

Differential too large. The differential will be too large, and cause wastage of heat, if the combustion becomes too intense and raises the temperature of the gases leaving the stove to an excessive level. In order to counter this, it is necessary either:

—to slow down combustion

or

—to regulate the stream of hot gases through properly designed duct sections, or by means of a damper.

If a damper is used, **it must never completely close the stove section** but must always leave space for the continuous evacuation of gases, which may include highly toxic carbon monoxide (CO).

Checking the chimney. A good method is to light a piece of paper and place it inside the cold stove just at the entrance to the

10. Tar condenses in a chimney in the form of creosote, a dark, gluey and highly inflammable substance which, if allowed to accumulate, may cause a chimney fire.

chimney. If the burning paper and ashes fly up the chimney, the draught is satisfactory. Several factors — including, for instance, local air turbulence — may give rise to serious difficulties with regard to the proper evacuation of smoke. Solving such problems is a real test of the stove maker's professional capacities (indeed, many failures in this respect may partly explain the pejorative meaning accorded in the French language to the name of the profession). The key to the solution lies in finding the most appropriate means of increasing the draught. This may be achieved, for example, by increasing the height of the chimney or by adding the correct cowl.

Diameter of the chimney. The optimal diameter of any chimney will depend on its height and the heat output in kcal/h of the fire-box. For family-size cooking stoves a fairly small diameter of 10 to 12 cm is generally sufficient and will ensure a steady draught.

Height of the chimney. The most important criterion is that the chimney should be perpendicular to the stove and at least half a metre above the highest point of the roof of the building in which the stove is situated. Thus, under the conditions prevailing in developing countries, a chimney height of approximately 2 m to 3 m should prove adequate. In the case of small stoves, particularly those which are taken in and out of premises, half a metre is sufficient.

Construction of chimneys. Brick or clay chimneys lose less heat, maintain a higher temperature, accumulate less tar and, generally, give better performance than those made out of metal.

A convenient means of constructing chimneys is to use **segments** made out of specially prepared clay (see page 28 "Preparation of clay"). This method uses a mould, 30 × 30 cm at the base and 50 cm high, which can be made with four planks. A metal pipe, of 10 cm diameter, is placed in the centre of the mould which is then filled with clay. Each lump of clay should be placed around the pipe and well kneaded and pressed to eliminate air pockets. During this process, measurements should be taken at regular intervals to ensure that the pipe is maintained exactly in the middle of the mould. When the clay is hard enough the pipe and planks are removed to leave a hollow chimney segment which has good stability and good heat insulation properties.

The construction of chimney segments.

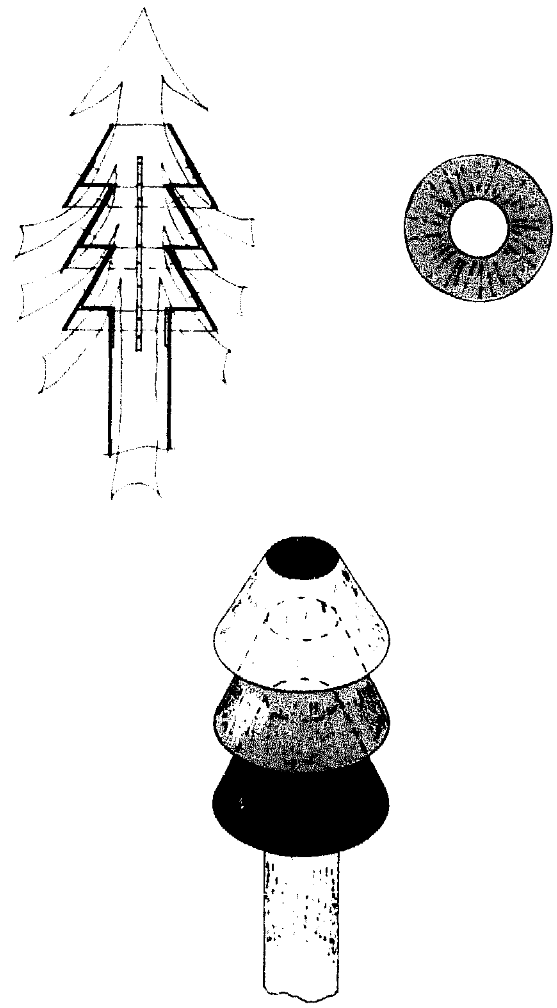
Cleaning chimneys. It is important to clean chimneys at regular intervals. The frequency will depend upon the rate at which soot and tar accumulate. Chimney cleaning is mandatory in developed countries, due largely to the insistence of fire insurance companies. In the Third World the burning of poor quality wood often causes soot to accumulate very rapidly, and chimneys should be swept more often as a consequence. With fairly small stoves the chimneys may be readily cleaned from above using weighted, coiled wire brushes. This kind of brush can and should be produced locally and made available to stove makers in developing countries. It is also essential to train local people as chimney sweeps in order to ensure that stoves continue to function efficiently at all times.

The cowl

The chimney should be topped with a cowl, of the same diameter and made from metal sheet, which offers protection against rain and improves the draught. This is particularly important for wood-saving stoves.

An efficient chimney cap or cowl, made out of scrap metal, which increases draught regardless of wind direction is shown in Figure 7. In order to ensure correct functioning the first cone should slightly overlap the top of the chimney pipe.

Figure 7 *Chimney cowl.*



General proportions of stove components

All the components described in this section must together constitute a homogenous entity. For this reason, it is essential that their comparative proportions be respected. **Thus, a change in the dimensions of any element must, in every case, be accompanied by a proportional change in the dimensions of all the other basic components of the stove.** This rule is particularly important when stove designs are being adapted to meet prevailing conditions. For example, in areas where there is good quality firewood, the size of the fire-box may be scaled down. On the other hand the size of the fire-box may need to be increased in regions where bulky fuel, such as bundles of hay or straw, is commonly used. The above considerations explain why the building of stoves must be considered as a profession, as well as an art, in which proficiency may only be increased through continuous striving to build better and better models.