HUYS ADVIES

IMPROVED COOKING STOVE (ICS)

Saving 50% Cooking Energy with a Metal ICS
Examples from Tajikistan, Pakistan and Afghanistan

Technical Working Paper ~ Number 10

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See www.nienhuys.info, page ICS, for CAD drawings of the ICS basic burning unit and wok pot shields (household and commercial sizes) and drawing of bread baking oven (Russian text).

TABLE OF CONTENTS

Abstract

ICS for households and restaurants made from 1.2 mm plain and 0.7 mm GI sheet metal, including open and closed pot shields for cylindrical cooking pots and large woks. The closed post shields have an attached chimney. Includes sketch designs for common baked brick filled ICS burning chamber and bread baking oven fitting onto the ICS basic burning unit or in the chimney of a space-heating stove. When placed in the chimney of a space-heating stove, the cover of the bread baking oven can be easily removed to provide additional heat radiation to warm the room.

In the markets, large woks are used on cut-opened barrels having very low firewood efficiency. In this picture, the left wok shows yellow flames pouring out of the barrel opening, evidence of the inefficiency of this cooking technique.

INTRODUCTION

The Technical Working Papers incorporate knowledge gained from more than 30 years experience in project development and implementation in several development countries. Much time has been dedicated to providing practical information on how to realise beneficial, low-cost solutions for the inhabitants of the mountain regions of the Himalayas.

Technologies need to be adapted to local circumstances because of socio-economic circumstances. Existing, proven technical solutions have been modified taking into consideration local customs; technical skills of local craftsmen; ease of transport; availability of materials in the local markets of the mountain regions; as well as the acceptability and affordability by the village people.

Making the buildings more comfortable and reducing Internal Air Pollution (IAP) in traditional and new high altitude buildings are important aspects linked to thermal insulation and cooking methods. This document provides a simple construction of an improved cooking stove (ICS) and bread baking equipment with chimney attachment, supplemented by CAD drawings of the same.

> For low-income people, it is important to find appropriate solutions taking into consideration the local economy of the people and local entrepreneurs, as well as the available skills, tools, materials and other resources, to create affordable products for improving living conditions and livelihood.

This Technical Working Paper #10 gives a resume of the development of the metal ICS with pot shields and bread baking oven, and includes the following topics:

- Background for the need of better cooking equipment.
- Various energy-saving options.
- Stove manufacturing of the ICS basic burning unit, pot shields, bread oven, and larger sizes.
- Promotion and marketing aspects.
- Sketch designs of the ICS pot shields and bread baking oven, with an option to make the ICS burning chamber from baked bricks.

Capacity building of technical staff, local entrepreneurs and manufacturers is realised by a combination of theoretical education and practical implementation, such as through entrepreneur exchange training with experienced entrepreneurs.[1] In this model, the key entrepreneur can be involved in the bulk supply of source material and the best tools.

The ICS is not yet the most efficient cooking instrument. Heat Retention Boxes (HRB), solar cookers and gassifiers are more efficient. While the sun is needed for solar cookers, gasifiers require shredding of fuel and more complicated instruments, adding to the cost. However, both developments are for the foreseeable future. The HRB requires an initial cooking process, but is most cost efficient.[2]

Sustainable marketing will be achieved only when the villagers buy the house improvements without the need for intensive promotion by external agents. Once a good understanding of the product is reached, local entrepreneurs and craftsmen can further improve upon it. Possibly the best way to introduce the ICS is through the organisation of small cooking clubs where villagers can experience how the product works and observe the energy and time saving aspects. The cooking clubs can develop recipes for local dishes using the equipment and produce a recipe book. Such a recipe book would make it easier for future ICS users to change their cooking habits and become accustomed with the stove.

The document can be used as a basis for awareness development, training and as part or basis of curriculum development and vocational training.

[1] For a detailed document on Entrepreneur Exchange Training, see website www.nienhuys.info, page home.
[2] See Technical Working Paper #21 - HRB on website www.nienhuys.info, page ICS.

1. REASON FOR ICS DEVELOPMENT

In the Himalayas, the space-heating stove doubles in the winter period as a cooking stove, resulting in traditional dishes having long cooking hours, such as stews.

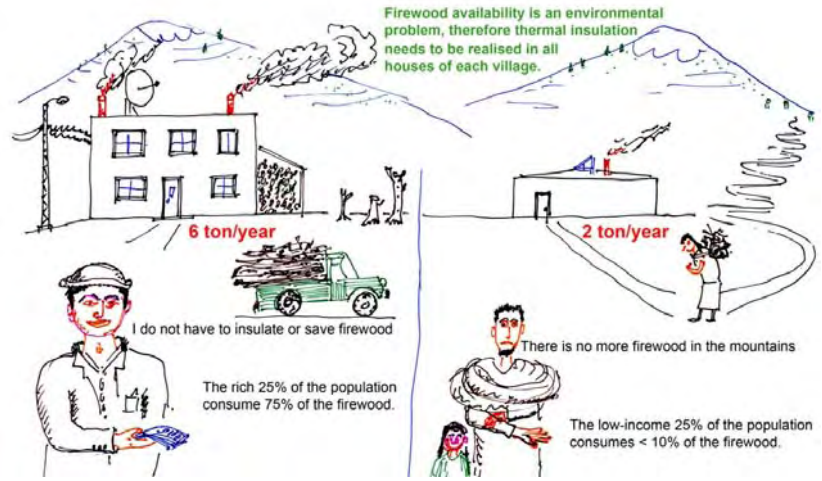
At altitudes of 1500 m, the amount of fuel for cooking (summer and winter) is about equal to the amount of fuel needed for space heating (winter). For small households, the two quantities together are between 3 and 4 tons of firewood per year. Above this altitude, the amount of fuel for space heating rapidly increases due to poorly insulated houses.[3]

The immediate effect of the large firewood requirement for both cooking and space heating is <u>massive deforestation</u>. Villagers then resort to burning *treshkin*, a slow growing heather-like bush and the staple food for yaks in the winter (photo left above). Once the *treshkin* is depleted, the only biomass fuel remaining will be dried cow dung cakes (photo right above) and fruit trees.

Continuous grazing of goats further reduces the available vegetation, which leads to soil erosion, landslides, river flooding, "natural disasters" and infertility of the land for crop production.

[3] All biomass fuel burned produces CO_2, which in turn increases global warming and causes climate change.

The first step to reverse this process is to reduce the fuel consumption per household for both space heating and cooking. This is a communal need and has to be implemented at the village and town level for all inhabitants. The application of thermal insulation and production of more fuel-efficient cooking equipment should therefore be a community interest.



Although some of the combined cooking-space heating stoves are relatively effective for that purpose (*buchari* ≈ 30%), they produce in the summer so much heat that many families place the stove outside in the yard to do the cooking. As a result, considerable heat is lost into the atmosphere and is not going into the cooking pot. Cooking on heat-radiating stoves in the summer is uncomfortable and wastes large amounts of firewood and/or other biomass. In addition, many old stoves produce large quantities of smoke, causing eye irritation, lung diseases and poor health of the cooks (women) and children playing or sitting in the area. The ICS is more energy efficient because more heat is directed into the cooking pot and less heat is lost to the environment.

Bucharis placed in an outside kitchen and in the yard during the summer period.

With <u>better house insulation</u>, the long cooking hours during the winter are no longer required as the room warms up faster and remains warm. ICS are important because they:

- Reduce firewood and biomass consumption year round and thereby reduce environmental degradation.
- Save large quantities of time in collecting biomass (often women).
- Save large quantities of time in cooking and cleaning the pots (no black ash residue).
- Reduce the amount of smoke in the house and with that reduce eye and lung diseases.
- Are safer to handle because the outside shell is less hot.

Improved Cooking Stoves (ICS) have been developed by various organisations of which Aprovecho[4] with the "Rocket Stove" has made a substantial and crucial contribution in disseminating the technology. Many different designs are now available worldwide and can be reviewed on various websites, such as:
www.crest.org, www.hedon.info/goto.php/ImprovedCookstove and www.stoves.bioenergylists.org

[4] The technology of the ICS is based on the "Rocket Stove" developed by Aprovecho, along with Dr. Larry Winairsky. Based on this principle, the Mobile One Pot (MOP) ICS was developed in Jaffna, Sri Lanka, for the tsunami victims under a project financed by Trocaire, Ireland.

2. ENERGY CONSERVATION

A. Energy conservation by thermal insulation for houses has priority over new technologies and/or equipment related to space heating and heat exchangers. When the open roof hole or flimsy roof window is not closed, improving space heaters and heat exchangers has little effect on firewood saving. Professionals, artisans and entrepreneurs should be aware of the relationship between thermal insulation and stove-connected space heaters.

The roof window in the traditional Pamiri house is the number one leakage of heat in the house.

Improving the stove does not lead to firewood savings if the roof window has broken glass and only little savings if it has single glass.[5]

In high altitude regions, the energy saving priority is on thermal insulation of houses. Because trees and other biomass grow slower at high altitudes, firewood saving becomes increasingly important with higher altitudes. Thermal insulation takes precedence over heaters for obtaining maximum energy-savings.

B. A basic ICS burning unit has been developed. Fitting onto this standard ICS burning unit, two different pot shields (for cylindrical pots and woks) with chimney attachments have been manufactured.

The material choice of the new ICS was determined by the availability of materials. The manufacturing design was partly determined by the skills of the local metalworkers and the available tools. By improving tools and skills, other design variations can be produced and production costs lowered.

C. Based on the ICS burning chamber, a "bread oven cum heat exchanger" has been developed. The current indoor and outside *tandori*-type bread making ovens are very inefficient in firewood use, especially when used only once a day.

Tandori Ovens – Clay Dome

Adobe Brick

Constructed in the Floor

Both the indoor or outdoor clay bread ovens *(tandori)* are "fired" with a large quantity of branches and cow-dung cakes *(tapack)* until it has attained a high enough temperature for baking the flat bread. The bread dough is then pasted against the inside wall to bake.

[5] For the full report on Roof Hatch Windows, see www.nienhuys.info, page thermal insulation: Technical Working Paper #7.

This technique is only firewood efficient when used constantly (i.e., 24 hrs per day) by community bakers. It is very firewood inefficient when used only once a day for baking a dozen flat breads *(chapatti)*. The firewood efficiency of the outdoor *tandori* oven is even lower in the winter because of the lower starting temperature of the oven. Furthermore, it is difficult to utilize the waste heat from this oven for heating the house.

A bread oven in a chimney box already exists (picture left); the bread being baked with the heat of the chimney flue gasses. A special advantage of this installation is that the widened chimney radiates more heat into the room than the straight chimney due to the increased surface of the box. A disadvantage is that the large space-heating stove needs to produce high heat temperature in order to bake the bread adequately. This not only requires large quantities of firewood, but also simultaneously heats up the room; an undesirable aspect in the summer period.

D. The existing "chimney heat exchanger cum bread oven" model has been improved with an insulating cover and a thick heat distributing bottom plate (picture right above). The unit can be placed directly onto the metal ICS, thereby avoiding the need to use the large space-heating stove for bread baking. It can also be placed in the chimney of the larger space-heating stove as a heat exchanger during the winter period. When used as a heat exchanger, the additional outside cover is removed.

E. The cost of the ICS can be reduced by making the burning chamber (11 cm x 11 cm) from factory baked clay bricks, rather than from 1.2 mm metal sheets. The bricks are piled inside the 0.7 mm GI metal sheet container box following the pattern in Annexe II.

F. Other cooking energy savers are the pressure cooker, especially for the higher altitudes, and the heat retention box (HRB). The combination of the two can achieve fuel savings up to 90%.

A good-quality solar box cooker can be used as a HRB to cook food after first bring it up to boiling temperature on a stove. A well-insulating solar box cooker can also work as a HRB without the sun.

3. STOVE MANUFACTURING

Local metalworkers require both education on heating principles and training in the manufacturing techniques of the ICS. In addition, training will be required in enterprise development and marketing techniques; the latter being essential for sustainability. Sales will need to 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. Principles of combustion of firewood, *tapack* and coal.
2. Small and larger cooking stove designs.
3. 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. Drawings and material specification lists.
10. Templates ("sjablons" [6]) and jigs.
11. The right tools and their use.
11. Quality control during the manufacturing process and delivery.
12. Brand name, serial number and manufacturing date.
13. User instructions, manuals, guarantee and complaint structure.

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.

Sketches for the ICS are presented in Annexe II.

Sketch #1 gives an overview of the ICS series developed.

- The 110 mm burning chamber is depicted in the lower left-hand corner. This unit fits into two different sizes of insulating containers (round or square). The containers provide stability. The pot supports attached to the pot shields all fit the burning chambers.
- A round Ø 33 cm container and a square 33 cm container. The containers are filled with a mix of fine (1-2 cm) and coarse Acloparit[7]. The large containers have good stability, especially when the large 50 cm wok is used.
- An open pot shield for the cylindrical Ø 26 cm (6ℓ volume) cooking pot. This model, however, was not liked very much by the villagers.
- A closed pot shield for the Ø 40 cm common wok and the larger Ø 50 cm wok.
- All the pot shields have a chimney for smoke evacuation.
- A bread-baking oven (heat exchanger) fitting onto the ICS burning chamber.

[6] The pattern to mark the cutting shape of the metal pieces is a template, but the local metalworkers better understood the word "sjablon".

[7] Acloparit is the sintered ash residue from the manufacturing of cement. The porous structure provides the insulation.

3.1 Burning Principle and Fire Grate

Biomass fire requires carbon (C) and oxygen (O) from the air and heat.[8]
Different biomass have different C content, for example:

- In dry wood: C ≈ 50%, but in wet wood only 40% because of the 10% more water.[9]
- In sundried dung or *tapack*: C ≈ 25%, reason for large amounts of ashes.
- In good quality coal: C ≈ 90%. However, often only low quality coal is available.

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 flue gasses a little above the fire.

The first improvement for the ICS is to ensure the air enters from below the fire or burning area. This is accomplished by the elbow shape of the firewood entrance and the grate and plate structure (see Annexe II 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

(a) 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 smooth reinforcement bars. Cutting the bars is difficult, so their use should be minimised.

(b) For household stoves 1.2 mm (maximum 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 welded by electric rods (2 mm). In one workshop, 1.5 mm steel plate was used, stretching the limit of workability with the table-mounted hand scissors.

(c) For commercial stoves being used intensively and for long cooking hours, the burning chamber should be 2 mm thick plates. An insulating ceramic burning chamber is better, but at present, these could not be produced by the brick making companies.

(d) 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.

(e) The design has been based on the minimum amount of cuts and welds.

(f) From the air separation plate, a template ("sjablon") in zinc sheet has been made for fast marking of many pieces in series manufacturing.

(g) A holding frame (jig) is used to hold the long Ø 12 mm bar in the same position while cutting it into many sections.

(h) A single (metal) jig should be manufactured for welding all the elements of the grate plate together in one go.

[8] Air contains about 80% nitrogen and only about 20% oxygen. For every 2 kg dry firewood containing 1 kg carbon, about 2 kg oxygen is needed (= 2 m^3). The amount of air to burn those 2 kg firewood will therefore be about 10 m^3. 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.
[9] One litre of water (in wood) will produce 1600 litres of vapour.

Village metalworkers have the habit of making one stove at a time and do not work from drawings or with precise measurements.

The use of fast cutting techniques (bars and profiles) and rapid assembly techniques by using jigs needs to be explained to the metalworkers.

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 is about ten times faster than measuring and cutting each piece separately.

The frequent cutting of concrete reinforcement bars is by far cheaper with the use of the rebar or bolt cutter, sometimes called a heavy-duty chain cutter (picture). Rebar cutters with a 100 cm long handle easily cuts ½-in. or 12 mm cold-deformed reinforced concrete bars without the need for electricity. The currently used electric cutting machines quickly waste away the corundum cutting disks, adding to the cost of the ICS. In addition, in many villages, there is no reliable electricity supply.

The manufacturing of jigs to allow welding the pre-cut components together also 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.

The making of templates ("sjablons") and welding jigs was new for the metalworkers. Practice with the cutting tools and welding jigs showed considerable time savings as compared to their usual practice of making one product at a time.

3.2 Training Metalworkers

With the introduction of a new product, training in the manufacturing is necessary.

First it is necessary to explain the burning principles of the cooking fire in general and the reasoning behind the ICS designs. Only when the metalworkers fully understand the principles behind the design, will they be able to make small modifications leading to faster production, lower material cost or increased heating efficiency.

To have an impact on the village and country environment, large numbers of firewood saving cooking and space-heating equipment are required. This requires good marketing techniques to reach the thousands of customers. However, after that, it allows for series production, a working method usually uncommon for village manufacturers.

Series manufacturing and the use of templates ("sjablons") and jigs need to be explained. Shortcomings in the skills of the metalworkers and their current working methods need to be analysed and eliminated. Once a small number of the best metalworkers have been upgraded with new skills, the methodology of Entrepreneur Exchange Training can be used for the training of other metalworkers from remote villages. Agreements can be made between the town-based larger entrepreneurs with heavier equipment and the village-based metalworkers for the delivery of pre-cut elements and local assembly.

The above allows a division between training the town entrepreneurs in series manufacturing and the village craftsman in assembly techniques. For large quantities of products (such as stoves), pre-cut and folded sections need to be precisely manufactured according to a precise pattern. By doing so, they can be easily transported and assembled locally, avoiding possible transport damage and transferring part of the labour cost to the local communities. Large production numbers of the assembled product can then be realised in short periods, minimising capital layout for stock.

Using patterns and series manufacturing is practiced by only a few metalworkers.

Series manufacturing allows substantial cost reduction. A 100-fold production allows halving the production cost as compared to a one-by-one production method. This is due to bulk purchase and transport of the source materials, better utilization of faster production equipment and less time wasted by switching from one activity to another.

Other elements requiring training are: the development of a quality control system during the production process, the development of a guarantee system and a responsible complaint structure.

3.3 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 galvanised steel plate for burning chambers, pot shields 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 1500 hours of burning. Is easy to weld electrically. The plate is difficult to cut with hand-operated scissors. Steel is a poor insulator and absorbs heat from the fire.
4	New sheet metal plate	1.2 mm	Adequate thickness allowing possibly 1000 cooking hours. Can be cut with hand-operated scissors. **Recommended material for house cooking,** but too thin for commercial ICS.
5	New steel plate	2 mm	More durable, but requires machine tools for cutting. The additional steel thickness will increase the material cost and consequently the stove price. **Recommended for commercial ICS.**
6	Stainless steel plate (SS) or chrome steel	1 mm	Excellent material for burning chambers lasting over 10,000 hours. Currently unavailable in many markets and needs to be imported. 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 from cement vermiculite or pumice	5 cm thick	Highly heat resistant and insulating at the same time. Currently volcanic pumice or vermiculite is not readily available and needs to be investigated if it can be found in the country. Adding a small quantity of aluminium powder will increase the insulating properties of the liner. **Recommended to develop.**
8	Refractory clay bricks from high grade clay	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 for common household ICS, 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.[10] 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.

To simplify the work, the sections cut from the steel plate are rectangular. A pattern 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 entirely.

[10] 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.

To ensure stability, the burning chamber is 4 mm higher than the two support strips which are welded to the top of the burning chamber. The burning chamber is elevated to allow room for insulation material under the chamber. The outside container is from galvanised sheet steel (0.7 mm). A coat of bright heat-resistant paint should be applied to the outside of the container; if not, the GI sheet will get a dull appearance after awhile.

It remains an option to seek the more durable stainless steel (SS), 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.

Research 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. It would be worthwhile to investigate whether a local brick factory could manufacture such burning chambers. 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 model is difficult to obtain and the size is too small for the liking of the cooks, larger pots cannot be used on the stove, the pot skirt is unsuitable for wok-type pots, the firewood support is too short and the outside material is flimsy – several reasons why this ICS was rejected as a possible product for dissemination.

Refractory Bricks

Baked bricks measuring 5 cm x 10.5 cm x 21 cm are commonly made and can be used as a liner in the ICS and larger space-heating stoves. The last sketch in Annexe II shows an ICS filled with 24 refractory bricks to make the burning chamber, instead of a steel plate. The pot support can be placed in the 11 cm x 11 cm opening, similar to the metal ICS container.

The advantages of this design are:

- The bricks are loosely placed in holders and can be easily replaced when broken/damaged.
- The bricks are both fireproof and insulating.
- The amount of labour needed for manufacturing the burning chamber is reduced.
- The durability of the burning chamber is extended.

The following conditions apply:

- ◊ The bricks should be of higher quality than ordinary baked bricks.
- ◊ The bricks should be rather straight so the sides join tightly together.
- ◊ The bricks should be selected on quality and marked with “ICS”.
- ◊ The bricks should be obtainable through an association of stove makers.
- ◊ The same size and quality bricks can be used as insulation bricks in the space-heating stove.
- ◊ The metal bar pot support fits into the top opening.

3.4 Open 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 the heat to the cooking pot.

The pot shield or skirt improves the firewood efficiency by 5-10%.

The first design of the ICS had a loose pot support made of Ø 8 mm bars to create a 3 cm space above the outlet of the flue gasses and a loose pot shield that could be adjusted to the pot size with a clip. Although this design had some flexibility when using different cylindrical or ball-shaped pots (Sri Lanka, India), the adjustable pot shield did not adequately fit the wide woks used in Tajikistan. This resulted in the pot shield normally not being used at all.

> *An open pot shield (skirt) with a pot blackened on the outside. The open pot shield can only be used outdoors or under a large hood. It was not liked by the households.*

Because the wok is already an inefficient pot shape for long simmering, this leads to an overall low efficiency of the ICS.[11] For this reason, the new design has the pot shield fixed to the pot support, but consequently, different pot shields will be required for the various sizes of cylindrical pots and large woks. Many households, however, only use one type of cooking pot.

The burning chamber has a cross section of 11 cm x 11 cm = 121 cm^2. The flue gasses need to envelop the cooking pot over the largest possible surface. A pot shield that keeps the flue gasses against the pot will increase the overall efficiency by about 10% as compared to without.

The cross section of the top outlet of the burning chamber should be similar to the net cross section of the top outlet between the top side of the pot shield and the cooking pot. When the top diameter is 40 cm, the gap is π x 40 cm : 121 cm $\approx$ 1 cm. Because of the large difference between the cylindrical cooking pot and the woks, 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 the two wok shields is kept the same (bottom = Ø 17 cm). Small spacers (minimum 10 mm thick) are fixed inside along the upper rim of the pot shield to ensure an even distribution of the escaping flue gasses around the wok; 6 for the small wok shield and 8 for the large wok shield.

The pot shield is made from 0.7 mm plain metal sheet and will absorb some of the flue gas heat. Making the pot shields from GI sheet is not advised since the zinc will burn off.

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

3.5 Closed Pot Shield with Chimney

The ICS with an open pot/wok shield is to be used outside in the summer when the space-heating stove is not used. The firewood commonly used is moist (freshly cut branches of poplar and willow) and therefore the smoke has a large soot content, resulting in blackened pots. With the ICS saving substantial amounts of firewood, the cook might like to use it indoors during the winter. This is only advisable under a good working hood that evacuates the smoke.

As an improved option, the wok/pot shields have been manufactured with a closing collar and a chimney, allowing it to be used indoors and at the same time reducing the amount of soot deposited on the pot.

Because the wok has some weight and the pot shield is a little flexible, it automatically closes the gap around the cooking pot (photo).

With cylindrical cooking pots, the pot shield has to be manufactured with an inside rim exactly to the size of the pot to minimise the upper gap between the pot and the shield.

The closed design with chimney was highly appreciated by the users, even though the ICS is slightly more expensive due to the additional material and work. Metalworkers did not find it complicated to make the closed pot shield with a chimney.

The pot shield with chimney attached can be used both summer and winter indoors and reduces pot cleaning.

Four flue gas deflector sheets are placed loosely in the chimney-type pot shield, further improving the heat transmission to the large wok.

The best sheet cutters need to be used for the work. From the three types available in the workshop, only the blue handle cutters were of good quality.

3.6 Bread-Baking ICS Extension

The same ICS can also serve as a base for a bread-baking oven.

The bottom sheet of the inner oven, above the flame, has been made from thicker steel sheet (1.2 mm) to avoid the flame rapidly burning through the thin GI bottom of the container.

The design was based on an existing chimney heat exchanger. The bread oven has a double wall and saves 90% fuel as compared with the traditional tandori-type oven when used for baking only a few breads.

Two common non-stick baking dishes of 26 cm are used.

The wall of the bread oven is insulated with a second detachable cover (photo right) and the door has been made double walled. The second sheet cover creates a 2 cm insulating air space by which the oven heat is better retained, rather than radiating out as is the case (and the purpose) with the chimney heat exchanger. This results in less firewood being required to maintain a constant baking temperature.

The detachable outside wall is made in two halves to allow easy fitting onto the bread oven for insulation.

The high-low position of the bread pans is changed once during the baking process and the bread turned over in the last phase to bake the upper side golden brown.

The new ICS bread oven can also be placed in the standard Ø 100 mm chimney pipe of the space-heating stove during the winter.

Double-walled bread oven. Heat damage of the thin GI bottom sheet is visible. The new oven design has a 1.2 mm plain metal bottom sheet (see picture above).

3.7 Different ICS Sizes

The most fuel-efficient ICS are those with a small burning chamber. Two dimensions are proposed; one for households and one for commercial kitchens or households cooking on *treshkin*:

- One standard (small) 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 small 8ℓ, medium 12ℓ and large 16ℓ woks. 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 a smoke catching hood should start at a height of 155-160 cm.

- One larger 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 (50ℓ) have a user 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 same **14 cm x 14 cm burning chamber** can be used for cooking on *treshkin*. The burning chamber is fitted with a larger feeder opening 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.

- An extra large ICS burning chamber can be made having a section of **18 cm x 18 cm** (324 cm^2), being 60% larger than the 14 cm x 14 cm burning chamber. People accustomed to using the open barrels perceive the smaller size to be inadequate for their cooking needs. This is a common misunderstanding.

Wheelbarrow with newly pulled up treshkin.

Tapack, dried cow dung.

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.

Blocks of *tapack* will not fit into the ICS. These large blocks can only be used in the larger space-heating stoves used during the winter.

3.8 The Wok

The wok is especially useful and energy efficient for stir-frying, but inefficient when used as the only cooking pot and for slow (long) cooking dishes. The wok causes large energy losses, partly due to excessive evaporation from the large open top surface.[12]

> *Woks are not recommended for long simmering cooking processes because their large surface will cause excessive evaporation and thereby greater energy loss than with cylindrical pots.*

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. Continued use for long periods 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. The open 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.
(c) The insulation under the burning chamber has been increased by 1 cm to 5 cm.
(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 filled with chunky (5-8 cm) Acloparit insulation for stability. Because of the greater weight of the filled container, handles are fixed on each side.
(f) The inner plates of the shield are four quarter round sections, placed loosely inside. These are made of 1 mm plain steel plate. The outside is plain sheet steel as well.
(g) The top part of each plate has two cut-outs of 5 cm x 6 cm = 30 cm^2 for the flue gasses to go down and through the chimney. The eight cut-outs together are 240 cm^2.
(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 with a 200 cm^2 section. A soot pot is fixed under the chimney for easy cleaning. This chimney needs a ground support.

Villagers will possibly still want a larger burning chamber, although documentation indicates that for the Ø 70 cm size wok (50ℓ, use 35ℓ), the 14 cm x 14 cm burning chamber is sufficient. This is not recommended for household cooking.

Because the rim of the wok is larger than the pot shield, the chimney is to be placed farther outwards.

The picture shows the chimney too close to the pot skirt.

A triangular reinforcement needs to be made under the chimney outlet for support. The wok support and shield is made of plain sheet steel.

When the chimney-fitted pot shield support is to be used during the winter inside the house, a chimney extension needs to be made to the outside of the house.

[12] At higher altitudes, boiling temperatures are lower. Frying allows higher temperatures than boiling, but evaporates more.

4. PROMOTION AND MARKETING

Although a product might be technically of good quality, if it doesn't look good, it will not sell. To make the item marketable, precise workmanship, straight edges and a clean neat finish are important factors. With the ICS, it will look very nice when new, but after some time the GI outside sheeting will become dull and non-appealing due to the heat. For this reason, the unit needs to be painted in an appealing colour using heat-resistant paint (400°C). Spraying equipment would be recommended. Painting names or a logo should be considered as well.

When the product has passed its final inspection, it should be given a code and number related to the manufacturer, model and manufacturing date. The same data should be entered in the books of the manufacturer. This way the origin and the age of the product can be traced. The development of a customer complaint structure should eventually be organised. When the ICS is part of a carbon credit scheme, they need to be numbered.

People do not buy what poor people receive for free or are given in one way or another. Villagers tend to buy new products when they see it being used by their wealthier, more prominent peers. Therefore, marketing needs to be focussed around this knowledge. When the users are able to explain the advantages (and the disadvantages) of the equipment, motivation to obtain the same equipment will be developed. Detailed information, next to seeing, should be available at the village level and include operation, maintenance, purchase price, where to order/purchase, delivery time and the local craftsman who can install the item.

When a project wants to benefit poor people who otherwise cannot afford the equipment, it should not give the equipment or articles away without special conditions, training and inputs of the receiver. An ICS costing Euro 10, for example, would require 10 full working days of community labour @ Euro 1 per day.

Another possibility is to extend a special credit line for the poorest people and allow the new product to be paid for by the monthly savings. Because the savings, and consequently the payments, are low for energy-saving equipment, village-based coordinators should administer the loans (clusters of small loans) rather than a Micro Finance Organisation where the high interest rates and commissions would not recover the expenses of the micro loan administration. Giving away equipment free to poor people will jeopardise the marketing to other villagers and actually work counterproductive.

Information

It is recommended to assemble detailed information about the various products in a catalogue of factsheets. The catalogue needs to be regularly updated when new or improved products become available and be accessible at the village level. Copies of factsheets from the catalogue should only be given out against actual photocopying cost.

A key person in each village should be selected and receive training on the various products – how they are used, installation, maintenance, benefits, etc. The key persons can sell the articles and receive a commission for each sale (10%). This way, the marketing model can be made self-sustainable when sufficient sales are made of a variety of useful products.

Cheap, non-durable or bad products should not be marketed.

5. 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.

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 house owner (with family) needs to assess the following 20 elements in order to make an informed decision about purchasing a new type of stove:

(1) Actual purchase price along with attachments.
(2) Possibility to obtain locally in the village; simplicity of purchase.
(3) Cost difference between local purchase and buying in a big town.
(4) Availability of spare parts or additional pot shields for other pot sizes.
(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 access to credit.
(7) Expected lifetime of the new stove; after how many years replacement of what parts?
(8) Expected savings in heating fuel. When used in combination with thermal insulation and the excess firewood saved can be sold, 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 chimney extension above the stove and to the outside.
(16) Reduction of smoke, eye and lung diseases due to less smoke inside the house.
(17) Reduction of fire hazard and burning risks for children.
(18) Quality of the food cooked or bread baked with the improved stove.
(19) Amount of maintenance and operational costs of the stove.
(20) Amount of firewood that needs to be collected, chopped and stored for long periods.

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 that 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.

Reliable and practical (based on home use) testing data must be available to convince house owners of the efficiency of the ICS. Current measurements indicate that the ICS firewood efficiency is about 40% compared with other stoves having a firewood efficiency of only 20-25%, using the same fresh firewood branches.

The only trees remaining are those on private property.
The mountains have been stripped bare by scavenging for firewood and goat grazing.

ANNEXE I TOOLS FOR METALWORKING

#	Tool Description	Tool Use
1	Manual large sheet steel scissors; extra hard/sharp carbon steel; minimum 30 cm long bit.	To cut plain and galvanised sheet steel up to 1.2 mm.
2	Electric cutting disk; requires electric power 2500W and uses corundum-fibre disks.	Currently used to cut all types of steel plates and bars.
2a	High quality corundum steel cutting disks.	To cut bars, pipes, angle iron and thicker than 1.2 mm steel plate.
3	Hand-operated concrete reinforcement bar cutter (rebar or bolt) with bits for minimum ½ inch (16 or 18 mm).	To cut concrete reinforcement bars from 7 - 12 mm.
4	Hard carbon steel marking pen for sheet steel.	Marking; made from an old triangular steel file with end sharpened.
5	Bending tool with pins on beam and bender arm. Commonly used by iron benders in construction.	Used for bending reinforcement bars; welded together from 18 mm and 12 mm rebars.
6	Pop nail pliers; hand operated; available for different nail sizes; requires the nails.	To place pop nails as connectors in thin galvanised sheet steel.
7	Roller bench; 140 cm wide hand-operated metal sheet bending apparatus with minimum three bars.	To roll steel plates precisely round up to 125 cm wide.
8	Electric welder with welding rods, including a large transformer.	For thin steel plate; 2 mm rod for the thinnest plates (1 mm and 1.2 mm).
8a	Electrodes for electric welder.	Several thicknesses, commonly available in local markets.
8b	Small pointed metal hammer for removing the crust from electric welding.	Can be made from old iron files or rebars.
9	Hand scissors for cutting thin GI sheet.	Best available type must be selected for cutting the sheets.
10	Wooden hammers for bending GI sheet; broad hammer 15 cm x 8 cm x 25 cm long head; hardwood preferred.	Hammers are locally made by carpenter. A straight heavy metal profile is used as basis for bending.
11	Metal ruler long 50 cm.	For precision measurement.
11a	Pocket roll-ruler, minimum 300 cm long.	
12	White marking chalk for marking metal.	Locally available; school board chalk.
13	Safety goggles for cutting with electric grinder.	Grinder produces large amount of sparks. Not using goggles is number one eye injury among metalworkers.
14	Safety mask for electric welding; with dark glass.	Eye and head protection. Not using a mask can cause permanent eye damage.
15	Safety gloves for electric welding.	Protects against sparks; locally available.
16	Electric hand drill with bits.	For making small holes for the pop nails.
17	Metal head hammer, 250 gram and 500 gram.	For closing folds; one side square, other side tent tapered; locally available.
18	Hand pliers with flat beak and insulated handle.	Locally available.
19	Hand saw for metal, 30 cm long blades.	
19a	High quality saw blades.	Sawing by hand iron profiles.
20	Hard metal number punches for punching numbers onto/into sheet metal for product identification.	Not asked for, but required when product identification and numbering of series products is desired.
21	Circle marker, hard steel point, diameter up to 20 cm and up to 60 cm.	The 60 cm circle marker (or larger) can be manufactured from an iron bar.
22	Pipe bending tool for ½-inch and ¾-inch water pipes to be fitted inside stoves.	Tool not yet requested, but necessary for bending seamless water pipes for stoves without causing folds.
23	Pipe cutting bits for ½-inch and ¾-inch pipes.	Tool not yet requested, but necessary for cutting pipes without the electric disc.

24	Pipe threading bits for ½-inch and ¾-inch pipes.	Tool not yet requested, but necessary for making thread on water pipes, also necessary for the manufacture of solar water boilers.
25	Micrometer or slide rule for measuring steel thickness from 10 to 30 gauges.	Sliding rule is cheaper option but some experience is needed reading the ruler.
26	Set of screwdrivers for fitting screws.	Flat top and cross (Phillips) tops.
27	Smoothening hand files for metalwork.	Removing sharp points.
28	Precise angle iron for marking straight angles.	Important tool, assuring precise work.
29	Adjustable “water-pump pliers”. Self-grip.	For tightening and loosening water piping fittings.
30	Teflon tape.	Watertight fittings in piping.

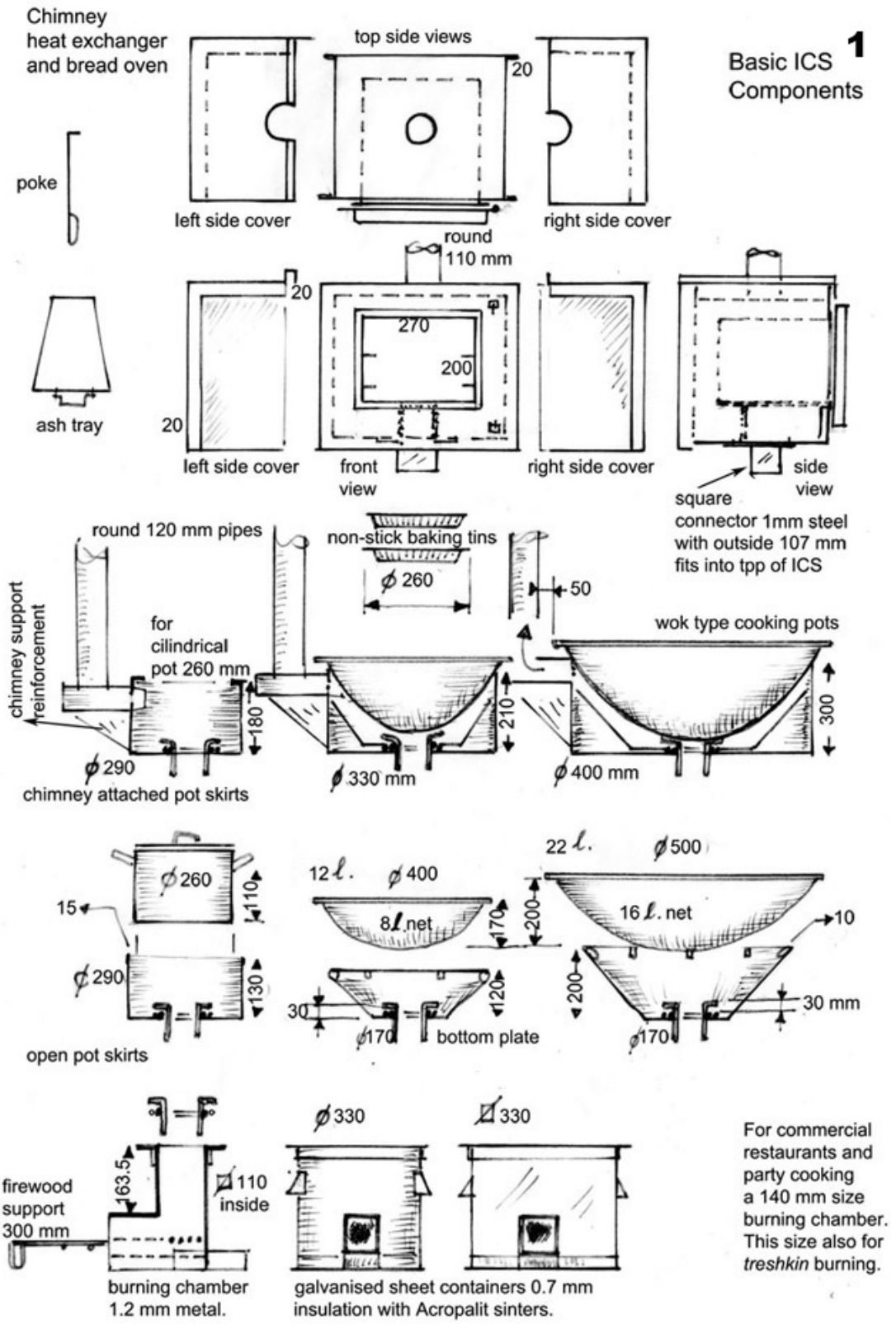
Training of metalworkers should include basic safety training and keeping the workplace tidy.

The metalworkers loved to use the cutting disk, also for the thin galvanised sheet metal. This, however, is costly in materials (poor quality discs) and electricity.

For bending the mild steel concrete reinforcement bars, construction workers made simple tools that allow rapid work. When many bars have to be repeatedly bent, making such tools will save large amounts of time and thus save on labour costs.

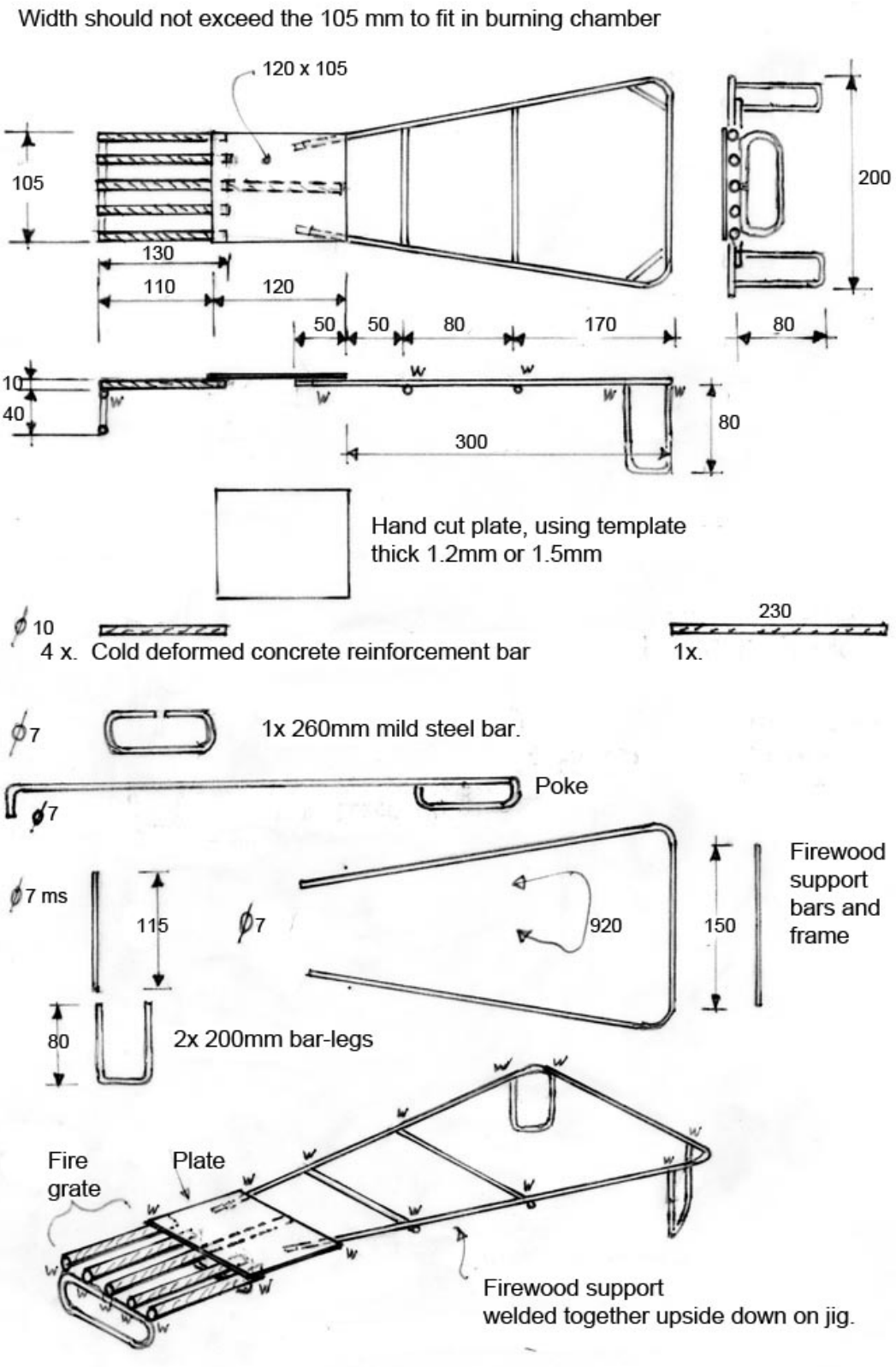
White chalk marks on the base plate indicate the position where the bar needs to be held before bending.

ANNEXE II ICS SKETCHES

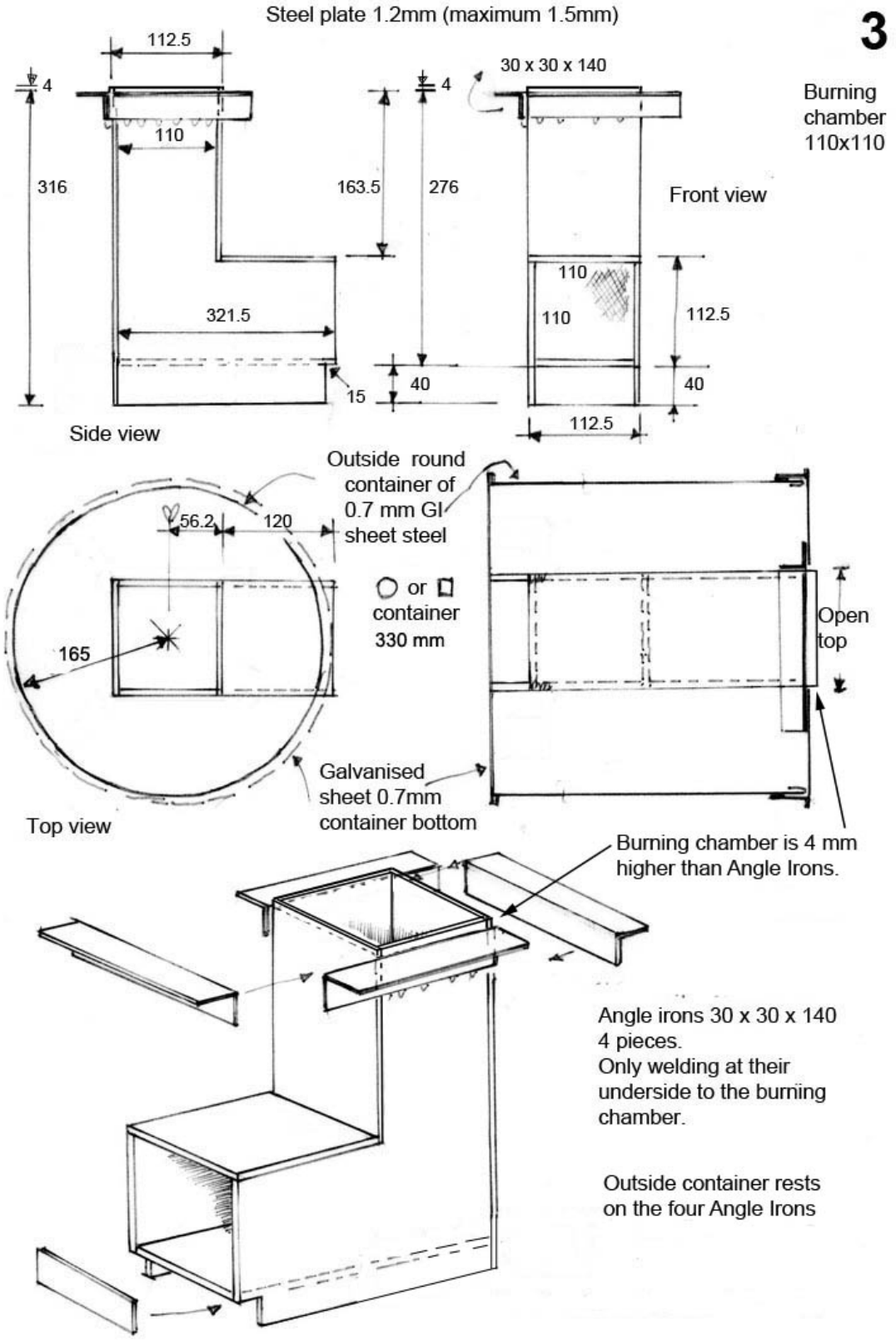


Overview of the ICS
Bread oven cum heat exchanger (1st and 2nd lines), closed pot shields with chimney attachments (3rd line), open pot shields (4th line) not liked by the people, and ICS base (5th line).

2

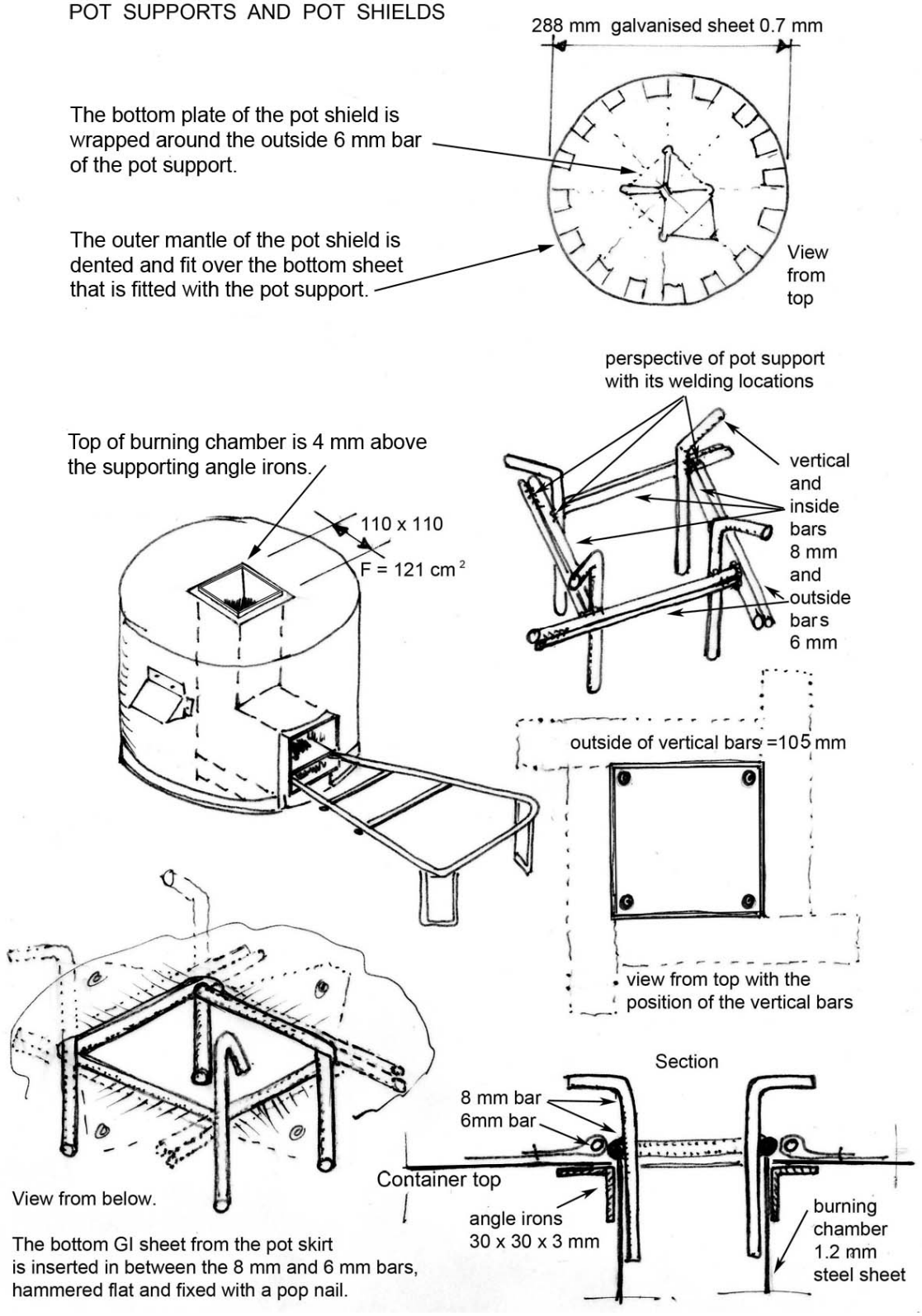


Manufacturing details of grill and firewood support.



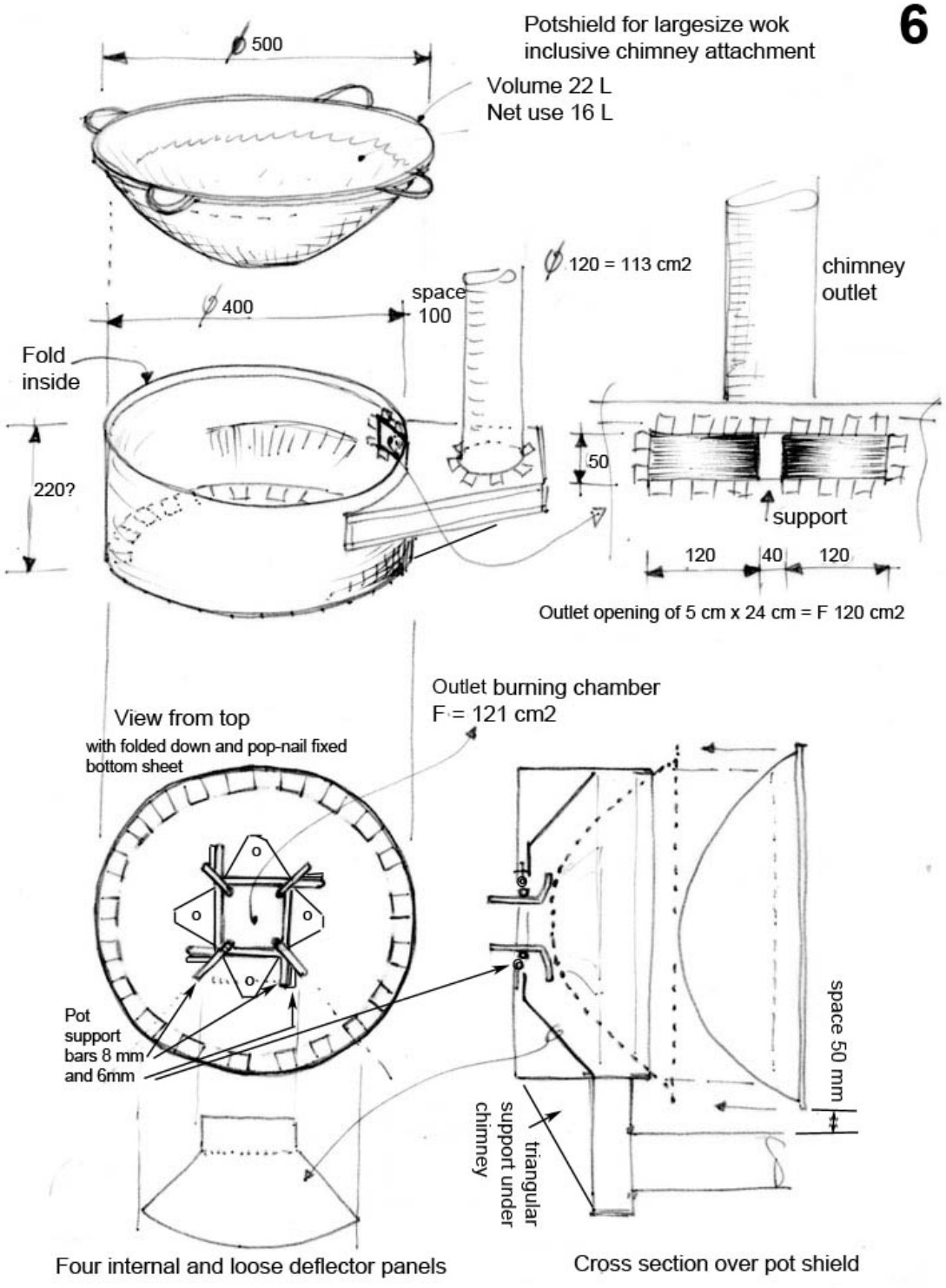
Manufacturing details of a 11 cm x 11 cm burning chamber.
The cover sheet of the container holds the burning chamber in position.

BOTTOM CONSTRUCTION OF ALL
POT SUPPORTS AND POT SHIELDS

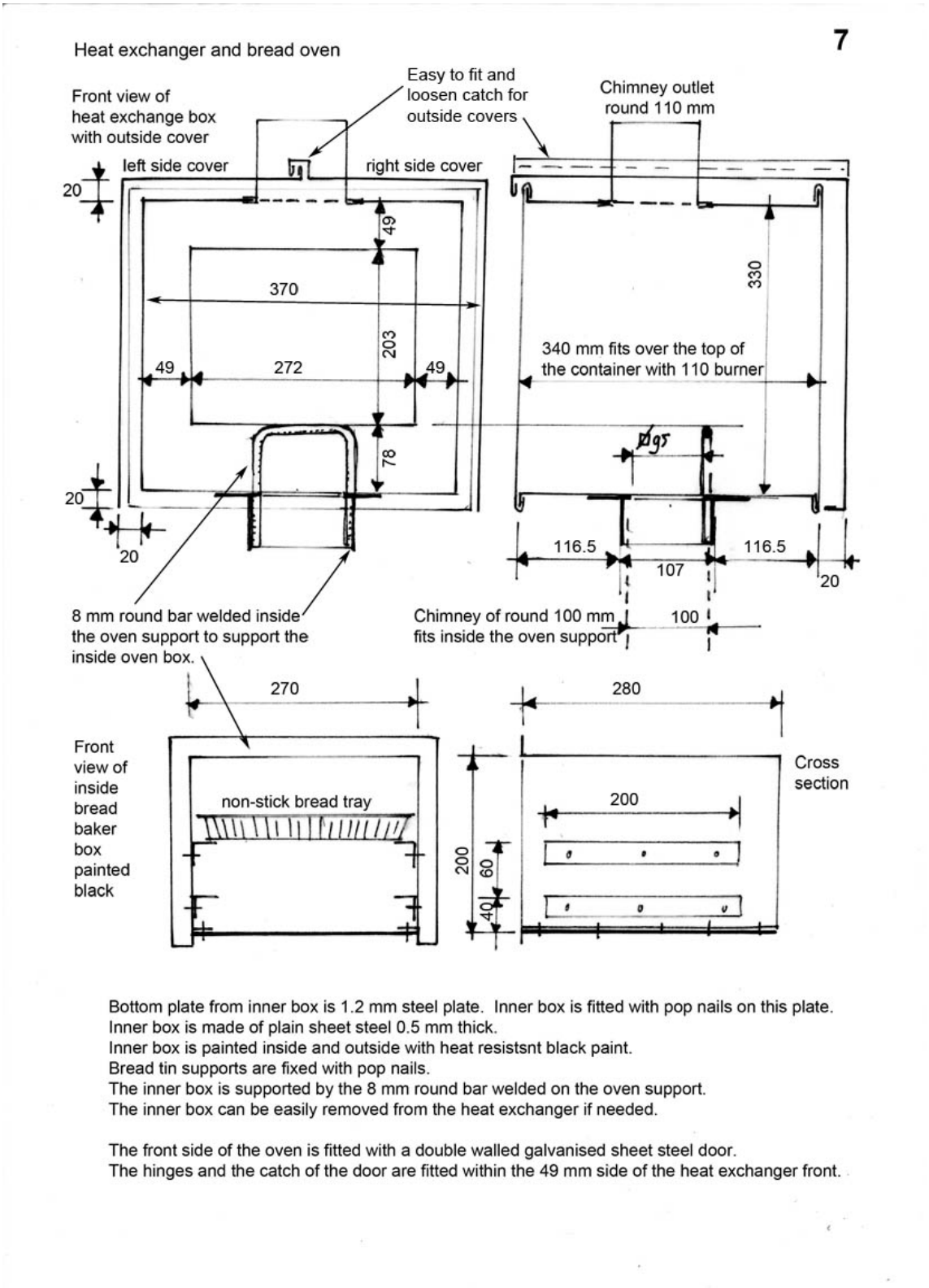


Manufacturing details of Ø 26 cm pot shield bottom with pot support.
The total section (area) of the gap between pot and shield is equal to minimum 121 cm^2.
The metal sheet of the bottom is inserted between the two bars of the pot support.
The pot shield needs to be made from plain, non-galvanised sheet metal or stainless steel.

Sketch number 5 of the open pot shield design has been omitted.



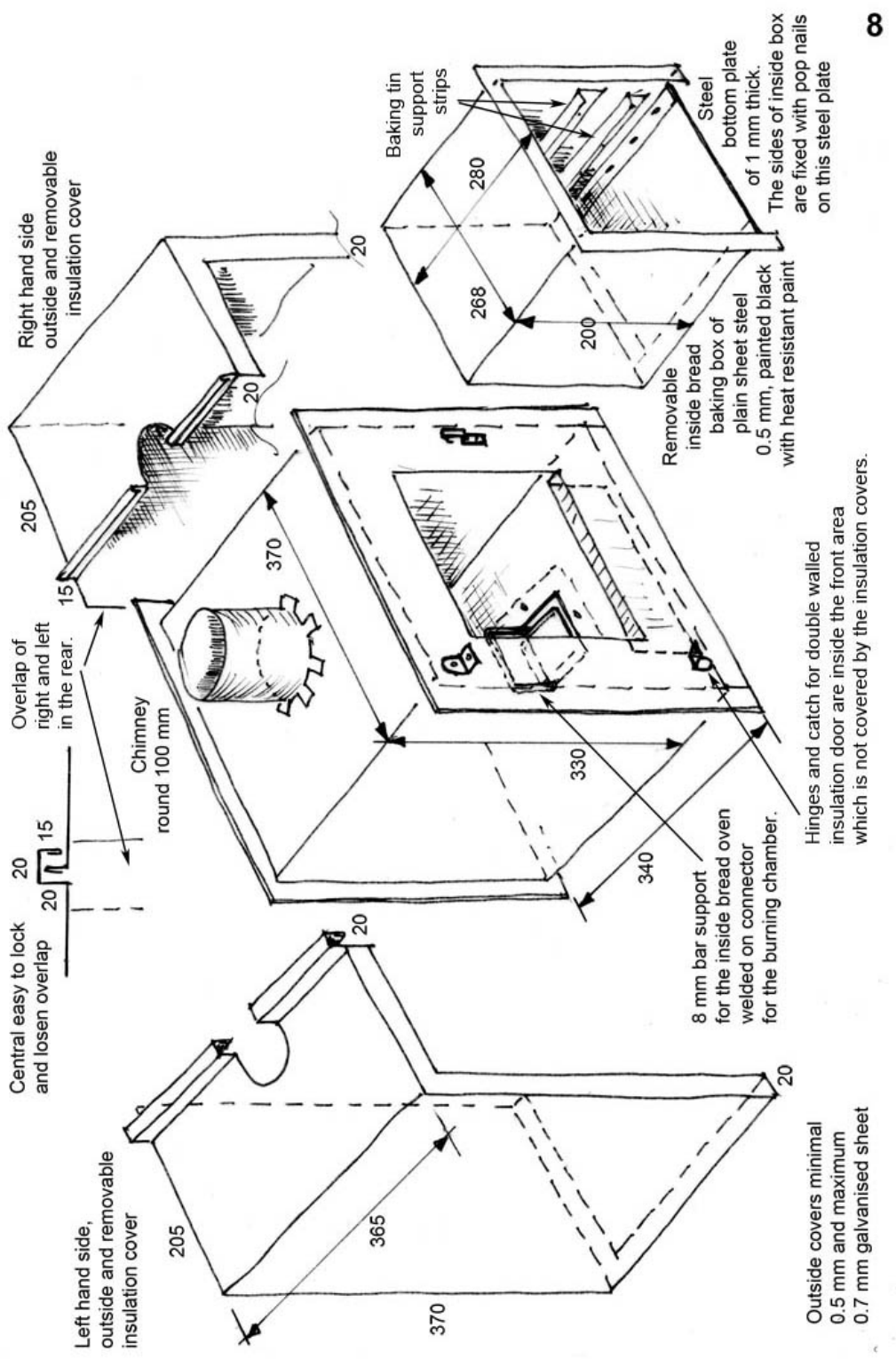
Dimensions of closed pot shield and chimney for large wok (22ℓ volume, 16ℓ net use).
An additional plain sheet is placed inside the pot skirt to improve efficiency.
A triangular support is constructed below the chimney outlet.



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.

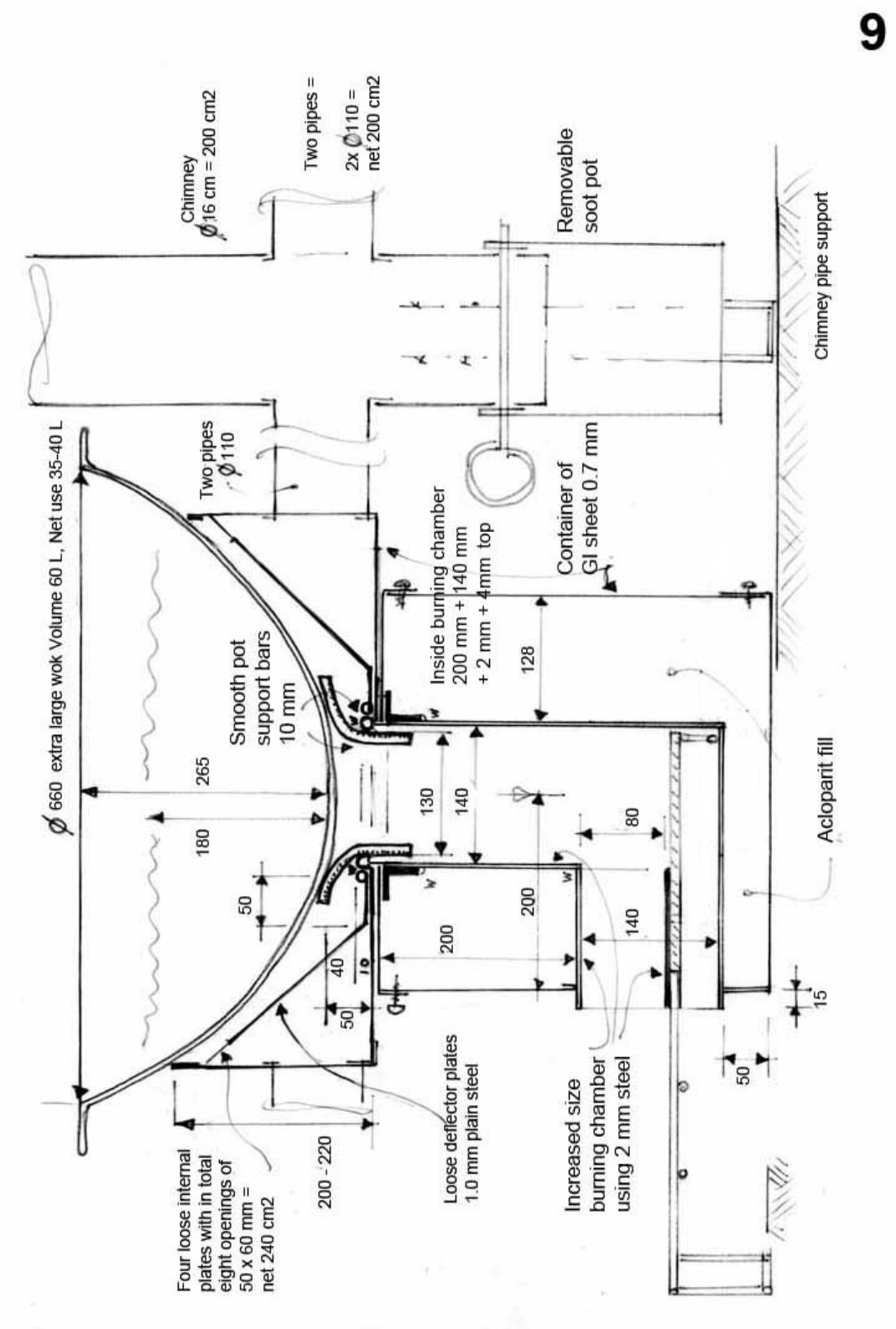
The front side of the oven is fitted with a double walled galvanised sheet steel door.
The hinges and the catch of the door are fitted within the 49 mm side of the heat exchanger front.

Drawing of improved bread oven to fit on the ICS and the space-heating stove.
Without the insulation covers, it can be used as heat exchanger on the chimney as well.

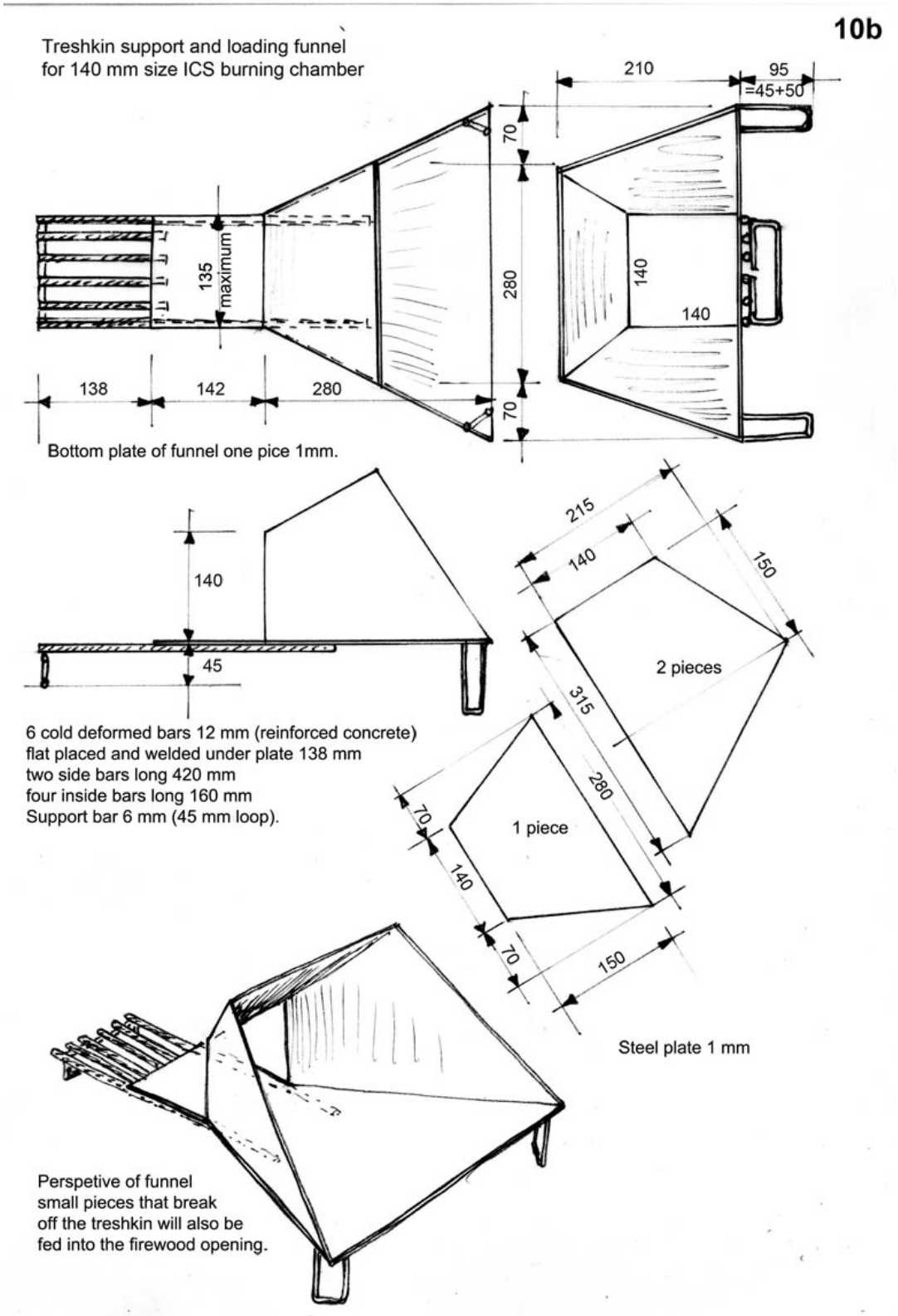


Axonometric drawing double wall, insulated ICS chimney bread oven.
The bottom plate is 1.2 mm or 1.5 mm steel plate and the inner box is fixed on this plate.
Without the two covers, the oven functions as a chimney heat exchanger,
increasing the overall efficiency of the space-heating stove by 20-25%.

9

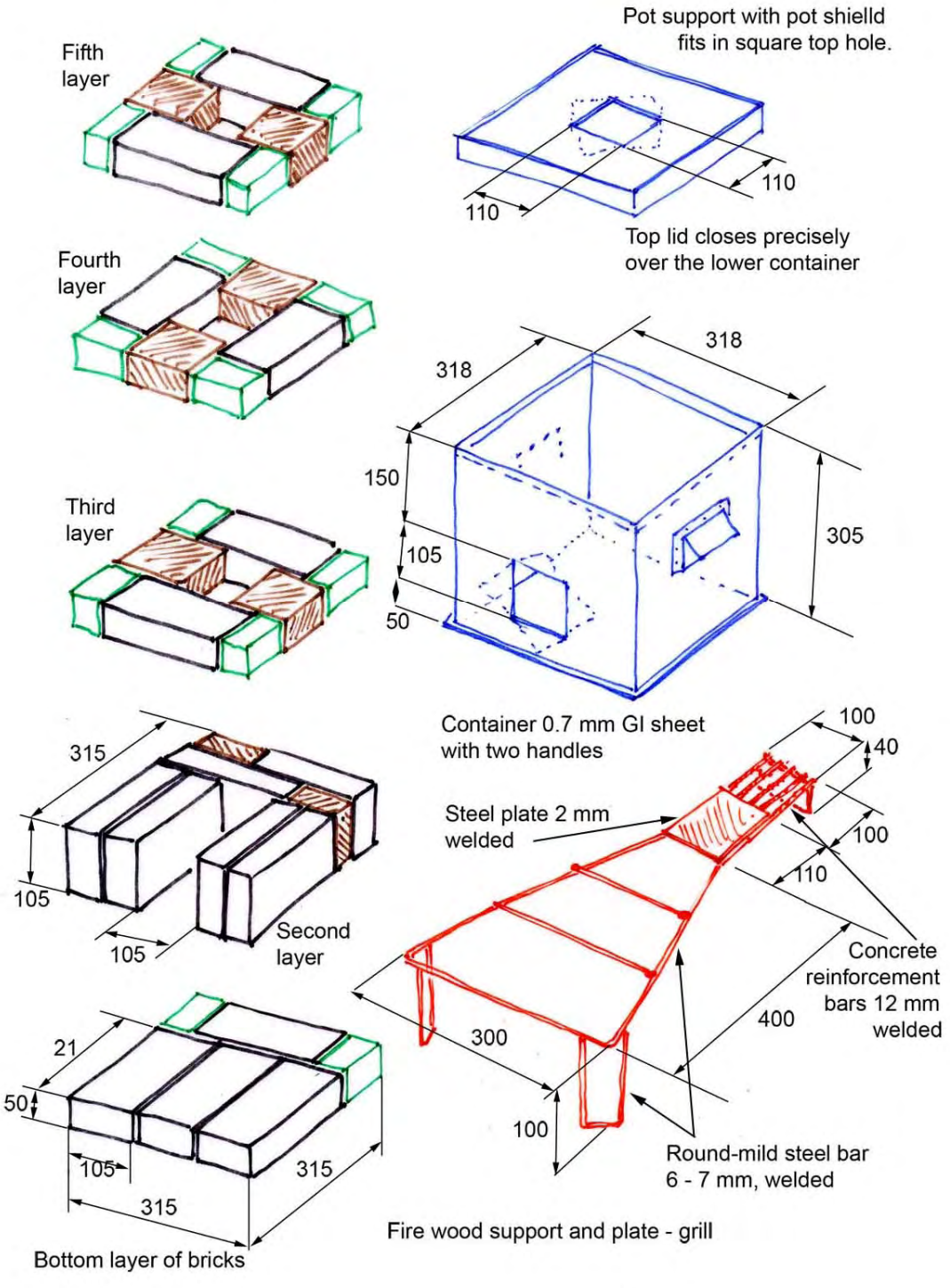


The 140 x 140 mm burning chamber has the same proportions as the smaller 110 x 110 mm unit. Used as burner under 60, 80 and 100 litre woks of restaurants and large parties. Because this size is for commercial use, the burning chamber should be of 2 mm thick plate.



Funnel-shaped feeder (or firewood support) for the 140 x 140 mm burning chamber.
Treshkin can be partly compressed into the burning chamber
when the larger branches have been clipped off using a garden scissor.

ICS WITH BAKED BRICK LINING AND GI SHEET CONTAINER



The same ICS can be made from a GI container filled with good quality baked bricks. When the inner bricks of the burning chamber get damaged, they can be exchanged with other bricks until all the bricks have to be replaced. Above brick sizes are common, but other sizes are possible, adjusting the container size.

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