HUYS ADVIES

Improved Cooking Stove (ICS)

Metal One Pot (MOP)

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ABSTRACT

The Metal One Pot (MOP) Improved Cooking Stove (ICS) has five main components: burning chamber; outer mantle; pot support with integrated pot shield and a firewood grate/plate. The "rocket" type burning chamber is made of welded 1.2 mm to 1.5 mm flat sheet metal. The round or square outer mantle or container is of 0.7 mm GI sheet and a loose top. The pot support is integrated with the pot skirt to optimise heat transfer. The firewood grate is made of 10 mm cold-deformed concrete reinforcement bars, and the outside support for long sticks is made of mild steel 7 mm concrete reinforcement bars. The outer mantle or container is filled with high temperature resistant sinters (crushed). The MOP can be fitted with a pot shield having an integrated chimney and with a bread baking box. The design has been developed for easy manufacturing by village metalworkers. The firewood efficiency is at least 40%. It saves cooking time and several hours in firewood and/or biomass collection per week. The outside body of the MOP-ICS does not get hot and is safer around children than the traditional half-open wood fire. Reduction in smoke and internal air pollution (IAP) may reduce respiratory diseases when used indoors with a kitchen hood. Manufacturing of the MOP-ICS generates business and income for micro entrepreneurs, while at the same time reduces dependency on non-renewable fuels. Guidelines for entrepreneur development are included.

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A MOP was first developed with Trocaire (Irish aid) as a firewood saving stove for the victims of the December 2004 tsunami in Sri Lanka, Jaffna (photo).

This first design allowed the mantel to be filled with wet firewood, which would partly gasify and supply very dry charred firewood after the first cooking cycle. This can be used to rapidly start a second cooking cycle.

The design was accepted for the following reasons:
Less firewood use, rapid making of tea, no need to keep a large fire going all the time, less smoke in the kitchen, and almost no risk for children getting burned.

The design was not accepted for four reasons:

1. After the tsunami large amounts of waste wood was everywhere and in the perception of the people, there would be no shortage, although new concentration of people caused them to walk farther to collect the daily ration of firewood.

2. Due to the large availability of funding after the tsunami of December 2004, donor organisations were providing everything for free and little time was available for explaining the advantages and disadvantages of more energy-efficient cooking systems.

3. The international staff was evacuated from Jaffna due to the developing war between the LTTE Tamil Tigers and the national army, thus no follow up of the initiative was provided.

4. The chopping of the firewood was too cumbersome for the household members; they preferred to use long logs and palm leaves. Filling the mantle was not done.

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1. INTRODUCTION

The first model of the Metal One Pot (MOP) Improved Cooking Stove (ICS) was developed by me shortly after the tsunami struck Indonesia, Sri Lanka, India and other countries on 26 December 2004. Hundreds of thousands of people were housed in transitional camps, many having lost not only loved ones and their homes, but their means of livelihood as well. In Indonesia and Sri Lanka, millions of household articles and cooking equipment were destroyed and most people reverted to open fires for cooking purposes. It was inevitable that the limited firewood surrounding the transitional camps would be quickly exhausted, thus the reason for introducing the MOP-ICS in northern Sri Lanka (Jaffna). The first designs needed to consider the locally available materials and skills, both in very short supply due to the recent disaster and the fact that in Jaffna most metalworkers had long ago emigrated to escape the internal conflict in the LTTE Tamil Tiger region.

Although the majority of the low-income population was accustomed to cooking on wood fires, the economic setback caused by the tsunami made it difficult to even consider upgrading their fuel source to kerosene or LPG gas. Purchasing new equipment and the recurrent expenditure of buying fuel was a heavy burden on their limited budget. These other types of fuels, however, had the advantage of not demanding the daily time-consuming activities associated with firewood collection, which was already becoming more difficult with increased population densities.

The common method of cooking in the transitional shelter camps consisted of a hearth on the kitchen floor with two fire points. These hearths were fuelled with firewood (logs) and biomass, such as palm leaves.

Stove on the floor in a transitional shelter (upper left photo).
The cooking stove design in the permanent houses followed the traditional stove design (photo right).
The ¾-closed fireplace has a slightly higher efficiency than the three-stone fireplace.
The pot supports are often made of metal (lower left photo).

The development of any ICS for easy manufacturing by local craftsmen would not only considerably reduce the time spent on firewood collection and cooking, but would also delay purchasing cooking equipment which operates on non-renewable fuels; fuel being an expenditure in many countries requiring foreign currency for importation.

Due to inefficient burning in semi-open fireplaces, the cooking process is long and large amounts of biomass need to be collected or purchased; up to 3-4 kg per day or 20-25 kg per week for an average household of 5-6 members. In the urban areas of Sri Lanka, the cost of firewood ranges from USD 1-4 per month for a small family of two adults and two children. It is the task of the women and girls (gender specific) to collect firewood (preferably branches) and biomass (palm leaves and coconut husk). USD 2 per week is for some families 10% of their family income. The substantial time involved in firewood collection (7 hours/week) and the long cooking hours (14-21 hours/week) do not allow women time to engage in other, more productive activities.

1.1. Development of the MOP-ICS for Tajikistan in the Himalayas

Cooking in the higher Himalaya altitudes of Tajikistan is traditionally done on large, firewood inefficient, steel plated house-heating stoves on which many cooking pots and kettles can be placed. These stoves are either Russian relics, during which period cooking and house heating fuel was free, or since 1992 manufactured from large metal fuel tanks and other scrap metal laying around. For many households, large size aluminium woks are used on these stoves for the hours-long cooking of traditional dishes or outdoors on cut-open barrels, both having very low firewood efficiency.

Flat bread *(chapatti)* is baked in *tandori* clay-soil ovens built in the floor, also having very low energy efficiency when used only for short periods every day.

Directly after the departure of the Russians in 1992, acute lack of fuel compelled the Tajik population to revert to cooking with firewood, resulting in massive deforestation. Collection of biomass included dung and the heather-like food plant of the mountain Yak, causing animal starvation. The stove improvement project is a current initiative of the GTZ and other development organisations[1], aimed at reducing environmental degradation. Stove improvement goes together with thermal insulation of houses and other means to reduce the massive energy needs during the long, cold winter periods.

Based on the findings in Tajikistan, the former MOP-ICS has been upgraded in this report.

[1] The Mountain Societies Development Support Programme (MSDSP), a project of the Aga Khan Foundation, Tajikistan.

2. IDENTIFICATION OF PROBLEMS

The following points have been identified:

A. Many people collecting branches from trees or buying agricultural residues want to minimise further chopping of firewood. The cook tries to maintain the fire using long sticks, gradually pushing the sticks inside the stove as they are consumed by the fire.

Seasonal firewood cuttings from trees in Tajikistan and bundles of agro waste for sale in Vietnam.

B. The usually poor combustion of the often freshly cut sticks causes large amounts of ashes to accumulate in front of the fireplace, which need to be removed daily. The ICS produces far less residue ashes due to the hotter combustion.

C. Many small cooking stoves, such as the charcoal-burning stoves, do not have a pot shield, which would enhance the heat transfer between flue gasses and the cooking pot. The pot shields seems to be better accepted in metal cooking stoves as being part of the design, although the shields can easily be made for charcoal stoves as well.

Similar designs of pot shield ICS have been produced by GTZ. (Internet picture)

D. Stainless steel (SS 304) or chrome steel sheets are not easy to come by for small entrepreneurs in many developing countries. Unfortunately, it is often these very countries having many low-income families who depend on free or purchased firewood; hence, tremendous firewood and environmental problems.

E. Although many good designs of stainless steel cooking stoves do exist based on the "rocket" model or down draft gasifier, these are invariably more expensive than the ceramic bucket stoves or the sheet metal stoves. Only with having personal experience and knowledge of the differences in operating costs between their traditional mud stove and that of the improved ICS designs, will people consider purchasing such a model, provided microcredit is available.

F. Most low-income people are not prepared to make the relatively large investment in a new ICS for cooking on firewood or agricultural waste wood. They would rather invest in a modern cooking appliance for a higher grade fuel, such as charcoal, kerosene or gas, even if they cannot afford the recurrent expenditures for the purchase of the high-grade fuel.

3. DESIGN CRITERIA

Although various types of low-cost ICS exist with a durable ceramic liner of the burning chamber, a low-cost, lightweight, all metal ICS was not locally available. The following criteria have been taken into consideration for the new construction:

- Useable for cooking both inside or outside the house; easy to move.
- Low firewood consumption.
- Shorter cooking period per cooking cycle.
- Low heat radiation, thus not heating the house.
- Reduce smoke emission inside the house – attaching a chimney.
- Safety of children.
- Improvement of overall stability (by widening and stabilizing the base).
- Use of long firewood pieces to minimize chopping wood into short pieces.
- Simple design for easy manufacturing by local craftsmen.
- Low manufacturing cost by minimising use of expensive metals.
- Durability – stronger/thicker metal for the burning chamber than for the mantle.
- Precisely controlled manufacturing dimensions for easy replacement of the burning chamber when burned through.
- Pot skirt dimensioned according to the pot or wok size, giving optimal heat transfer.
- Possibility to upgrade the design when chrome steel or stainless steel (SS) becomes available, or when refractory bricks can be locally manufactured.
- Possibility to use the ICS for baking bread, instead of in a large oven.

The following disadvantages remain:

- ◊ Need to have different pot skirts when more than one type of pot is used.
- ◊ Soot and smoke still blackens the cooking pot within the pot skirt.
- ◊ Large pieces of dried cow dung cannot be used as biomass material.

The MOP-ICS pictured on the cover page is the result of adaptations of the Sri Lankan design made in Tajikistan and based on available materials and skills of local metalworkers. For example, they wanted thicker galvanised sheet steel for the container and the local population preferred the closed pot skirt with the chimney attachment.

The time saved by the improved MOP-ICS is estimated at minimal 3 hours/week per household on firewood collection and another 3 hours on cooking time; the later being the result of the hotter flame and more efficient stove use. Bread baking is considered as a useful option because during several periods in the year, no electricity is available for the electric bread oven.

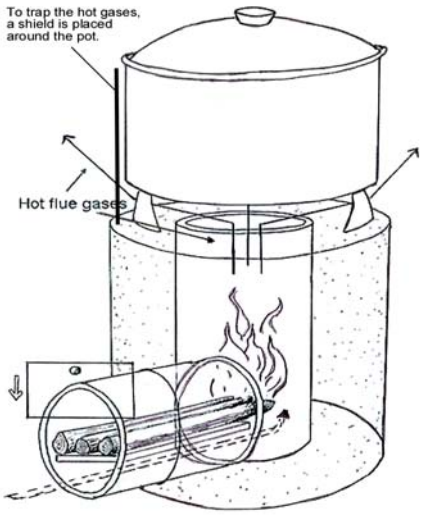
Comments from a MOP-ICS user in Sri Lanka:

Since having this model, I use it for most of my cooking because the time used is much less. I do not have to watch the baby all the time now or close the kitchen. Also, I now use this stove for making tea fast because before I was making tea on the gas, but that is too expensive.

Two new ICS, one without a closed pot skirt (black) and a wok design with chimney attachment.

4. ICS TECHNOLOGY

The technology of the MOP-ICS is based on the existing "Rocket Stove" developed by Aprovecho, along with Dr. Larry Winairsky (sketch). All elbow-shaped ICS have the following aspects and components:



(a) Thin, long wood pieces allow a better combustion.
(b) Air enters from below the fire position and improves combustion.
(c) The metal plate and grill are essential features for minimal air entry above the fire and enhanced air entrance from below.
(d) The small, elongated burning chamber increases the temperature and allows complete burning of the wood gasses. The height is 1.5 times the diameter.[2]
(e) Insulation of the burning chamber increases the burning temperature and therefore completes the burning of gasses.
(f) The complete burning of the firewood produces little amounts of ash residue and unburned gasses, resulting in less smoke and soot.
(g) The hottest point is just above the flames, about 15 to 20 cm above the burning firewood.
(h) The narrow space between the pot and shield increases heat transmission to the pot.
(i) The heat of the fire can be regulated by adding or removing sticks.
(j) Removal of all the sticks quickly extinguishes the fire and stops further firewood consumption.

Main advantages are:

- ✓ About half the amount of firewood is needed as compared to the traditional stoves.
- ✓ Time saved in firewood collection or money spent on the purchase of firewood is reduced by half.
- ✓ The fire is enclosed and the outside mantle is not hot.
- ✓ The pot skirt can be closed and fitted with a chimney, evacuating all smoke.

Disadvantages of this type of stove are:

- Most ICS require thin pieces of wood or branches having a cross section of about 3-4 cm. This means more lengthwise chopping of firewood. Thin wood sections burn much faster than thick wood and allow good regulation of the heat, but people do not want to chop firewood or split branches. Change in chopping behaviour.
- The person tending the fire needs to constantly feed the burner to maintain adequate temperature for the cooking process. Change in cooking behaviour.
- The fire does not emit light because it is totally enclosed (no yellow flames).[3]
- There will be no charcoal remains and little amount of ashes. Some people use the charcoal from outside fires for small stoves inside the house.
- When the mantle is not filled with ash (insulator), stability will be less. This will become a problem when thick porridge or stews are stirred in the pots.
- The pot shield is not easily adjusted to different pot sizes or individual shields are needed for each pot.
- Designs without a chimney need to be used <u>outdoors or under a kitchen hood</u> to provide good exhaust of the smoke and flue gasses.
- Designs with a chimney have increased manufacturing cost; with an LED, even more.

[2] In one case, the height of the burning chamber was reduced because the villager wanted the flames to touch the pot as with the traditional fire. However, by doing so, the efficiency of the ICS is reduced.
[3] Fitting a thermo-electric generator, a heat sink and a LED illumination to the chimney may resolve this problem.

5. MOP-ICS DESIGN

Technical Issues of the MOP-ICS

1. The burning chamber is made of 1.2 mm flat mild steel sheets (MS), a material available in most markets. Chrome steel (3CR12) and stainless steel (309, 304) sheets would be better, if available. Based on field practice of metal stoves, the 1.2 mm flat steel will probably burn through after 1000 full cooking sessions or roughly two to three years. If thin chrome steel burning chambers could be centrally manufactured in a country's capital, the chambers could then be bought by local village metalworkers for assembly into GI containers.

2. Because of the manufacturing limitations of village metalworkers, a round inner burning chamber with elbow cannot easily be made from 1.2 mm sheet metal. To overcome this problem, the new MOP-ICS design has a square burning chamber with a rectangular air inlet. The exterior container is also square.

A standard ICS unit with a 110 mm burning chamber and an outside square box container of 330 mm x 330 mm. The container is 0.7 mm GI sheet for a large wok (Ø 50 cm = volume 22ℓ, net use 16ℓ) with a chimney attachment. To increase firewood efficiency a lid should be used with the wok.

3. A custom-made pot shield is required for each pot size because the shield needs to be close to the pot. Hence, the stove seller must have different sizes of the most common pot shields in stock (cylindrical pots Ø 26 cm and various wok sizes). The house owner needs to supply the cooking pot for a correct fit.

4. To have a strong but low-cost outside mantle (container) and allow easy working, this is made of 0.7 mm GI sheet steel. The shiny silver colour of the galvanised sheet metal gives the stove a nice appearance, but this will become dull with use of the stove.

5. The 1.2 mm or 1.5 mm (thickest) steel plate can be hand cut with locally available cutters, avoiding the need for expensive electric cutting equipment. Electricity is not always present and often only poor quality cutting disks are available.

Extra hard carbon steel hand cutters fixed onto the work bench.

Of the hand scissors pictured above, only the one with the blue handles was of good quality to cut thin 0.4 mm to 0.7mm GI sheet.

6. Good quality tools are an important element in fast and precise production. Some tools, such as steel bar benders, may need to be manufactured.

7. Metalworkers need to be trained on various techniques to speed up production and reduce labour costs:
   - Use of templates ("sjablons") and jigs, especially import for series manufacturing.
   - Fast cutting techniques (bars and profiles) and rapid assembly techniques by using jigs. Ordinarily the village metalworkers have the habit of making one stove after another and do not work from drawings or with precise measurements. Cutting only a few pieces and then doing something else is time wise very inefficient. Making a holding structure and cutting all the pieces from the same position would be about ten times faster than measuring and cutting each piece separately.
   - Making of jigs to allow welding pre-cut components together. This proved to be both easy (not holding the loose pieces in position) and time saving. All the pieces of the grate could be electrically welded in one go.

A timber frame has been made with markings and a stop at the end. The metalworker's stomach is protected from the sparks with a deflector. Emphasis should be given on the need for protective clothes and glasses.

The metalworker is cutting reinforcement bars with an electric cutting machine. By not measuring all the pieces, but cutting the bar with the aid a fixed stop made the cutting about ten times faster than commonly done. If electric cutting machines are available in the local market, this would allow even faster work, but would be useless in areas where there is regularly electricity shortage.

8. Many metalworkers cannot easily read drawings and require a real model for copying; hence, prototypes must be made to serve as copy models.

The making of templates ("sjablons") and welding jigs is new for many metalworkers. Here a jig is being made for the upside down welding of the fire grate and firewood support. Practice with the cutting tools and welding jigs proved to save considerable time as compared to their ordinary practice of making one product at the time.

6. STOVE MANUFACTURING

Local metalworkers require both education in the heating principles and training in the manufacturing techniques of the improved cooking stoves (ICS). In addition, training will be required in enterprise development with all its marketing aspects. The education on marketing techniques will be necessary because a project should not continue to buy the stoves; sales should eventually be coordinated between the manufacturer and the final client through local trading networks and supported by local micro-finance. The following aspects are relevant in such a training programme:

A. Theoretic Explanations on ICS:
1. Explanation of the principles on combustion of firewood or biomass.
2. Explanation of the small and larger cooking stove designs.
3. Explanation about the use of smoke for secondary heating purposes.
4. Aspects of smoke evacuation, chimney, hood, vents, cover and fresh air.

B. Material Use for Stoves:
5. Metals, thickness, galvanisation, stainless steel, chrome steel and uses.
6. Insulating materials and fire resistance.
7. Cutting, welding, connecting and surface finishing.
8. Heat pipe, installation of water connections and storage.

C. Series Production:
9. Having drawings and material specification lists.
10. Templates ("sjablons") and jigs. Having the right tools for the jobs.
11. Quality control during manufacturing process and delivery.
12. Brand name, serial number and manufacturing date.
13. User instructions, manuals, guarantee and complaint address.

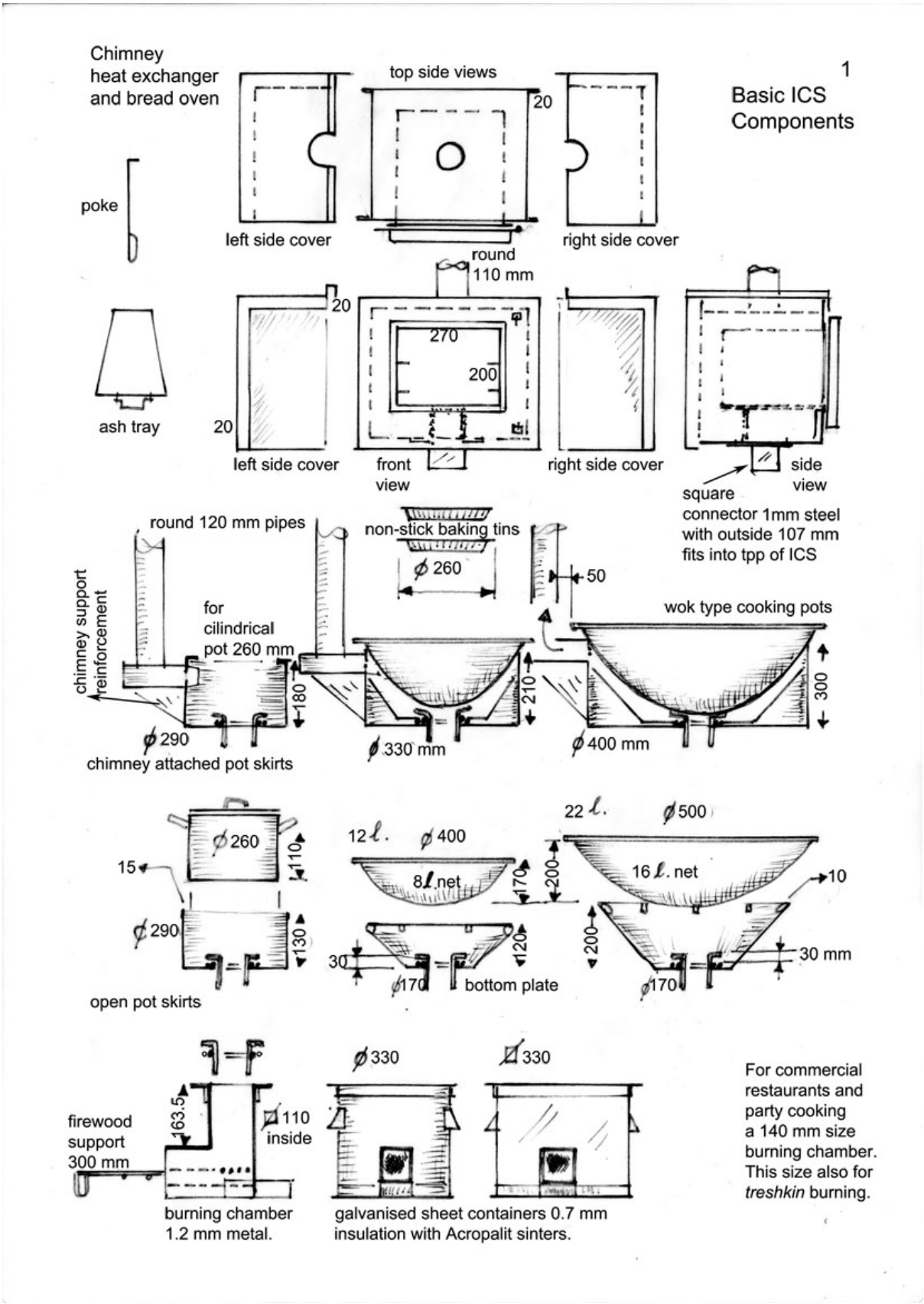
A self-sustainable activity requires the managers of the metal workshops being able to understand all of the above-mentioned elements and handle every aspect of the activities. Machine purchases and subcontracting (e.g. pre-cut components from the capital) are to be handled by the managers. The manager of the metal workshop also needs to do the financial planning and assess how much working credit is required, advance payment from the buyer and down payment of source material supply. In a regional or rural operation, it will be beneficial to all parties involved if group material purchase and transport is centrally organised by a cooperative.

Only during the initial period should a project allow credit in the form of material supply, against the timely delivery of a number of quality-controlled and accepted products. For this purpose, exact material purchase and product descriptions with quality control are required. For obtaining larger credits from financial institutes, the presentation of a business plan is required, reliably indicating the potential market and all production costs.

Sketch # 1 (next page) gives an overview of the ICS series developed.

- The burning chamber is depicted in the bottom left-hand corner. This unit fits into three different sizes of insulating containers. The containers provide stability. The pot supports attached to the pot shields all fit the burning chambers.
- A round Ø 33 cm container, a square 33 cm container and a smaller 26 cm square container. The smaller containers are filled with fine (1-2 cm) Acloparit[4]. The largest container has greater stability, especially when the large 50 cm wok is used.
- Three open pot shields were made for the cylindrical Ø 26 cm and 6ℓ volume cooking pot, the Ø 40 cm common wok and the large Ø 50 cm wok.
- Three closed pot shields with chimney were made for the same pot sizes.
- One bread-baking oven (heat exchanger) fitting onto the burning chamber.

[4] Acloparit is the sintered ash residue from the manufacturing of cement. The porous structure provides the insulation. Similar materials such as volcanic pumice stone or sinters from brick manufacture are also highly suitable.



OVERVIEW OF TYPES OF ICS AND THE "BREAD OVEN CUM HEAT EXCHANGER" FITTING ON THE ICS. THE MIDDLE LINE DEPICTS THE ICS WITH CHIMNEY ATTACHMENT TO THE POT SKIRT.

6.1. Burning Principle and Fire Grate

Biomass fire requires carbon (C) and oxygen (O) from the air and heat.[5]
Different biomass has different C content, for example:

- In dry wood: C ≈ 50%, but in wet wood only 40% because of the 10% more water.[6]
- In sundried dung: C ≈ 25%, reason for large amounts of ashes.
- In good quality coal: C ≈ 90%.

The minerals and water convert to dust particles, gasses and vapour. All what does not disappear as flue gasses through the chimney will remain as ashes. High resin content in the wood and smoke may condense inside the chimney as soot and liquid tar.

The amount of smoke with non-burned particles and gases will reduce when the burning temperature is very high and sufficient oxygen is entering the fire (from below). For this reason, the burning chamber needs to be aerated from below, insulated and kept small. A well-insulated stove does not emit heat from the body (burning chamber), but rather from the chimney (flue gasses).

The first improvement of the Improved Cooking Stoves (ICS) is to ensure the air enters from below the fire or burning area. This is done by the elbow shape of the firewood entrance and the grate and plate structure (see next page for details).

The fire grate is made from high-tension cold-deformed concrete reinforcement Ø 10 mm or Ø 12 mm bars. The five short bars are welded to a 1.2 mm steel air separation plate. The grate bars and the separation plate will be strongly heated during the burning process and pre-heat the incoming air. The separation plate is fitted with a support rack for long firewood sticks, made of mild steel bars of Ø 6 mm or Ø 7 mm. The firewood support rack projects 30 cm in front of the stove to allow long firewood sticks and minimise the need for chopping by the cook.

Technical Issues

- The design has been based on the minimum amount of cuts and welds.
- The high-tension cold-deformed concrete reinforcement Ø 10 mm or Ø 12 mm bars have been chosen because these bars are more heat resistant than the smooth reinforcement bars. Cutting these bars is difficult, so their use should be minimised.
- 1.2 mm to 1.5 mm flat steel plate is recommended because it can still easily be hand cut with table-mounted scissors. The 1.2 mm steel plate can still be properly welded by electric rods (2 mm). In the workshop, 1.5 mm steel plate was used, stretching the limit of workability with the table-mounted hand scissors.
- For the firewood support, thinner Ø 7 mm bars can be used because they are not heated by the fire. The bars are lower in cost and require less energy to cut.
- From the air separation plate, a template ("sjablon") in zinc sheet has been made for fast marking of many pieces.
- A holding frame (jig) was used to hold the Ø 12 mm bar in the same position while cutting it into many sections.
- For welding all the elements of the grate plate together, a single (metal) jig was manufactured. The jig has a hinged part to provide stability for the four support elements.

As an additional feature, an ashtray can be made which fits under the firewood opening. A poke with a hook will complete the instruments.

[5] Air contains about 78% nitrogen and only 21% oxygen. At higher altitudes, the oxygen content is lower. Therefore, a biomass fire also uses four times the amount of air as the oxygen needed for the burning process. All that heated air goes out through the chimney. Incomplete burning due to large amounts of moisture, low temperatures and inadequate air supply causes large amounts of vapor, unburned particles and gasses respectively.

[6] One litre of water (in wood) will produce 1600 litres of vapour.

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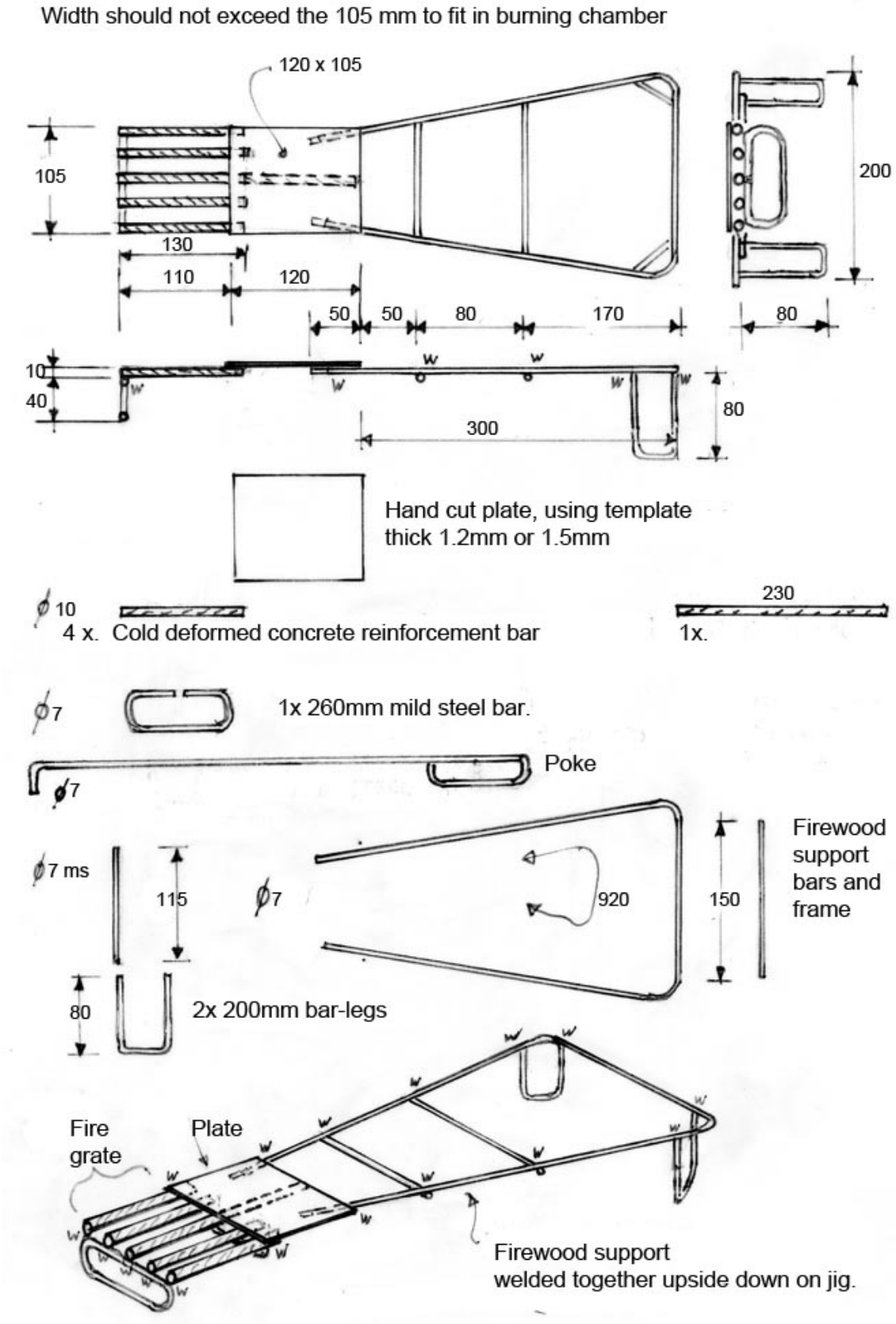


MANUFACTURING DETAILS OF GRILL AND FIREWOOD SUPPORT.

6.2. Material of the Burning Chamber

The burning chamber can be made of different materials, each having its technical characteristics with advantages and disadvantages.

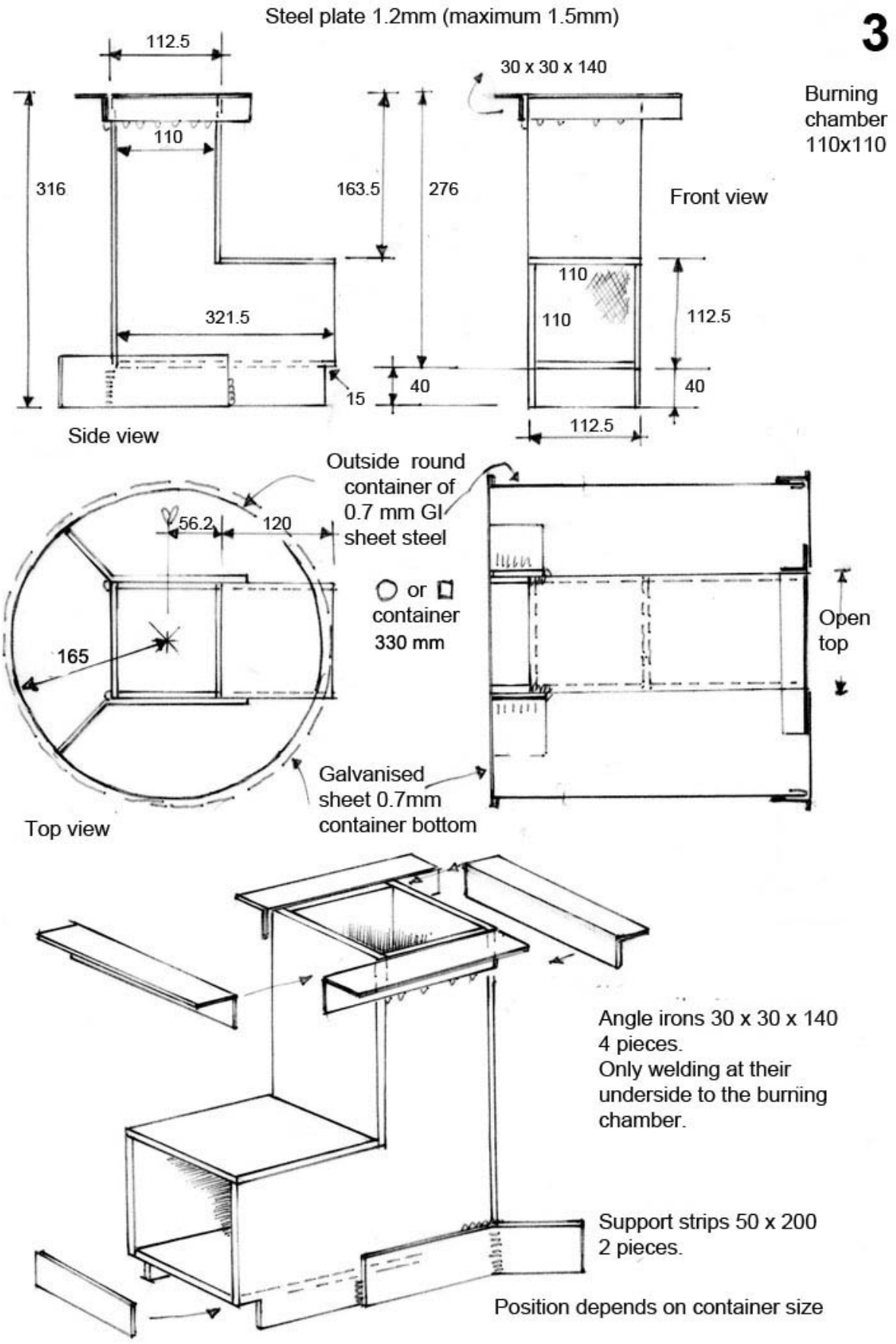
#	Material	Thickness	Remarks
1	Galvanised steel plate	0.7 mm to 0.8 mm	This will soon burn through with a wood fire. The use of any galvanised steel plate for burning chambers or chimneys is not recommended because the zinc will evaporate, emitting poisonous gasses.
2	Metal plate from old oil barrels	1.5 mm	Reasonable thickness. Oil barrels often have residues that need to be cleaned out. Many second-hand oil barrels need to be flattened first to allow making straight burning chambers.
3	New sheet metal plate	1.5 mm	Reasonable thickness, may last over 1000 hours of burning. Is good to weld electrically. The plate is difficult to cut with hand-operated scissors. Steel is a poor insulator.
4	New sheet metal plate	1.2 mm	Adequate thickness allowing possibly 1000 cooking hours. Can be cut with hand-operated scissors. **Recommended material.**
5	New steel plate	2 mm	Very durable, but requires machine tools for cutting. The additional steel thickness will increase the material cost and consequently the stove price. Better source is stainless steel.
6	Stainless steel plate (SS 304) or chrome steel	1 mm	Excellent material for burning chambers lasting over 10,000 hours. Stove will be more costly and people need to be convinced that it will be a good investment. 309 SS is rated 1050°C, 321 SS is rated 850°C, and 310 SS is rated 1100°C.
7	Refractory liner of cement vermiculite or pumice	5 cm thick	Highly heat resistant and insulating at the same time. It needs to be investigated if volcanic pumice is found in Tajikistan. Adding a small quantity of aluminium powder will increase the insulating properties of the liner.
8	Refractory clay bricks	6-8 cm thick	Can be manufactured in high temperature kiln (1100-1300°C). For the feed channel, low density bricks (0.7 kg/dm^3); for the burning chamber, high density bricks (1.2 kg/dm^3).

To keep material consumption and the amount of work low, the burning chamber has been made from easy to work 1.2 mm to 1.5 mm new flat steel plate. The cross section is 11 cm x 11 cm = 121 cm^2. If the metal workshop has a roller bench to make round plates, a cylindrical burning chamber is possible.[7] The cylindrical shape is slightly more energy efficient than the rectangular shape because less steel is involved (heat conductor) and the temperature is more homogenous due to lack of corners. While it uses less material, it does require welding.

To simplify the work, the sections cut from the steel plate are rectangular. A template is used for marking the pieces on the metal sheet. After cutting, the pieces are flattened precisely. This is a Quality Control (QC) checkpoint. Based on experiences from the Aprovecho, the height of the burning chamber is 1.5 times the cross section. The total height is therefore 2.5 times the width.

The prepared sections are fitted into a metal jig and point welded together to ensure precise dimensions. Afterwards, the sides are fully welded. If the burning chamber burns through, additional sheeting can be welded onto the outside or the burning chamber replaced in its entirety, fitting precisely into the outer frame.

[7] The workshop did not have all the tools or equipment necessary, a situation commonly found in other workshops. The bar-bending tool was manufactured and the sheet-cutting tool was bought.



MANUFACTURING DETAILS OF A 11 CM X 11 CM BURNING CHAMBER.

To ensure stability, two support strips (50 mm x 200 mm) have been welded to the base of the L-shaped burning chamber. The burning chamber is also slightly elevated to allow room for insulation material under the chamber. The outside container is from galvanised steel sheet (0.7 mm) for economical reasons. A coat of bright heat-resistant paint should be applied to the outside of the container; if not, the GI sheet will in time get a dull appearance.

It remains an option to seek the more durable stainless steel (SS 304), but it should first be assessed whether the additional material cost and Argon welding is worth the investment. The SS stove will only become economically feasible once it is mass-produced.

Further search for an insulating or ceramic burning chamber is necessary. Due to adverse transport conditions in the mountain areas, the ceramic or refractory core needs to be of high resistance against breakage. The apparent disadvantage of the metal burning chamber is rapid temperature loss; a reason to keep the metal thin.

This Chinese ICS has a ceramic burning chamber, being both highly fire resistant and insulating. The ICS is difficult to obtain, the size is too small for the liking of the Tajik cooks, larger pots cannot be used on the stove, the pot skirt is inadequate for wok-type pots, the firewood support is too short and the outside material is very flimsy – several reasons why this ICS was rejected as a possible product for dissemination.

Refractory Bricks

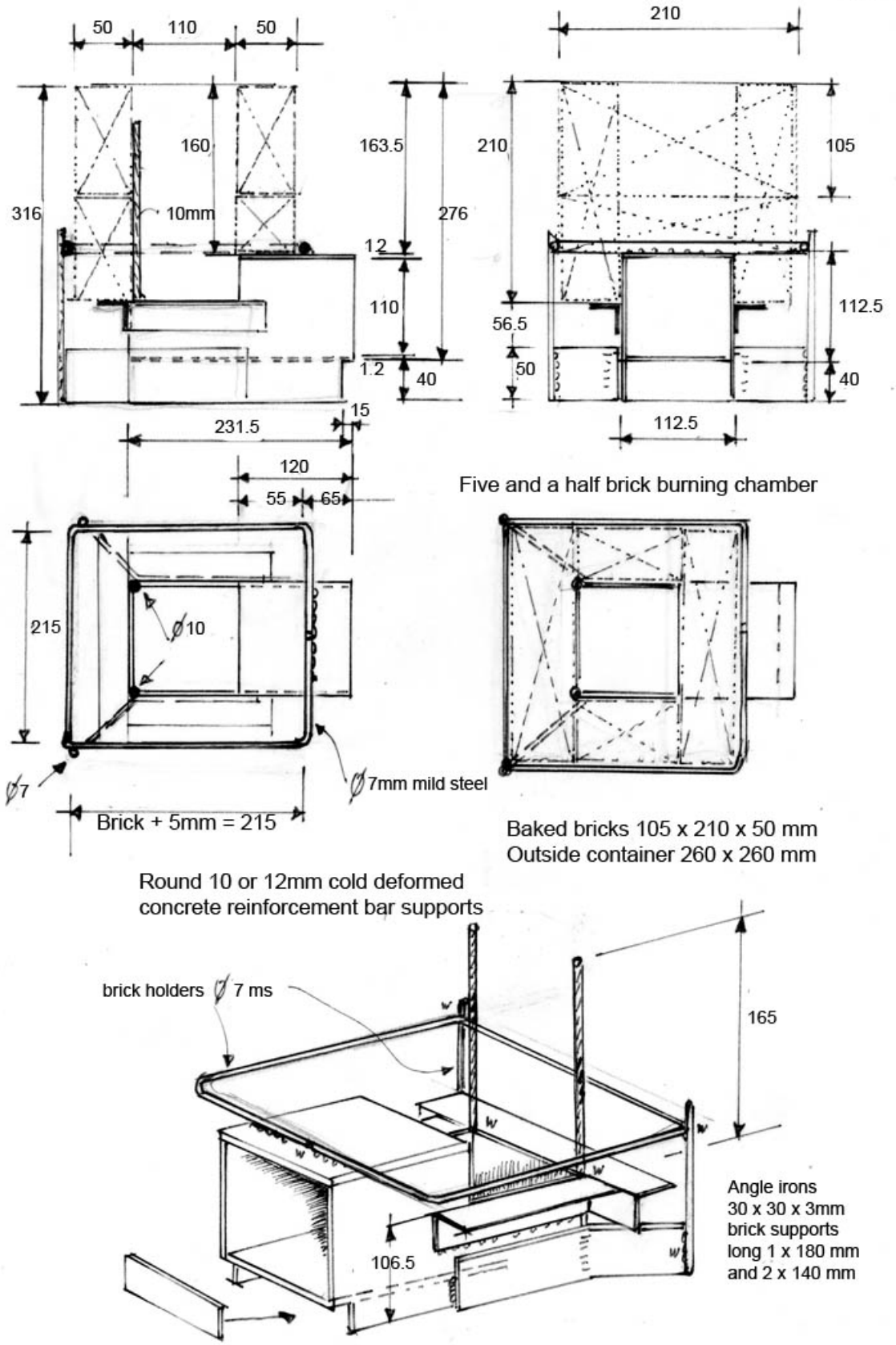
A clay brick factory can make refractory bricks that can resist high temperatures. Bricks measuring 5 cm x 10.5 cm x 21 cm are commonly made. The ICS stove design (sketch 3a) has a burning chamber made from five refractory bricks instead of a steel plate. The advantages of this design are:

- ✓ The bricks are loosely placed in holders and can be easily replaced when damaged.
- ✓ The bricks are both fireproof and insulating.
- ✓ The bricks support the cooking pots; no metal support is required.
- ✓ The amount of labour needed for manufacturing the burning chamber is reduced.
- ✓ The durability of the burning chamber is extended.
- ✓ Less steel sheet used for the burning chamber.

The following conditions do apply:

- ◊ The bricks should be of higher quality than ordinary baked bricks.
- ◊ The bricks should be rather straight. Two of the five bricks should have a very straight side so the joint fits tightly together.
- ◊ The bricks should be selected on quality and marked with "ICS".
- ◊ The bricks should be obtainable through the association of stove makers.
- ◊ The same size and quality bricks are used as insulation bricks in the house-heating stove.

3a



ICS BURNING CHAMBER – BOTTOM PART TO FIT QUALITY BAKED BRICKS.
A FURTHER IMPROVEMENT WOULD BE THE MANUFACTURE OF SPECIAL REFRACTORY BRICKS.

6.3. Insulation of the Burning Chamber

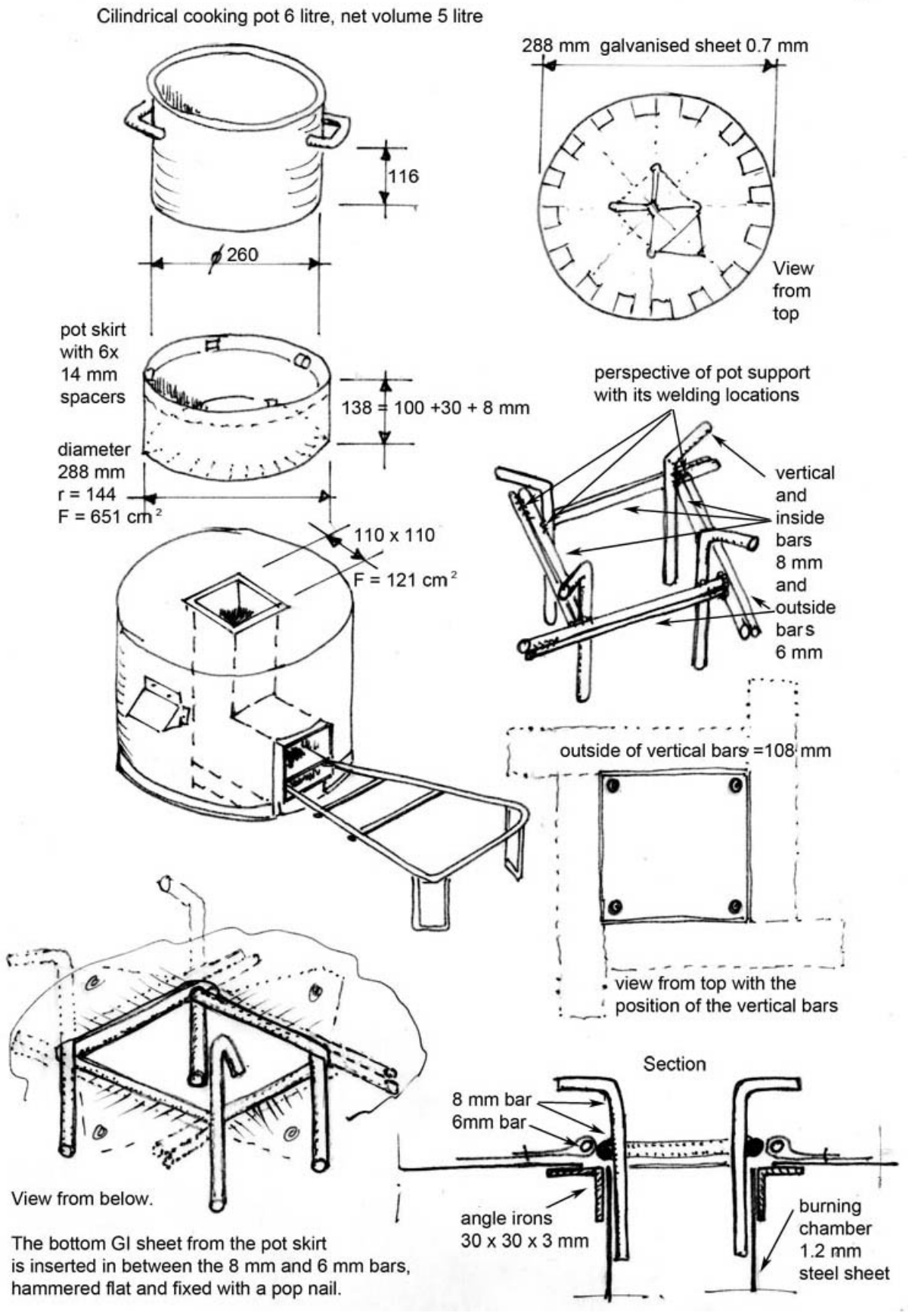
A round metal shield has been made around the burning chamber to contain the heat. The container sheet is made from 0.7 mm galvanised (GI) sheet metal. Although thinner GI sheet metal can be used, the metalworkers found working with the thicker 0.7 mm sheet easier. The resulting space is filled with sintered ashes (Acloparit) from the cement factory.

For the stove container exterior, a square shape was chosen, although this requires a little more material. Because of the larger volume of the container, three large-sized Acloparit were used. However, these larger chunks (5-8 cm) allowed more heat to pass in between the chunks and the outside of the container became warmer than the smaller round container filled with small-sized (1-2 cm) Acloparit aggregate.

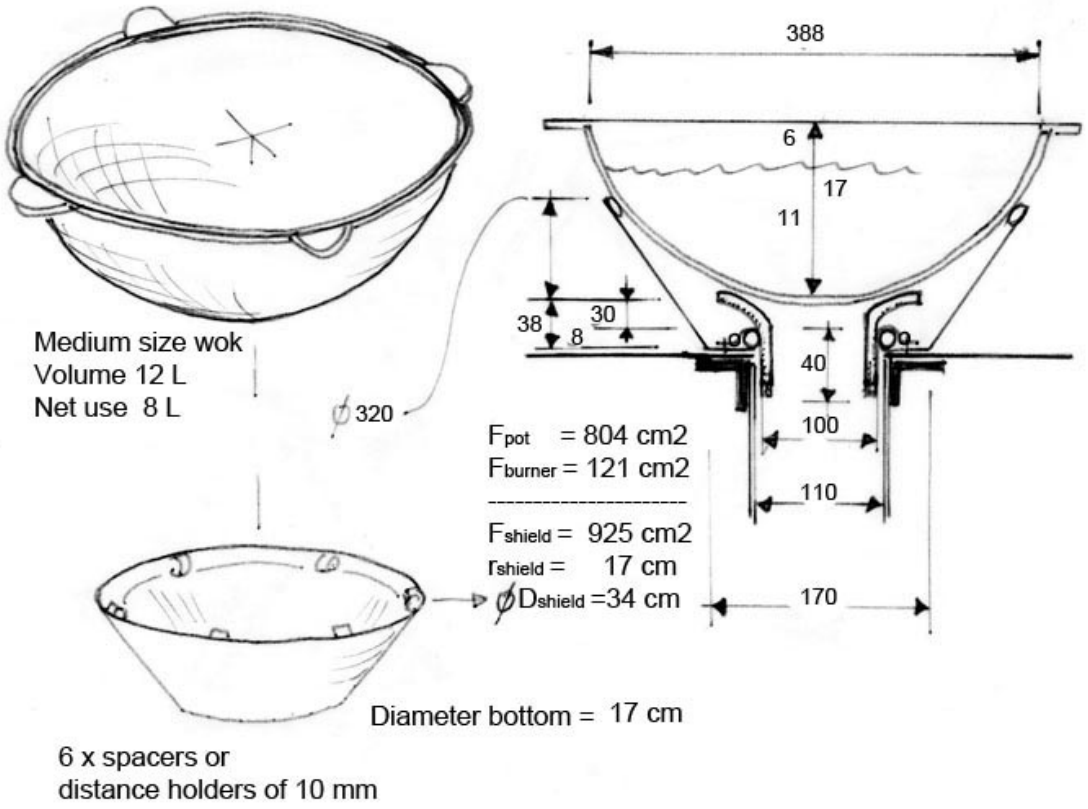
6.4. The Pot Shield

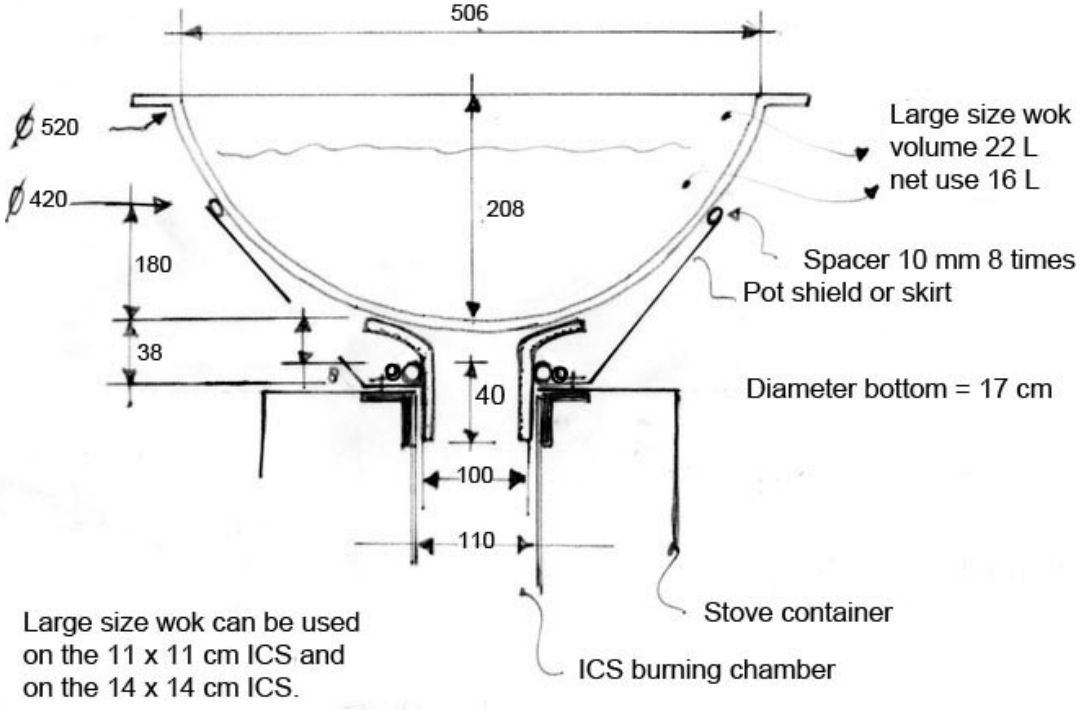
For ICS, the cooking pot needs to be above the fire in the hottest flue gasses, not in the flames. Yellow flames are a sign of incomplete combustion and therefore energy loss. The hot flue gasses need to touch as much cooking pot surface as possible to transmit heat to the cooking pot.

- The design pictured above has a cylindrical cooking pot of Ø 26 cm.
- The circumference of this pot is 81.6 cm.
- The cross section of the burning chamber is 121 cm^2 and the gap around the cooking pot needs to be equal in section.
- The width of the gap is therefore 121 cm^2 : 81.6 cm = 1.5 cm.
- The circumference of the outlet of the burning chamber is 4 x 11 cm = 44 cm.
- The height above the outlet and under the pot is therefore 121 cm^2 : 44 cm = 3 cm.
- The pot skirt stands on Ø 8 mm smooth concrete reinforcement bars; the GI sheet is attached to this support.



MANUFACTURING DETAILS OF Ø 26 CM OPEN POT SHIELD WITH POT SUPPORT.
THE TOTAL SECTION (AREA) OF THE GAP BETWEEN POT AND SHIELD IS EQUAL TO MINIMAL 121 CM^2.





DIMENSIONS OF OPEN POT SHIELDS FOR MEDIUM (12ℓ VOLUME, 8ℓ NET USE) AND THE LARGE (22ℓ VOLUME, 12ℓ NET USE) MOST COMMONLY USED WOKS.

Because of the large circumference difference between the cylindrical cooking pot and the wok type pots, at least three types of pot shields need to be manufactured; one for the cylindrical standard cooking pot (Ø 26 cm) and two pot shields for the medium (top = Ø 40 cm) and large (top = Ø 50 cm) woks. The base plate of these two woks is kept the same (bottom = Ø 17 cm). For the open pot skirt of the medium wok, six small spacers of minimum 10 mm thickness are fixed around long the upper rim of the pot shield to ensure an even distribution of the escaping flue gasses; and eight spacers for the large wok.

The wok is an inefficient pot shape for long simmering or slow cooking, which causes substantial evaporation at the higher altitudes; this leads to an overall low efficiency of the ICS.[8] Omitting the pot skirt will keep the firewood efficiency of the ICS below the 40%.

For this reason, this design pot shield is fixed to the pot support, but, consequently, different pot shields will be required for different cylindrical pots and large woks. However, in many households, only one type of cooking pot is used.

To better the firewood efficiency, a lid should be used on the wok and cylindrical cooking pots. Using a pressure cooker is even better. To further increase the firewood efficiency and reduce the smoke and soot emission from the ICS, thoroughly dried firewood is needed. The branches of willow and poplar trees need to be air dried for at least one year.

6.5. Closed Pot Shield with Attached Chimney

In the Himalayas, cooking is traditionally done inside the house on the main house-heating stove during the winter and outside during the summer because the house-heating stove generates too much heat. With the ICS, substantial amounts of firewood will be saved during the summer, but the open ICS cannot be used indoors due to the smoke.

When the house is insulated (roof window, ceiling), far lesser heat will be needed from the house-heating stove and the ICS with a chimney can be used for cooking during the winter period as well, further saving firewood and time.

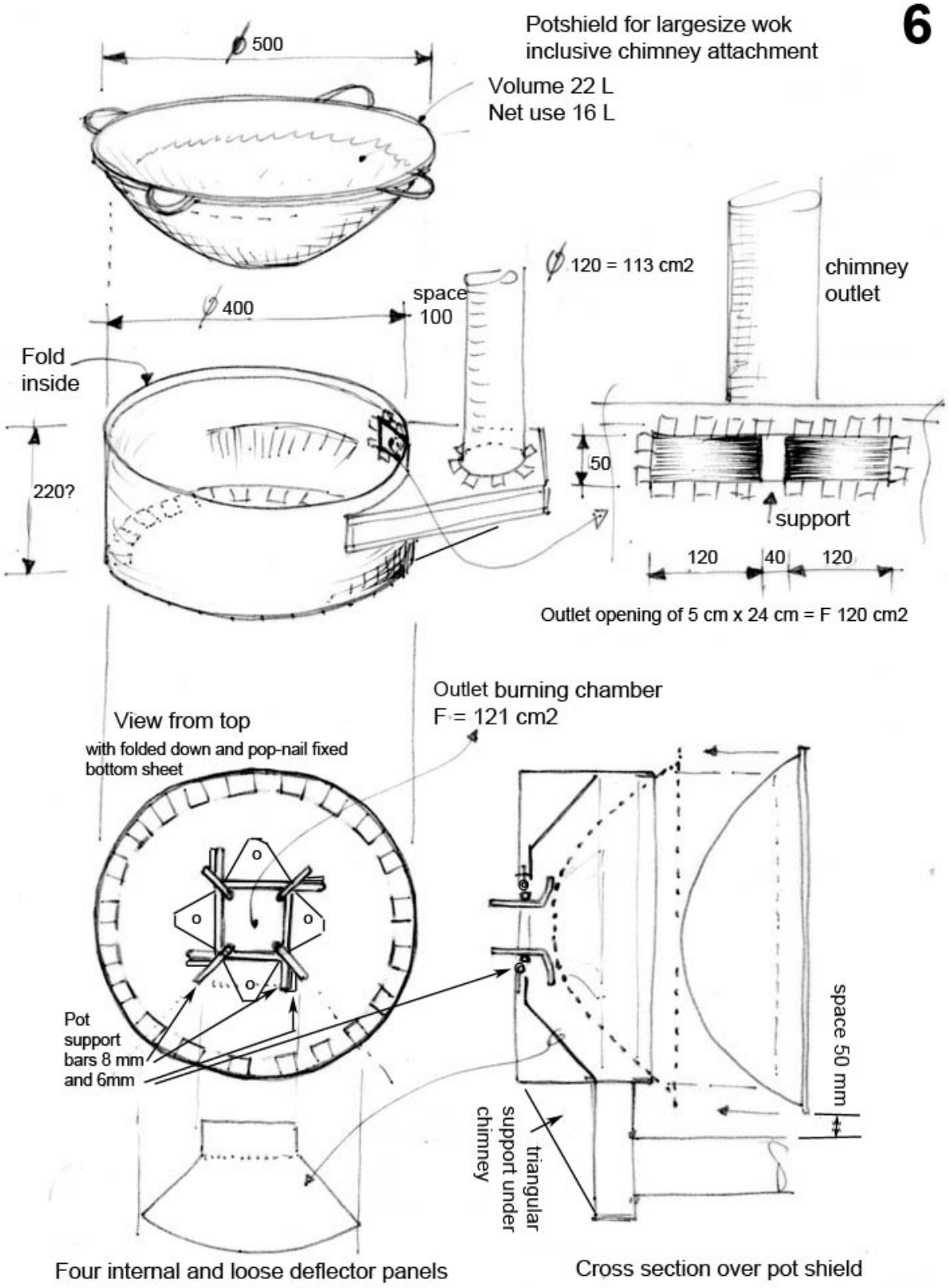
The chimney attachment has the following advantages:

- ✓ Smoke evacuation to outside the house.
- ✓ Can be kept in the indoor kitchen during both summer and winter.
- ✓ Less soot development on the lower outside of the cooking pot and therefore less cleaning needed.

And the following disadvantages:

- Higher purchase cost due to additional material used and manufacturing costs.
- The need for an additional chimney outlet through the roof or a branching connection to the main chimney (preferred).

[8] The wide top side of the wok allows high water evaporation. This is accelerated by the higher altitudes of the GBAO and results in only the food in the bottom of the wok being well cooked; so constant stirring is required.



DIMENSIONS OF CLOSED POT SHIELD AND CHIMNEY FOR LARGE WOK (22ℓ VOLUME, 16ℓ NET USE).

6.6. Bread-Baking Extension

To improve the heat transmission from the house-heating stove to the air in the room, a GI sheet heat exchanger has been designed to be fitted in the chimney. The same construction can also serve as a bread-baking oven and was adapted to fit onto the top of the ICS, with its hotter fire. The bottom sheet of the inner oven, above the flame, has been made of thicker steel sheet (1.2 mm) to avoid the flame rapidly burning the thin GI bottom of the container.

Based on a chimney heat exchanger, an improved bread oven has been designed which can be placed on the ICS.

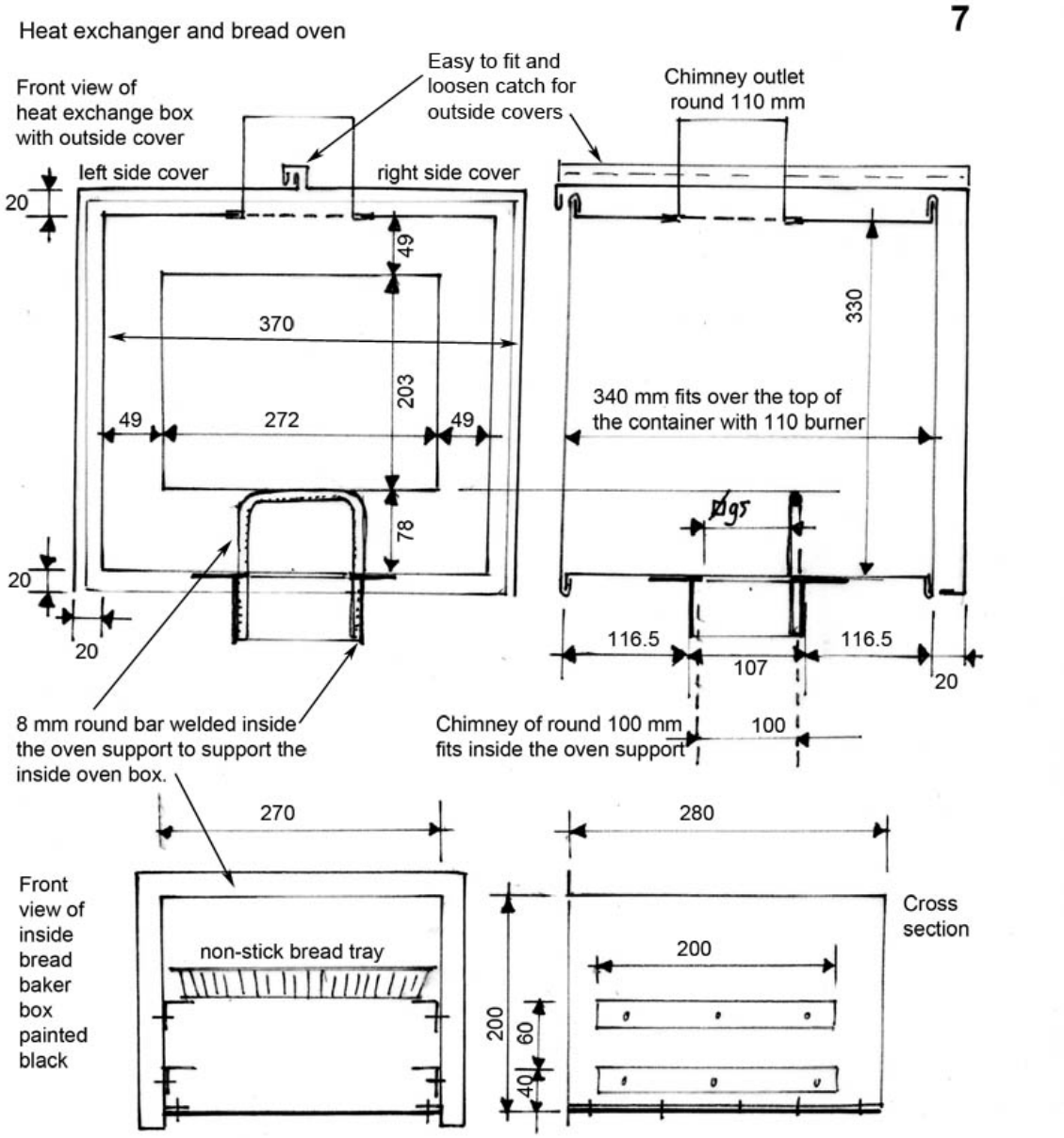
The new ICS bread oven will probably use one-fifth of the amount of firewood as the traditional *tandori* bread oven. The photo (right) shows an outside wood-fired bread oven. The entire oven is preheated by burning large amount of branches, probably five times the amount needed for the ICS to bake the same quantity of bread.

The wall of the heat exchanger box has been insulated with a second, detachable cover (made in two halves) and the door has been made double. The second sheet creates a 2 cm insulating airspace by which the oven heat will be retained rather than radiating out as is the case (and the purpose) with the heat exchanger. This way, little fire is required for reaching a sustainable baking temperature.

The new bread oven can still be used as a heat exchanger on the chimney. In that case, a small interface pipe (from square 110 mm to round Ø 110 mm) is used to fit it in/on the chimney pipe because the ICS outlet is square.

The oven was tested by baking two breads and worked adequately. The high-low position of the bread pans was changed once and the bread was turned over in the last phase to bake the upper part golden brown. Applying egg white will give the bread a shiny golden brown surface.

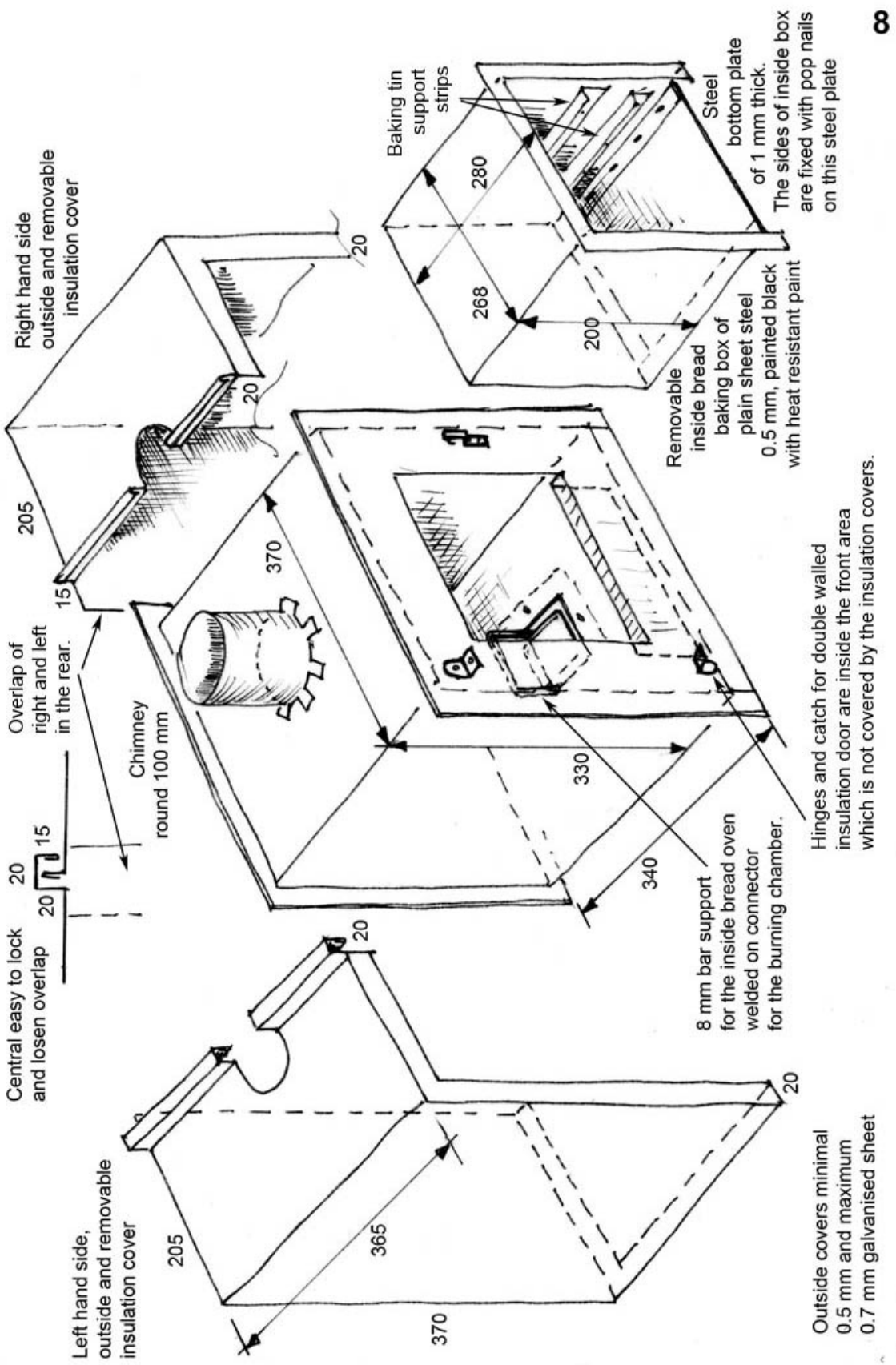
Double walled bread oven. Heat damage of the thin GI bottom sheet is visible. The new oven has a thicker (1.2 mm) metal bottom sheet.



Bottom plate from inner box is 1.2 mm steel plate. Inner box is fitted with pop nails on this plate.
Inner box is made of plain sheet steel 0.5 mm thick.
Inner box is painted inside and outside with heat resistsnt black paint.
Bread tin supports are fixed with pop nails.
The inner box is supported by the 8 mm round bar welded on the oven support.
The inner box can be easily removed from the heat exchanger if needed.

The front side of the oven is fitted with a double walled galvanised sheet steel door.
The hinges and the catch of the door are fitted within the 49 mm side of the heat exchanger front.

DRAWING OF IMPROVED BREAD OVEN TO FIT ON THE ICS AND THE HOUSE-HEATING STOVE.
WITHOUT THE INSULATION COVERS, IT CAN BE USED AS A HEAT EXCHANGER IN THE CHIMNEY AS WELL.



AXONOMETRIC DRAWING OF THE IMPROVED AND INSULATED ICS CHIMNEY BREAD OVEN.
THE BOTTOM PLATE IS 1.2 MM OR 1.5 MM STEEL PLATE AND THE INNER BOX IS SCREWED ONTO THIS PLATE.

6.7. Large Size ICS

In designing a practical ICS size, two dimensions are proposed.

- One ICS with an **11 cm x 11 cm burning chamber** (121 cm^2) for normal 5ℓ and 6ℓ cylindrical cooking pots (including pressure cookers) and the small 8ℓ, medium 12ℓ and large 16ℓ woks. The small ICS can also be used indoors, but needs to be placed under a hood to evacuate the smoke from the house. The ICS plus cooking pot is approximately 50 cm high. If used while standing, the ICS needs to be placed on a low (40-45 cm high) table, whereas the hood should start at a height of 155-160 cm.

- One ICS with a **14 cm x 14 cm burning chamber** (196 cm^2) for the extra large woks for commercial and restaurant use, fitted with a chimney attachment. The burning chamber of this ICS is 50% larger than the former one. The extra large woks have a use volume of 35-40ℓ. This larger ICS is placed on the ground. Increasing the section of the burning chamber to 15 cm x 15 cm (225 cm^2), it will be about two times the section of the small burning chamber.

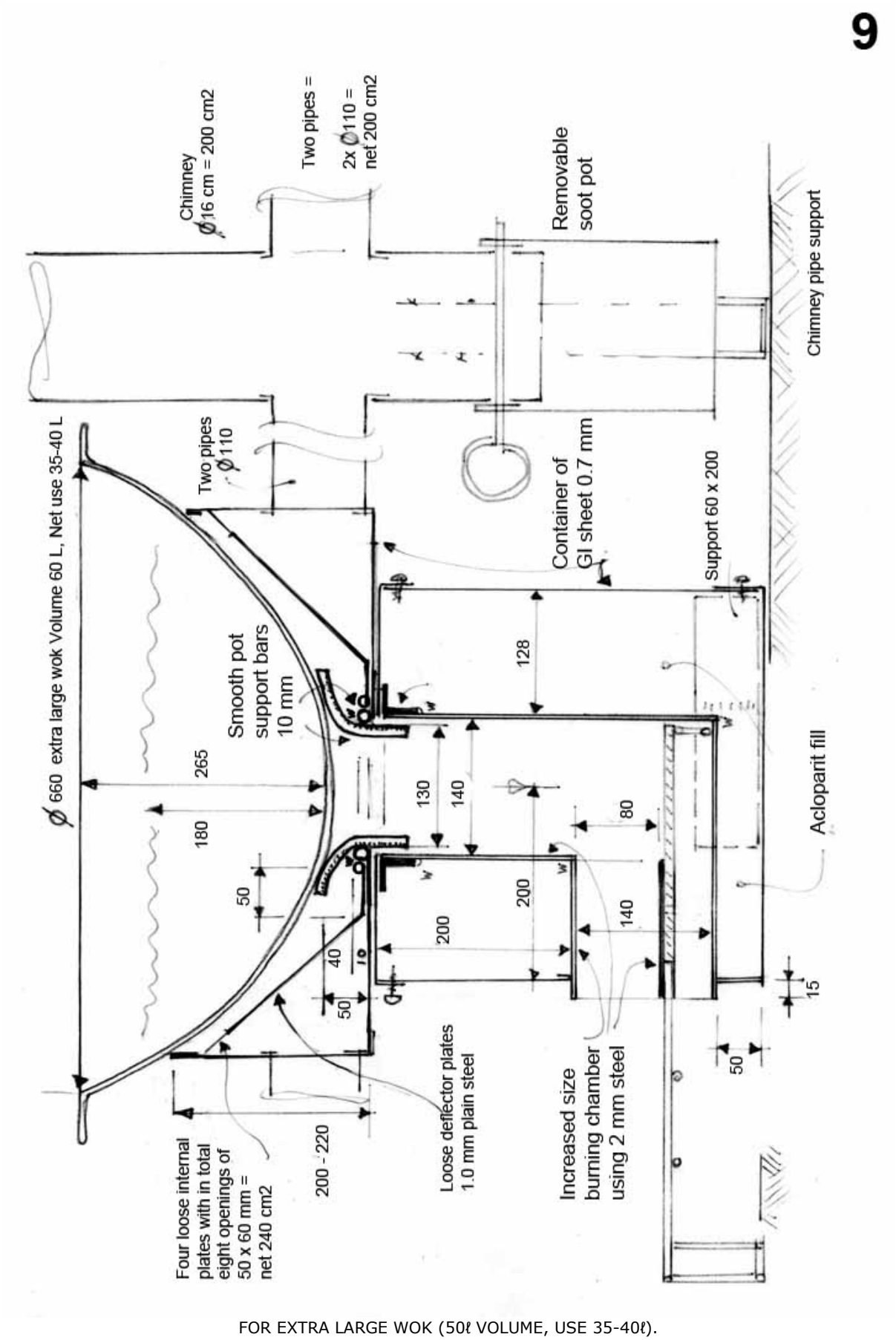
The wok is especially useful and energy efficient for stir-frying, but in Tajikistan the wok is commonly used as the only cooking pot and for slow (long) cooking dishes as well. This causes large energy losses, partly due to excessive evaporation from the large open top surface.

> Woks are not recommended for long moist/wet/simmering food cooking processes.

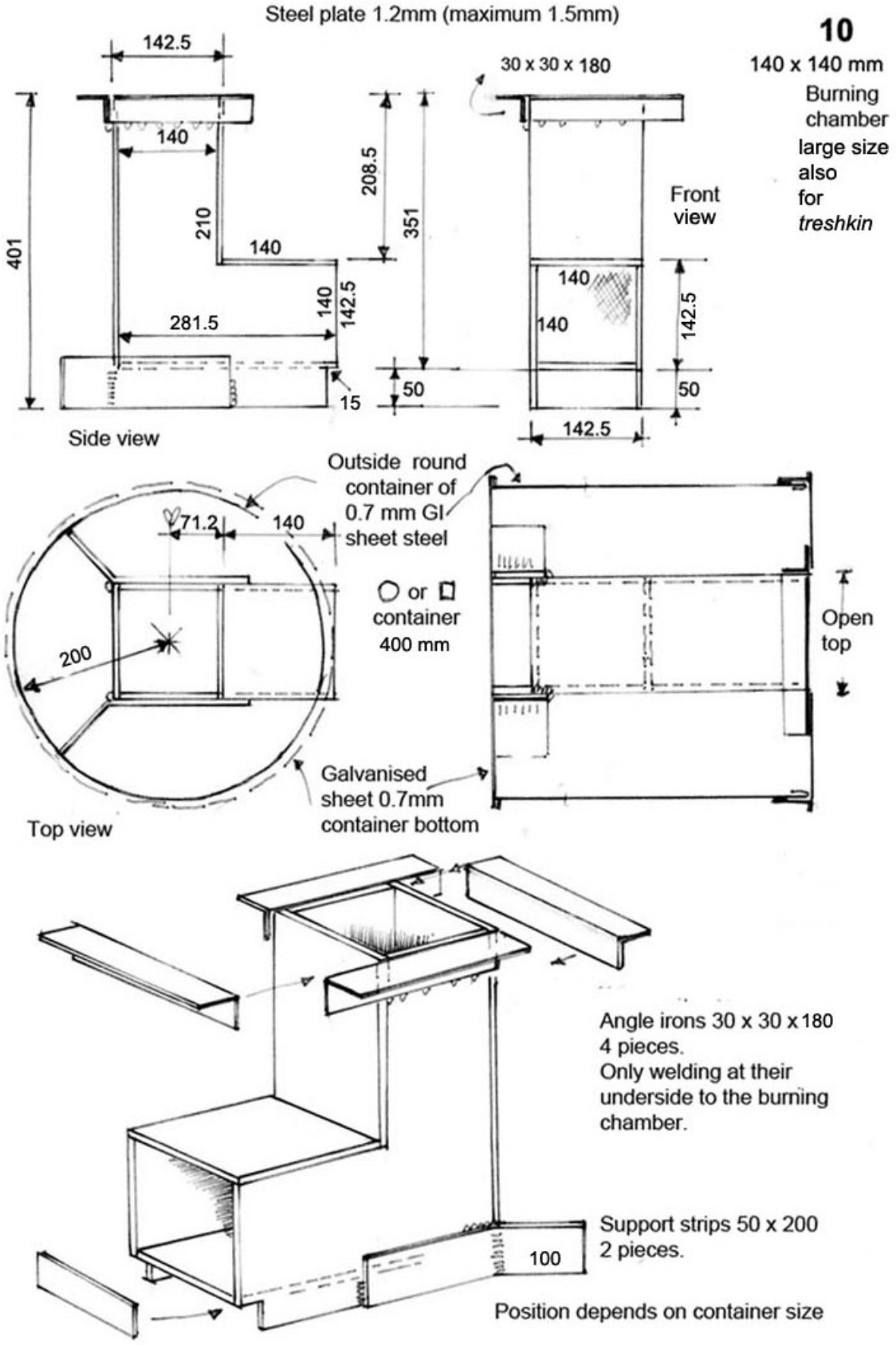
The construction differences for the larger 14 cm x 14 cm (196 cm^2) ICS are the following:

a. The steel plate of the burning chamber is 2 mm for increased durability. Because this ICS size is used for a long time on end, extra heat loss by the thicker burning chamber is minimal.
b. The overall height of the stove is higher because the burning chamber is 1.5 times the cross section of the feeder opening and the burning chamber. In addition, the insulation under the burning chamber has been increased by 1 to 5 cm.
c. The spacing between the top of the burning chamber and the bottom of the pot has been increased to 4 cm because of the larger cross section of the burning chamber.
d. The width of the container has been increased to 40 cm for stability. If the width needs to be further increased, the firewood-feeding opening also needs to be extended in length.
e. The container is fully filled with chunky (5-8 cm) Acloparit insulation for stability. Because of the greater weight of the filled container, two handles are fixed on each side.
f. The inner plate consists of four quarter round sections placed loosely inside. These are made of 1 mm normal steel plate. This is different from the smaller ICS.
g. The top part of each plate has two cutouts of 5 cm x 6 cm = 30 cm^2 for the flue gasses to go down and through the chimney. The eight cutouts together are 240 cm^2. Also different.
h. For improved distribution of the flue gasses, two small chimney pipes are connected to the pot skirt, each Ø 110 mm, totalling 200 cm^2 section.
i. The single chimney is Ø 160 mm, also with a 200 cm^2 section. A soot pot is fixed under the chimney for easy cleaning. This chimney needs a ground support.

Possibly villagers will still want a larger burning chamber, although documentation indicates that for the Ø 70 cm wok (50ℓ, use 35ℓ), the 14 cm x 14 cm burning chamber is sufficient. When again a larger design is made, the height of the burning chamber should remain 1.5 times the cross section of the burning chamber or feeder opening.

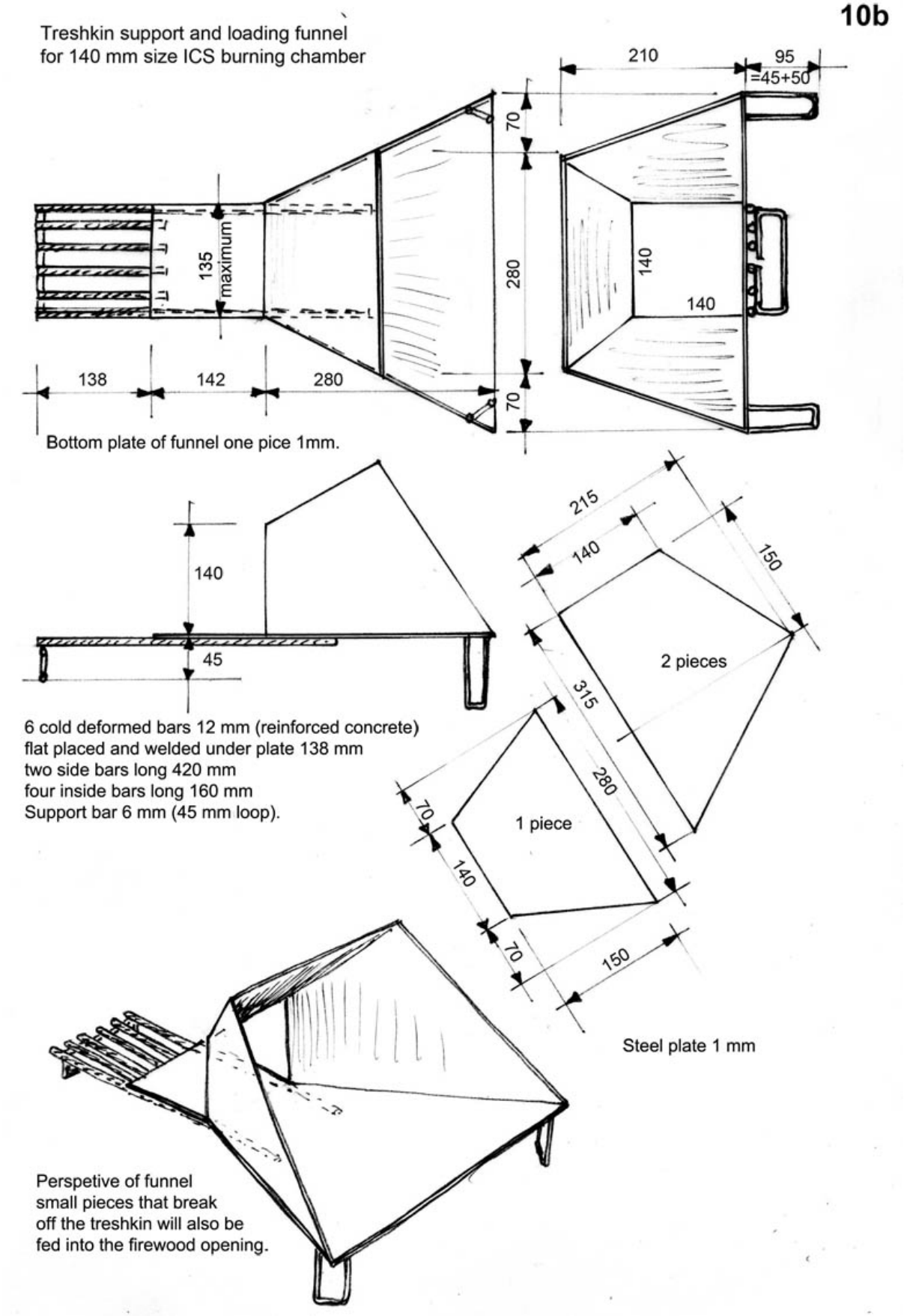


FOR EXTRA LARGE WOK (50ℓ VOLUME, USE 35-40ℓ).



14 CM X 14 CM BURNER FOR INDUSTRIAL –COMMERCIAL STOVES AND EXTRA LARGE PARTY WOKS.
THE LARGER BURNER CAN ALSO BE USED FOR BURNING TRESHKIN WITH ADAPTED FIREWOOD SUPPORT.
TRESHKIN IS A HEATHER LIKE PLANT GROWING IN VERY HIGH ALTITUDES (YAK FOOD)

10b



MODIFIED FIREWOOD SUPPORT FOR BURNING TRESHKIN IN THE 14 CM X 14 CM BURNER.
THE FUNNEL SHAPE ALLOWS THE BUSHES TO BE COMPRESSED A LITTLE
ADDITIONALLY A GARDEN SICCORS MAY BE NEEDE TO CLIP SOME BRANCHES.

- The **14 cm x 14 cm burning chamber** can be used for cooking on *treshkin*. The burning chamber is fitted with a larger feeder and firewood funnel to allow the *treshkin* to be pressed inside the burning chamber without the many small branches breaking off in the process. Additionally, a garden scissor can be used for cutting the widest branches off the bushes.


WHEELBARROW WITH NEWLY PULLED UP *TRESHKIN* (LEFT).
EACH BLOCK SELLS FOR ABOUT S/ 12 IN THE SUMMER AND S/ 15- 20 IN THE WINTER.
COLLECTING *TRESHKIN* FROM THE STORAGE FOR COOKING (RIGHT)

Tapack (dried cow dung cakes) is made in thick layers, cut into blocks and sun dried. By burning, large amounts of ash are produced, whereas the heating value is lower than firewood.

Most blocks of *tapack* (picture left) will not fit into the ICS. These large blocks can only be used in the larger house heating stoves used during the winter.

7. COOKING EFFICIENCY

Large families, markets and restaurants use open woks for cooking and frying, consuming massive amounts of firewood. The commonly used modified oil-barrel stoves have the aeration of the fire from the wide open side entrance and from the top. Most of the fire leaves the barrel through the wide front opening, heating only partly one side of the wok.

The firewood efficiency of this design is very low and can be improved by 75-80% when modified to a small-size "Rocket Stove" with a well-adjusted (fixed) pot shield and a 11 cm x 11 cm burning chamber. A larger size ICS is not needed.

In countries where firewood is not (yet) a problem and can be bought against low prices, very inefficient stoves are a common sight. The photo right is an example found in the markets in Cameroon. Once the cooking or frying is completed, the firewood is pulled out a little, but continues to burn away.

Only comparative measurements and demonstrations will convince the cooks and marketers that the ICS is substantially saving firewood and therefore costs for those that need to buy the firewood.

Efficiency Improvement in Cooking

The overall cooking efficiency (less firewood consumption and less cooking time) can be improved by the following simple measurements:

1. Always use a **lid or cover** on the cooking pot. Savings of 10% compared to no lid.
2. Cut vegetables and meat **into small pieces** and cook in a small amount of water.[9]
3. Minimise fried or deep fried dishes requiring oil and high cooking temperatures.

Measurement for which additional equipment is needed:

4. For cooking rice or lintels, use a **Heat Retention Box (HRB)** after bringing the food and water to a boil.[10] Savings of 50% can easily be obtained.
5. Use a **pressure cooker** at high altitudes and for cooking pulses, beans, lentils and other ingredients that normally require long cooking periods. The higher the altitude, the larger the savings. For many dishes savings of 50-75% are common.

Use of solar heating:

6. Place food which has been brought to boil in a **solar box cooker** for further cooking.
7. Use **pre-heated water** from a solar water heater (SWH). Because in the cooking process a lot of water is used, using warm water saves cooking time.

[9] See www.bioenergylists.org/nienhuysrecurriculum on food preparation and the energy effect of using small pieces in the cooking process.

[10] For some suggestions on heat retention cooking, see: www.solarcooking.wikia.com/wiki/Heat-retention_cooking

8. DECISION MAKING

Without understanding the practical firewood savings of a stove and the most energy-efficient way to use the stove, it will be impossible to compare the ICS with the traditional model. In addition, the cooking possibilities should be known. When comparison is realised based on the purchase price of the stove only, and not taking firewood or time into consideration, a potential buyer will not invest in a more energy-efficient ICS.

> A new stove should be accompanied with a simple manual on what to do and what not to do in order to make optimum use of the equipment. What is the maintenance and operation?

A house owner (with family) needs to assess the following 20 elements in order to make a balanced decision about purchasing a stove:

(1) Actual purchase price of the product with its attachments.
(2) Possibility to obtain it locally in the village; simplicity of purchase.
(3) Cost difference between local purchase and buying in a big town.
(4) Possibility to obtain spare parts or additional pot shields for other pots.
(5) Has the required cooking pots or needs to buy other cooking pots.
(6) Amount of money or credit needed to finance the stove, and ease to get credit.
(7) Expected lifetime of the new stove; after how many years replacement of what parts?
(8) Expected savings in heating fuel, either in purchase cost or time savings. When excess firewood can be sold after the application of the thermal insulation, this is income.
(9) Added comfort level and cleanliness of the house.
(10) Added status improvement resulting from the new stove.
(11) Possible needed modifications to the chimney or kitchen area, such as a hood.
(12) Separation of cooking area from the general sitting area.
(13) Reduction of drudgery work for the women in the household.
(14) Lack of light emitted from the new stove.
(15) Additional cost of a LED in the chimney above the stove.
(16) Reduction of smoke, eye diseases and general health issues caused by smoke in the house.
(17) Reduction of fire hazard and burning risks for children.
(18) Quality of the cooked food or bread by the improvement.
(19) Amount of maintenance and operational costs.
(20) Amount of firewood that needs to be collected, chopped and stored for long period.

Weighing these aspects will depend on the particular financial situation of the house owner. Clear information on the advantages and disadvantages of the new stove is required, as well as knowledge of its operation instructions. This means for each article an easy to understand factsheet must be made and, for some articles, a small manual on its operation and maintenance. For example, what kind of dishes can be cooked on the stove and which ones not.

The implementing agency needs to collect reliable testing and use data that will additionally convince the house owner on the efficiency of the ICS. Current measurements indicate that the firewood efficiency is about 40% compared with other stoves having only a firewood efficiency between 20 and 25%, using the same fresh firewood branches.

9. ICS PROMOTION

Experience shows that neighbour-to-neighbour promotion is the most effective method to ensure success of a new product in rural areas. Villagers tend to value and respect the opinions of their peers when this is based on personal experience and testimony.

Demonstration of Models

To make women aware of the features and possibilities of the MOP-ICS, local demonstration in a real household situation by a family who has been using the ICS for an extended period is required. The user can then explain how it changed her life and cooking behaviour; giving the pros and cons. This is the best method to convince others. MOP-ICS models need to be used in selected households under the following conditions:

a) The household spends substantial time on firewood collection or pays for firewood. When firewood is readily available or very cheap, the economical benefit is little.
b) The household uses firewood and biomass as their principal cooking fuel.
c) The household needs to measure (weigh) the total amount of firewood used on a weekly basis. Each new supply of firewood added to the stock must also be weighed. At the end of the week, the balance is weighed and the consumption calculated. The household must record the number of meals cooked on a chart (see below).
d) The household must be willing to receive visitors in the kitchen and explain the functioning, savings, advantages and disadvantages of the MOP-ICS.
e) The household needs to provide feedback information to the animator who will visit the same villager after a few weeks to collect the information.

Registration Form - Firewood Consumption for Cooking per Household												
Name MOP-ICS Owner:									**Measure 0.1 kg Precision**			
Village:					**Number of Adults:**				A. Total kg of firewood at the start of the week	B. Total kg of firewood added during the week	C. Remaining amount of firewood at end of week	D. Total firewood used during week. D=A+B-C
House:					**Children under 6:**							
	Number of Meals/Day (child < 6 yrs = 1/2 meal)							**Total Number of Meals**				
	Monday	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**	**Sunday**					
WEEK 1 Breakfast												
WEEK 1 Lunch												
WEEK 1 Dinner												
WEEK 1 Tea												
Total												
Average use of firewood per meal = Total D divided by total number of meals												
Name of Record Collector:									Date:			

A simple spring-scale is required for the firewood measurements.

Promotion Team (Animators)
The promotion team should select rather intelligent recipients who can understand the principles of the MOP-ICS and can explain the same to others. It also means that the household should have an adequate status in the society to accept receiving neighbours and other people in their kitchen.[11]

A technically educated animator needs to explain the advantages and disadvantages of the model MOP-ICS to the recipient. The animator is also responsible for assembling the data into a table/chart and reporting on the experiences of the villager.

> An ICS is not specially designed for the poor,
> but rather to save time, money, health and the environment.

Efficiency Testing
In order to provide clear data on the efficiency of the ICS, the standard water boiling test should be realised by the promotion team for both the traditional stove and the MOP-ICS. The standard water boiling test can be copied from the TOP-ICS paper.

Marketing Strategy
NEVER promote an ICS (or any other article) "for the poor" as this will work VERY counterproductive in the general acceptance by the public. It is the wealthier and intelligent people who should use the ICS for economic and efficiency reasons. Other people will follow or copy the behaviour of the more advanced people from their society, not the poorest. The newly introduced article will then sell itself.

Limit Subsidy to Entrepreneurs
The NGO or development agency should not subsidise consumer products, but only support the demonstration process. From the very onset, collaboration needs to be sought with local entrepreneurs and distribution channels to be involved in the manufacturing and marketing. The manufacturer, entrepreneur or sales outlet can be supported with the supply of free user or installation manuals, advertisement, credit in the form of supplies, training, etc.

Community-Based Promotion
Community-based promotion and dissemination allows maximum communication with the target groups and their influence on the decision-making process of individuals. This is important for replication and sustainability reasons. It is always the most advanced citizens in each village who are followed by others in the application of new technologies.

It is necessary that the villagers pay a real price for the equipment so they make a financial investment and take better care of the equipment. Their household economy will indicate whether or not the financial investment is worthwhile and if the return on that investment is cost effective. Clear data on firewood and other fuel costs must be available in combination with the possible savings the new ICS will provide.

[11] In one case, the household was from a very low caste; hence, the higher (wealthier) caste did not want to visit the house. Because this higher caste did not apply the technology, others also ignored the innovative design.

10. ENTERPRISE DEVELOPMENT

The ICS needs to be marketed through locally existing networks, such as hardware stores, firewood suppliers, market places and mobile traders.

Contracting and Subcontracting

The initial series of MOP-ICSs can be contracted to metalworkers on the basis of the drawings. Good quality control on design, measurements and functioning is required. For contracting in an illiterate or semi-illiterate environment, the production of a small series of approved units is necessary. The approved units with the drawings should be left with the contracted entrepreneurs to copy.

Jigs for Series Production

For series manufacturing of the metal component, jigs and patterns should be made, especially for cutting, folding and welding. The jigs will assist in ensuring all components are cut to the same length and welded correctly. Although some initial time and material investment will be necessary for making the jigs, the cost will be quickly recovered owing to the improved and faster working method.

Cost Reductions with Improved Efficiency

The overall manufacturing cost price of a product is approximately halved when the production is 100-fold. For example, a single MOP-ICS would cost USD 40 if made one at a time, excluding the cost of one-by-one distribution. The same MOP-ICS can be made at about USD 20 if 100 units are manufactured and sold at once or USD 10 for 10,000 units.

An NGO should not be involved in the production and sales of a consumer product, but rather support the development of the local entrepreneur. This is to avoid market price distortion by the NGO when it does not include all its administrative and overhead costs as part of the consumer price. NGO consumer subsidy will almost guarantee that the product never becomes a sustainable article.

Financial Monitoring by NGO

In order to assess if the production is profitable, good bookkeeping is required of the material costs, subcontracts, operation and distribution expenses. When the production and employed staff increase, good financial records need to be kept of contracts. Contracting staff or production should preferably be done per produced unit, rather than on a salary basis. Precise quality control is necessary.

Entrepreneur Support

The following steps in the development process can be realised by an NGO:

a) Capacity building of the local staff in the general ICS technology through study of relevant documents and available Internet information.
b) Manufacturing of several model ICS by local craftsmen, considering available materials, manufacturing techniques, current use of cooking equipment and cooking habits of the target population. The manufacturing of the models will go through several phases of field testing, efficiency measurements and adjustments.
c) Ensure quality control during the production process, not only at the end.
d) Develop promotional material and translate into local languages and picture stories.
e) Place the models in villages with interested (motivated) families who normally collect firewood for all their cooking needs.
f) Realise promotion with the users in the villages and develop a marketing network. Involve current ICS users in the distribution network and establish commission and re-sale mechanisms. These persons need to collect orders and coordinate production and delivery through local entrepreneurs.
g) Develop, in coordination with entrepreneurs, local sales outlets and distribution networks through commercial service providers and contractors, linking them to the manufacturers.

h) Identify additional cooking equipment, such as pressure cookers, heat retention boxes (HRB) and other small kitchen or cooking-related equipment which will increase the financial turnover of the sales persons.
i) Invite colleagues from other NGOs to partake in the promotion activity and provide them with the promotional material and marketing network.
j) Invite colleagues from other districts in the country to explain the technology, production and dissemination process, advantages, bottlenecks and solutions. Provide them with the technical and financial details for local replication.
k) Organise entrepreneur exchange visits between different regions, so a new entrepreneur can learn from an experienced one.
l) Organise networking between entrepreneurs so they can benefit from central supply and transport facilities against reduced prices.

Technical and Environmental Aspects

- *Reduction of minimal 50% of the biomass or fuel needed for cooking.*
  Fewer people will switch to kerosene, hence saving fossil fuel. One MOP-ICS saves approximately 500 kg firewood/year. When the ICS is used instead of a kerosene stove, the equivalent of minimal 100-150 litres of kerosene is saved per year per family (2-3 litre/week). This amount times 10,000 families is minimal 100 million litres of kerosene (or liquid gas) per year. With increasing fuel prices, this becomes an important sum in foreign currency savings on importation.

- *Substantial reduction in carbon emissions.*
  Less cooking fuel requirements signifies an equal reduction in carbon gas emissions. These gases consist of CO_2 (Carbon Dioxide), some CH_4 (Methane) and other poisonous gases, such as formaldehyde. One MOP-ICS saves about 500 kg firewood/year, about half of which consists of carbon. For every 250 kg carbon burned, about 750 kg CO_2 is produced. For every 150 MOP-ICS used, about 100 tons of CO_2 is saved annually.

- *Finance with credits.*
  In theory, considerable international CER payments can be obtained when ICS are accepted for carbon trading under the Kyoto Protocol. Current trading price is around USD 10/ton CO_2 equivalent saved.

  A separate trading agreement needs to be made for every design and country as the CDM calculation savings will differ per region and the country's fuel situation. An ICS will become eligible for CERs once it has been proven that it lasts sufficient time and is being used. The use of SS cookers lasting many years is therefore more suitable for CERs than GI and MS metal stoves. For this reason, it is important that close monitoring is realised to assess the savings and durability of the equipment.

  The registration costs for small projects may be as high as USD 50,000 to 100,000; hence, large numbers of stoves need to be produced and the stoves should have a durable design. When CERs can be obtained, the organisation promoting the stoves should make credit contracts with the people buying the ICS and apply the CERs to the repayment of the credit. This way the buyer does not have to pay cash. After a determined number of months, the stove becomes the property of the buyer.

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For more information on cooking stoves see: www.stoves.bioenergylists.org www.crest.org and www.hedon.info/goto.php/ImprovedCookstove

For more information on indoor air pollution: www.who.in/indoorair/presentations and www.who.in/indoorair/publications