MAKINI WOODFUEL STOVE HANDBOOK

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PREFACE

This manual is a compilation of the result of the studies and projects in line with the development of improved wood fuel stoves in collaboration with the APPROTECH ASIA and the Asia Regional Cookstove Program (ARECOP). The main objective of this manual is to provide interested organizations a guide in designing, constructing, operating, and testing the Makini Wood Fuel Stove which was developed at the Appropriate Technology Center of the Department of Agricultural Engineering and Environmental Management, College of Agriculture, Central Philippine University, Iloilo City.

The first chapter of the handbook gives the brief resason of the development of the stove. Chapter II describes the design, advantage features, and performance of the stove. Chapter III presents the different designs of the traditional wood fuel stove developed in the Philippines and in other Asian region. Chapter IV presents the stove design particularly the factors that need to be considered in designing the Makini wood fuel stove. Sample computations are also included in the discussion. Chapter V carefully describes the step-by-step procedure in constructing the stove starting from material preparation until finishing a unit of the stove. Chapter VI describes the operation and maintenance of the stove while Chapter VII gives the procedure in testing the stove. The procedure in determining the economics of producing and using the stove is also presented in the last chapter.

This manual may still needs improvement. Comments and suggestions to further improve and enhance its content are highly appreciated.

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Chapter I
INTRODUCTION

The cost of fuel for domestic cooking is increasing at a fast rate. Fuel such as LPG, kerosene, and electricity are becoming expensive nowadays because continued increase in the prices of oil.

Figure 1. Sample of Woodfuel Sold in the Market

Households especially in the rural areas are gradually shifting to fuel wood and wood charcoal. Howver, the increasing denudation problem in the forest makes the cost of wood fuel to increase. At present, a bundle of wood in the market cost about P20.00. Presenly, it continued to increase to as high as P25.00 per bundle. The excessive cutting of trees being experienced both for fuel and lumber can bring a lot of damage to the environment. One of this is flood during the rainy season and drought during the dry season.

The used of single-burner traditional woodfuel stoves are usually common in every households in the rural areas. The stoves are simple in design and construction and cheap enough to produce. However, traditional stoves are usually inefficient with efficiency of about 5 to 10 percent. They consumed more wood fuel before they can cook food. Because of low cost material, they are not durable which breaks when subjectied to excessive amount of heat and physical damages. Traditional stoves also give off high amount of carbon dioxide that are detrimental to health and environment.

In April 2003, the Appropriate Technology Center of CPU in collaboration with the APPROTECH ASIA and ARECOP has led to the development of improved traditional woodfuel cookstove by modifying the Sri Lanka "Anagi" clay cookstove using concrete mixed with rice hull ash as material.

This technology minimizes the used of the tradiational clay material in the construction of stove while promoting the use of masonry cement materials and the indigenous rice hull ash in the construction. Improved models of the stove using mild and stainless steel materials are presently developed to make the technology adoptable not only to rural people but also for those urban households.

(a)

(b)

Figure 2. Pictorial View of the Stoves: (a) Traditional, and (b) Improved Wood fuel Stoves.

Chapter II
THE MAKINI WOODFUEL STOVE

Description of the Stove

The Makini Stove basically is an improved version of the locally produced Anagi Stove that is made of clay material. The design was basically the same in the burner construction except that the Makini stove uses cement, sand, and rice ash mixture as material or for the elegant one it uses ordinary and stainless steel as material. With this innovations, the design and construction of the stove become easy and simple, hence make the mass production simple and fast.

(a)

(b)

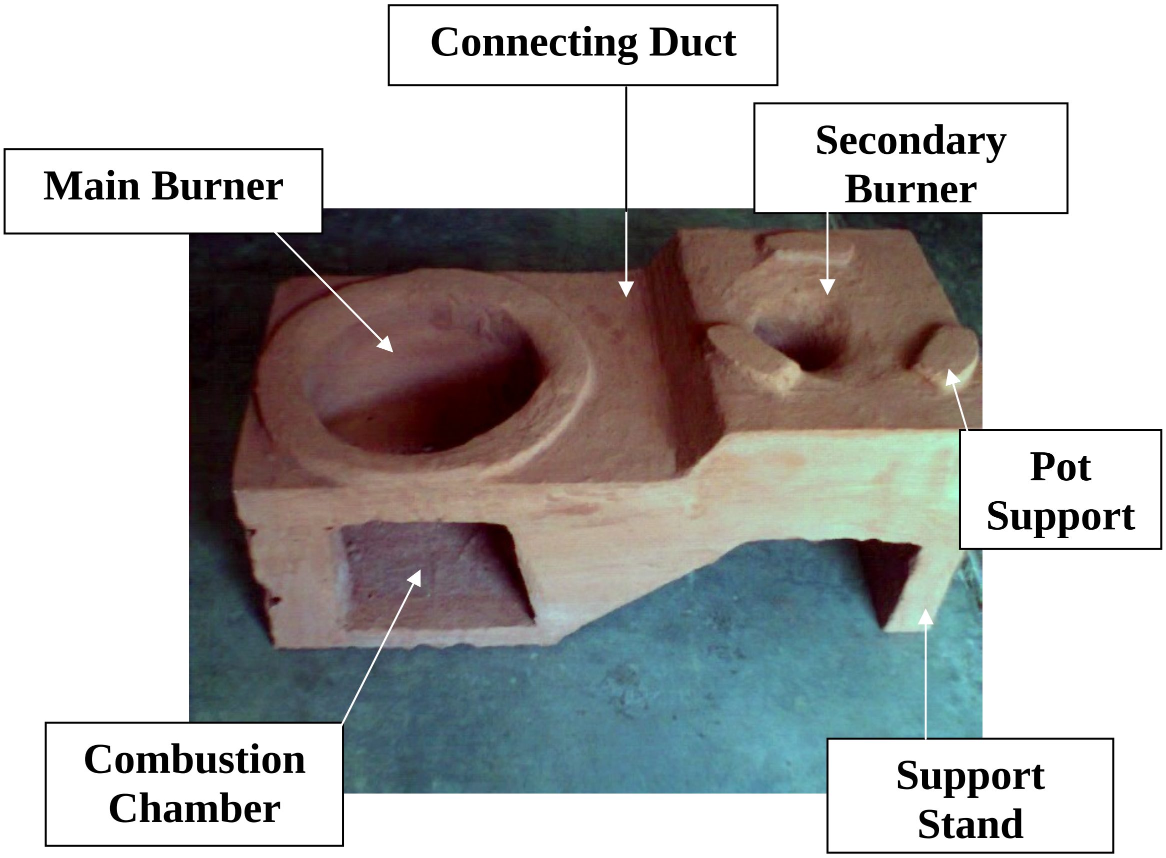
Figure 3. The Makini Stoves: (a) Concrete Material, and (b) Steel Maaterials

As shown in Figure 3, the stove consists of the following major component parts: (a) Primary Burner, (b) Secondary Burner, (c) Combustion Chamber, (d) Connecting duct, (e) Pot Support, and (f) Stand.

The primary burner is where the main of food is taking place. The burner is directly position into the combustion chamber having the diameter of about 18 cm. The pheriperal surface of the burner is designed to be well-fitted to prevent excess heat from escaping the stove. The secondary burner is located on one oside of the stove. It is slightly elevated in position as compared with the primary burner to create enough draft in order to make the excess burning gas and flue to supply the needed heat required in the burner. The connecting duct that served as the port for the excess heat from the primary burner to the secondary burner has a port area of 16 to 100 square centimeter. This can be made into circular or rectangular in shape depending on the desired of the constructor or fabricator. The inlet port of the duct is slightly raised about 2 cm from the floor of the combustion chamber and its outlet port is centrally positioned from the secondary burner.

The combustion chamber of the stove is directly located beneath the primary burner. It has a diameter of 18 cm and a height of 18 cm. The chamber wall is made of smooth refractory or stainless steel materials to provide good reflection to the fuel and burning gases during operation. On one side of the stove is hole for the exhaust of combustible gases and flue to the duct. To properly hold the fuel while they are being fed into the stove, a fuel support hopper is placed for the stove. For concrete Makini stove, no fuel support floor is presently provided.

The pot support is slightly raised by about 2 to 3 cm from the secondary burner to hold the pot during cooking operation. Excess heat of combustible gases centrally leaves the exhaust port of the burner at hit the pot as porpoerly positioned by the spot support. The stand supports the secondary burner in proper poistion with respect to the primary burner. In in the improved model of the stove that utilized steel as material, the space for the stand served as a heating oven for baking bread.



The Combustion Chamber

The Connecting Duct

Figure 4. The Makini Stove Showing the Component Parts.

Advantage Features

1. High Thermal Efficiency – The concrete stove has a thermal efficiency of 1 to 2 % higher than the existing clay-type stove

2. Easy to Start – This requires only about 3 to 4 minutes of firing using 4 pieces of papers and properly arranged wood fuel.

3. Convenient to Operate – Operation is similar to the traditional woodfuel stove. Fuel is placed in a cris-cross arrangement inside the combustion chamber and ignition is introduced using burning paper.

4. Less Fuel Consumed – It can cook food with less amount of fuel due to high thermal efficiency. The thicker wall provided for the stove minimies the amount of heat loosing from the stove wall.

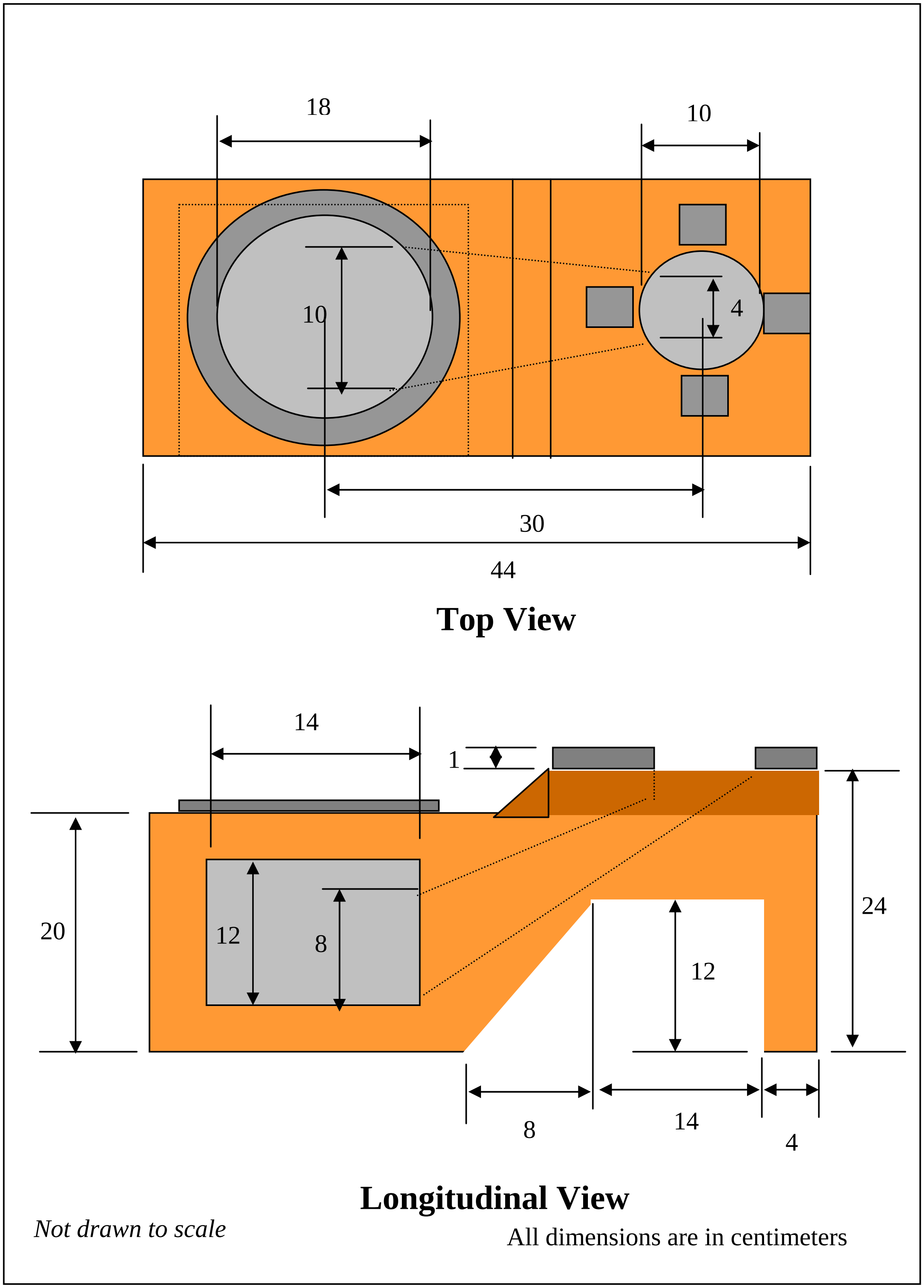
5. Robust – Heavy duty since it uses concrete as material of construction. Thicker mild steel plate and stainless steel make the construction durable and heavy.

6. Easy to Mass Produce – It requires local skills and indigenous materials in the production of stove. Mass production can be done on masonry or steel works. All can easily be made in either workshop.

7. Provides Employment – It provides employment and income generating projects for out of school youth in barangays , farmers coop, masonry workers, and small metal crafts. It is also a good IGP for engineering or technical school projects, etc.

8. Low Investment Cost - It can be reproduced with minimum cost needed for materials and labor. Mass production of the stove especially with the use of steel material can be signficantly reduced.

9. Affordable to Consumers – It sells similar in price with commercially produce wood fuel stoves of the same construction quality.


18
10
10
4
30
44
Top View
14
1
20
12
8
12
24
8
14
4
Longitudinal View
Not drawn to scale
All dimensions are in centimeters

Performance of the Stove

Performance testing of the Makini stove compared with the modified two-burner clay stove produced in the Philippines showed that the Makini stove is higher by 1 to 2 % in terms of thermal efficiency. This means that the makini stove can slightly consume less amount of fuel as compared with the clay stove. Firing time for both stoves is almost the same as well as the number of burning pieces of papers used. Boiling time of water for Makini stove is longer both in the primary and secondary burner which makes the fuel consumption lesser for the same amount of fuel used.

Parameters	**Makini**		**Anagi**
	1	2	Clay
Start-Up, min	4	3	3
No. of Papers Used	4	4	4
Volume of Water, liters 1/	3	3	3
Weight of Fuel, kg	1.5	1.5	1.5
Boiling Time, min 2/	19, 32	21, 31	16, 23
Total Operating Time, min 3/	58	61	56
Fuel Consumption Rate. Kg/hr	1.55	1.48	1.61
Thermal Efficiency, %	12.15	12.77	11.41

1/ Combined burner 1 and 2.
2/ For burner 1 and burner 2, respectively.
3/ From the time the fuel is ignited until it is fully consumed.

Figure 6. The Makini Stove During Testing.

Chapter IV
STOVE DESIGN

Factors to Consider

1. **Size of the Stove –** This is dependent how much would be the energy is needed to be supplied by the stove. The higher the energy output of the stove, the bigger would be the combustion chamber.
2. **Firebox Diameter to Height Ratio –** This is very important to give proper draft for the stove. Usually the ratio ranged from 1:1 to 1:25. The firebox should have enough diameter to accommodate the required amount of fuel to be burned in the stove.
3. **Thickness of Material -** The thicker the material for the stove, the lesser would be the amount of heat to be lost by conduction. The firebox if possible should have thicker wall as compared with the wall at the second burner.
4. **Mixing Proportion of Materials –** The higher the amount of cement and sand, the stronger would be the mechanical properties of the material. However, the more like the material would have a tendency to break due to thermal stress. A good solution to this is to increase the amount of rice hull ash in the mixture. Rice hull as has 90% silica and a good insulating materials for concrete and prevent breakage due to thermal stress. The recommended proportion may vary from 1:1:1 to 1:1:2 for cement, sand, and ash.
5. **Distance Between Burners -** Shorter distance between two burners would much be better in terms of heat transfer. However, inconveniences during cooking due to limited space between pots would be experienced**.**
6. **Height Between Burners -** There should be height difference between primary and the secondary burner.

The difference in height contributes to the draft that causes the fire to move and reach the second burner. Too much difference in height would not be good. The optimum height is when the flame can touch the bottom of the pot sat the second burner. Excessive flame means heat loss.

7. **Size of Flame Duct -** Optimum size for flame duct is about 1/3 the diameter of the fired box. In addition diameter configuration should be decreasing in size from the primary burner to the secondary burner.
8. **Ventilation Holes –** There should be two sources of air to sustain proper combustion of fuel in the stove. The primary air which is used for the combustion of wood fuel and the secondary air for proper burning of volatile gases produced during combustion in the fire box. Primary air in the makini stove is supply at the fire box entrance and at the hole provide on its side protruding through the fire duct. Secondary air on the other hand is supplied at the base of the fire duct. This can be constructed in the stove with the use of a power hand drill.
9. **Height of Space Between Pot Holders -** Height of pot holder of about 1 cm is enough for the secondary burner. Too high will allow heat to escape and do not hit the port. Space if possible should be optimized for heat loss reduction reason. Not that only the second burner is provided with pot support. The primary burner do not require pot support. The pot should be fitted or larger in size then the burner to prevent flue gas from escaping and reducing the draft to the second burner.
10. **Shape of the Fire Duct -** Circular fire duct is best one but it is difficult to build during production. Rectangular or square duct could be a good option in terms of construction.

Chapter V
STOVE CONSTRUCTION

Materials

In the construction of the Makini Stove made of concrete material, the following will be needed:

1. Screened sand (1/8 in. mesh) - The sand should be made of materials commonly used in the building construction material. Sand should be well screened to provide uniform sizes so that thermal breakage during heating operation could be minimized.

2. Screen Rice Hull Ash (1.8 in. mesh) – This should be newly burned rice husk to provide assurance on thermal insulation and possiblity of breakage when heated.

3. Portland Cement – This should be similar to the cement sold in hardware. Freshly delivered cement in bags should be used instead of the one that is already opened for a month.

4. Grout – This will be mixed with cement purposely for finishing and to give color to the stove. Rice hull ash is also mixed especially when finishing will be done on the combustion chamber and flue duct section of the stove.

5. Steel Bar and Tie Wire – This should be about 6 mm diameter deformed round bar serving as reinforment support to the concrete.

Screened Sand

Portland Cement

Newly Burned Rice Hull Ash

Grout

Figure 7. The Different Materials Used for the Makini Stove.

Tools

The following tools will be needed in the construction of concrete Makini stove:

1. Stove Mold Assembly – This is use to hold the concrete mixture before it will be totally hardened. Mold assembly is made of several componentsto easily position and remove them during construciton.

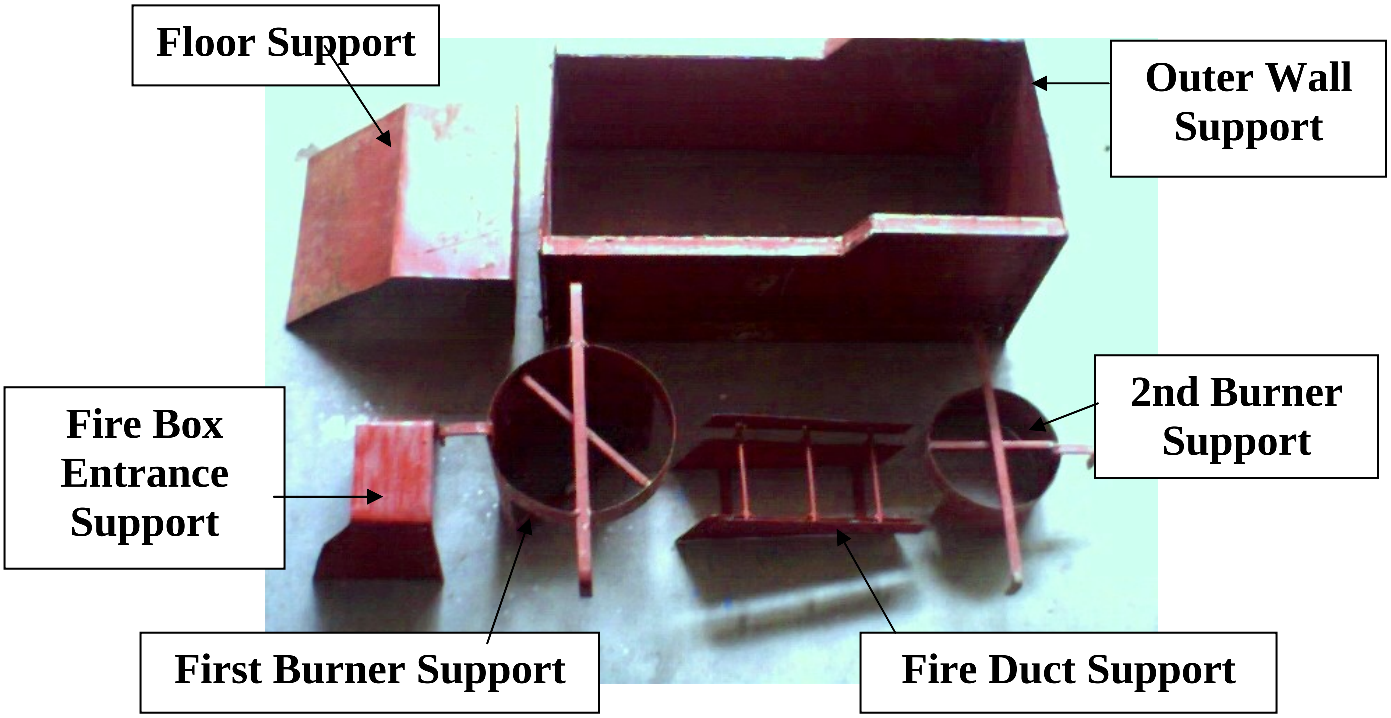
2. Mixing Platform – This will be used for mixing the cement, sand, and rice hull ash mixture. Waste of material can be minimized when having a flatform.

3. Flat Tip Shovel – This will be used for mixing the cement, sand, and ashes.

4. Water Container – This will be used to contain water needed in concrete preparation for the stove.

5. Flat Trowel – This will be used for filling additional concrete to the mold and for finishing work during construction of the stove.

6. Paint Brush – This will be used to apply the mixture of cement and grout into the stove.



Exploded View

Assembled Unit

Figure 8. The Makini Stove Molder.

Production of the Stove

The following are the guideline in the production of Makini Stove.

1. One bag of cement can produce 4 to 5 units of Makini stove. At 1:1:1 mixing proportion, this will also need an equivalent amount of sand and newly burned rice hull ash of 1 bag each.

2. Two persons is required to finish an average of 4 to 5 units of Makini stove per day. This can be doubled if well-trained workers will be employed.

3. Cost of production per four units of the stove is about P442.00 as shown in the itemized table below. Approximately, selling price would be about P150.00 per unit or even higher.

Cement	P120.00
Sand	20.00
Ash	2.00
Labor	300.00
Total	P442.00

Price per unit - P110.50
Selling Price- P150.00 or even higher

4. If someone would like to invest in the production of the stove, an investment requirment of about P2,500.00 would be needed as start-uip capital. For raw materials such as cement, sand, and ash including reinforcement steel bars and grout, the estimated investment would be P1,000.00. Tools for mixing and finishing would be P500.00. The cost for the molder is about P1000.00. The cost for the space and shed is not included in the investment.

Raw Materials	P1,000.00
Tools	500.00
Mold	1,000.00

* Does not include space and shed

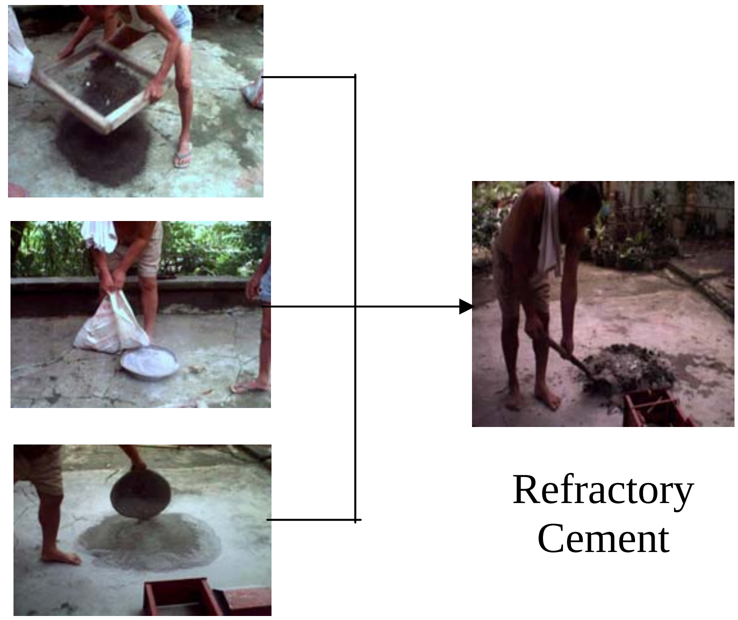
Recommended Mixing Proportion

In constructing the stove, the recommended mixing proportion for the cement, sand and ash is 1:1:1. Test has shown that the mixture is optimum in terms of minimizing mechanical and thermal breakages.

One part Sand

One part Rice Hull Ash

One part Cement



Refractory Cement

Construction Procedure

Step 1 - Prepare all necessary materials and tools needed in the construction of the stove. This includes the following: (a) sand, (b) ash, (c) cement, (d) grout, (e) mold, and (f) tools (shovel, screen, etc). Cement should be freshly bought from the hardware. Sand should be a good one that is commonly used in the building construction. Minimize the use of low quality sand such as those obtain in unreliable quary or a beach sand. Ricer hush as should be a newly burned. Quality silica can be obtained from newly burned rice husks.

Step 2 - Screen sand and ash to remove impurities and to provide uniform sizes of sand particle. Common source of cracks for stoves are caused by the mixture of larger particles of sand or unburned organic materials in the mixture. Mixtures of varying sizes of sand particles developes non-uniformity of expansion by heat in the stove.

Step 3 - Prepare mixture by adding one part sand, one part ash, and one part cement. Mix the materials thoroughly and add water to the mixture to form a concrete mixture of good consistency. The cement in the mixture serves as binder. The sand will be the filling material for greater strength whereas the rice hull ash that has higher percentage of silica (90%) will serve as insulator to minimize transfer of heat within the stove.

Step 4 - Prepare mold and properly set parts together. The mold will hold the concrete mixture while they are fresh. Brush mold with used oil before pouringthe conrete for ease of removal when they are ready for removal.

Step 5 - Fill mold with concrete to level until all parts as completely filled with the mixing material. There is a need to take time in setting up the concrete in the flue duct section since this will be the critical one.

Step 6 - Allow the concrete to harden for about an hour and remove the inner molds to form the burners and the duct. Be carefull in removing the mold because it may damage the stove.

Step 7 - Set concrete to cover duct and allow it to harden. Provide a combustible platform support to the top of the flue duct cover so that when the concrete hardens, there is no need of removing the cover.

Step 8 - Remove all molds and gradually finish the stove to the desire configuration. Usually the surface of the stove will be smooth upon the removal of the mold. Projecting parts should be removed with the use of flat trowel to make the edges smooth.

Step 9 - Apply paint in the stove with plaster mixture of grout, cement, and ash. This will also fill-in some holes that can be found at the surface of the stove.

Step 10 - Allow the stove to temper and dry for about two weeks. If the stove is immediately needed, 3 to 4 drying is the sand is sufficient enough to make the stove durable when fired.

The series of photographs shows the procedure of constructing the makini stove. Basically at the start, constructio of the stove is quite difficult. However, continuous work will makes you better and makes the work easier and simplier.

Installation of the Stove

In order to maximize heat generated in the stove and to prevent difficulty during operation, the stove should be placed on a covered shed or dirty kitchen. Dirty kitchen with hood to discharge smoke and flue gases is recommended. These make cooking operation better and healthy.

Screening Sand

Screening Ash

Adding Cement

Mixing Concrete

Filling Mold

Leveling Concrete

Removing Mold

Covering Duct

Removing Mold

Removing Molds

Finishing

Painting

Tempering and Storage

Testing and Evaluation

Chapter VI
OPERATION AND MAINTENANCE

Operating Procedure

The makini stove is operated similarly with the other traditional woodfuel stove. The following steps are recommended for the proper operation of the makini stove:

1. Clean the stove before using. Remove all residual unburned fuel and ashes from the stove. Be sure that there is no obstruction at the fire duct of the stove.

2. Prepare woodfuel for the stove. Woodfuel should not be too large that it cannot be accommodated in the firebox. A maximum of 1-inch diameter wood is best fuel for the stove. The larger the diameter of fuel, the more time is required to ignite wood. Also choose dry wood for fuel.

3. Arranged wood fuel at the firebox in criss-cross manner. This will allow better aeration of the fuel that is necessary for combustion. Too smoky operation means that air is insufficient during combustion.

4. Place cooking pot at the primary burner. The pot should be well fitted or larger in size from the burner. Smaller will not do for the stove.

5. Place another cooking pot in the secondary burner. Flame can only be observed in the second burner when pot is placed in the primary burner.

6. Add fuel if necessary until all the food are well cooked. Note that the primary burner can cook or boil water faster as compared with the secondary burner. Pot location can be changed from either of the two burners depending on the desired amount of heat. However, pots should have the same sizes.

7. When cooking is finished, allow the stove to cool before removing the unburned wood and ash for cleaning. Never wash stove with water while hot. It may possibly crack due to sudden excessive thermal stress.

8. Always keep the stove in the proper place when not in use.

Chapter VII
PERFORMANCE TESTING AND EVALUATION

Parameters

The following parameters can be used in evaluating the performance of the Makini stove:

1. **Start-Up Time** – This is the time required to ignite wood fuel. This can be measured from the time a burning pieces of paper was introduced at the firebox entrance until the fuel attained spontaneous combustion.

2. **Boiling Time** – This is the time obtained from the water casserole was placed on top of the stove until the water was observed boiling.

3. **Total Operating Time** – This is the time from which the pot was placed on top of the stove until about no more fuel is remained in the firebox and no indication of boiling water was observed.

4. **Fuel Consumption Rate** – This is the amount of fuel that is burned in the stove per unit time. This is computed using the formula,

$$FCR = \frac{\text{Weight Fuel Used (kg)}}{\text{Operating Time (hr)}}$$

5. **Fuel Consumption Index** – This is the amount of wood fuel used per unit water boiled and evaporated. This is computed using the formula,

$$FCI = \frac{\text{Weight of fuel Used (kg)}}{\text{Volume of Water Boiled and Evaporated (liters)}}$$

6. **Sensible Heat** – This is the amount of heat energy required to raise the temperature of water from before and after reaching the boiling temperature. This can be computed using the formula,

$$SH = Mw \times Cp \times (Tf - Ti)$$

Where: Mw – mass of water, kg (1kg/liter)
Cp – specific heat of water, 1 kCal/kg-C
Tf – temperature of water at boiling, approx 100 C
Ti – temperature of water before boiling, 27-30 C

7. **Latent Heat** – This is the amount of heat energy used in evaporating water. This is computed using the formula,

$$LH = We \times Hfg$$

Where: We – weight of water evaporated, kg
Hfg – latent heat of water, 540 kCal/kg

8. **Heat Energy Input** – This is the amount of heat energy available at the fuel. This is computed using the formula,

$$HF = WFU \times HVF$$

Where: WFU – weight of fuel used in the stove, kg
HVF – heating value of fuel, kCal/kg

9. **Thermal Efficiency** – This is the ratio of the energy used in boiling and evaporating water to the heat energy available at the fuel. This is computed using the formula,

$$TE = \frac{SH + LH}{HF} \times 100$$

10. **Power Output -** This is the amount energy available for use. This is computed using the formula,

$$Po = FCR \times HVF \times TE$$

Where: FCR – fuel consumption rate, kg/hr
HVF – heating value of fuel, kCal/kg
TE – thermal efficiency, %

Other information should also be taken during the test. This includes the following:

1. Frequency of attendance
2. Smoke emission
3. Heat emission
4. Portability
5. Maintenance
6. Cleaning
7. Presence of fly ash
8. others

Chapter VIII
ECONOMICS

Comparative study of the use of the Makini stove compared with the traditional single burner wood fuel stove is shown in table below. As shown the single burner stove is much cheaper in terms of the investment cost for the household. However, continued use of the stove would be able the household to save in terms of fuel.

For Makini stove, the cost of investment for the household is P150.00 as compared to the traditional single burner wood fuel stove of P40.00. Per liter of water that can be boiled in the stove, the Makini stove can boil P4.48 per liter of water while in traditional single burner stove can boil P7.85 per liter of water in a day. The computed daily savings in terms of liter of water is P3.37. To pay for the investment in the stove, the use of makini can be recovered within 44.5 days if it will be based on the traditional single burner wood stove. A savings of P 1,229.53 can be realized in the use of thethe stove annually.

Table __ Operating Cost Analysis of Using the Makini Stove.

Stove Design	Traditional Single- Burner	Makini Woodfuel Cookstove
Investment Cost	45	150
Fixed Cost (P/day)		
Depreciation [a]	0.06	0.18
Interest on Investment [b]	0.03	0.10
Repair and Maintenance [c]	0.01	0.04
Total	0.1	0.32
Variable Cost (P/day)		
Fuel Consumption [d]	15.60	17.60
Total Cost (P/day)	15.60	17.60
Operating Cost (P/Li of water - day) [e]	7.85	4.48
Savings (P/Li of water-day)[f]		3.37
Payback Period in boiling a liter of water (days) [g]		44.5
Yearly Savings per Liter of Water Boiled		P 1,229.53

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APPENDICES

Appendix I
Number of Households per Region in the Philippines During Year 2000

Region	Number of Families
National Capital Region	2,188,675
Cordillera Administrative Region	275,075
Ilocos Region	807,528
Cagayan Valley	566,692
Central Luzon	1,517,069
Southern Tagalog	2,274,664
Bicol Region	1,096,921
Western Visayas	1,211,734
Central Visayas	1,104,989
Eastern Visayas	734,809
Western Mindanao	603,728
Northern Mindanao	535,735
Southern Mindanao	1,032,587
Central Mindanao	514,406
CARAGA	409,790
ARMM	394,255

Source: National Statistics and Coordinating Board

Appendix II
HEATING VALUE AND PROPERTIES OF WOOD

Fuel	Proximate Analysis				Heat Content (BTU/lb)
	Moisture (%)	Volatile Matter (%)	Fixed Carbon (%)	Ash (%)	
Apitong Bagasse		19.2	79.7	1.2	13713
Bagtikan		24.1	72.5	3.5	8933
Bakauan Babae		4.2	90.9	4.9	
Bakauan Lalaki		4.1	90.0	5.0	
Coconut Husk	13.7	72.4	26.0	6.3	8736
Coconut Shell	10.8	78.9	20.3	0.8	8630
Coconut Trunk		79.7	19.3	1.0	8182
Cotton Stalk		70.9	22.4	6.7	7956
Ipil-ipil Wood		82.6	16.6	0.8	8144
Jute Stick		75.3	19.0	5.7	8434
Lanipau		25.7	72.8	1.5	14000
Mayapia		19.3	80.4	0.2	16776
Mill Residue		5.2	80.5	4.3	
Mix of Lauan & Tangile		20.8	78.9	0.3	16791
Mix of Red Lauan w/ Lauan, Bagtikan & Tangile		20.5	78.3	1.2	15010
Pine Needle		72.4	26.1	1.5	8739
Red Lauan		14.5	85.2	0.2	15498
Tangile		18.6	80.5	1.0	15444
Wood		77.5	17.5	2.0	6710
Wood Waste					7454

Appendix III
BULK DENSITY OF MATERIALS USED FOR MAKINI STOVE

Material	Weight (kg)	Volume (m^3)	Bulk Density (kg/m^3)
Sand	0.607	0.00040	1,517.5
Cement	0.312	0.00028	1,114.3
Rice Hull Ash	0.160	0.00040	400.0
Grout (Almagre)	0.054	0.00030	1,166.7

Appendix IV
AVERAGE DENSITY AND MIXING PROPORTION OF VARIOUS INSULATING MATERIALS FOR MAKINI STOVE

Mixing Proportion	Average Weight of Samples (kg)	Average Volume of Samples (m^3)	Average Density of Samples (kg/m^3)
Pure Cement	0.01693	1.2079×10^{-5}	1,398.48
1:1:0	0.01922	1.2073×10^{-5}	1,591.98
1:1:1.5	0.01450	1.2292×10^{-5}	1,184.95
1:1:1.0	0.01634	1.1903×10^{-5}	1,372.76
1:1:0.5	0.01875	1.3010×10^{-5}	1,441.31

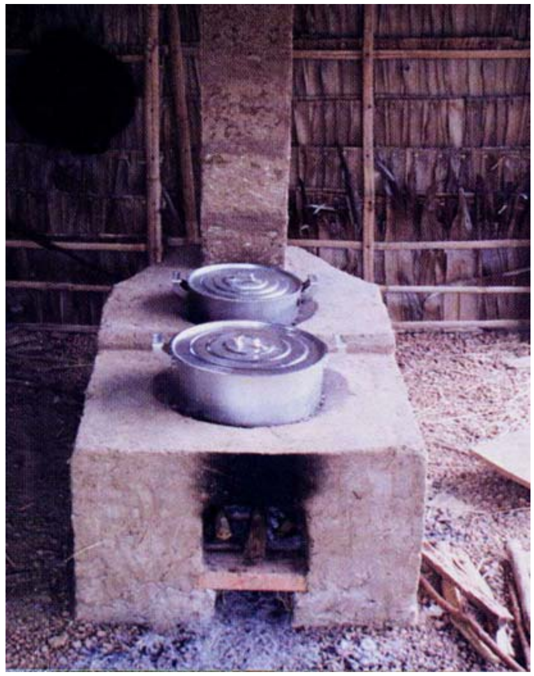
Note: Mixing proportion refers to cement/sand/ rice hull ash

Appendix V
BREAKAGE CHARACTERISTICS OF INSULATOR AT DIFFERENT MIXING PROPORTIONS

Mixing Proportions	Drop Test at 1.5 m Height	Firing Test on Bed of Burning Wood Charcoal
Pure Cement	Chipped off	With Crack
1:1:0	Chipped off	Without crack
1:1:1.5	Chipped off	Without crack
1:1:1.0	Chipped off	Without crack
1:1:0.5	Cracked	Without crack

Note: Mixing proportion refers to cement/sand/rice hull ash mixture
Firing test is done by placing the samples on top of the burning bed of fuel for 5 minutes,

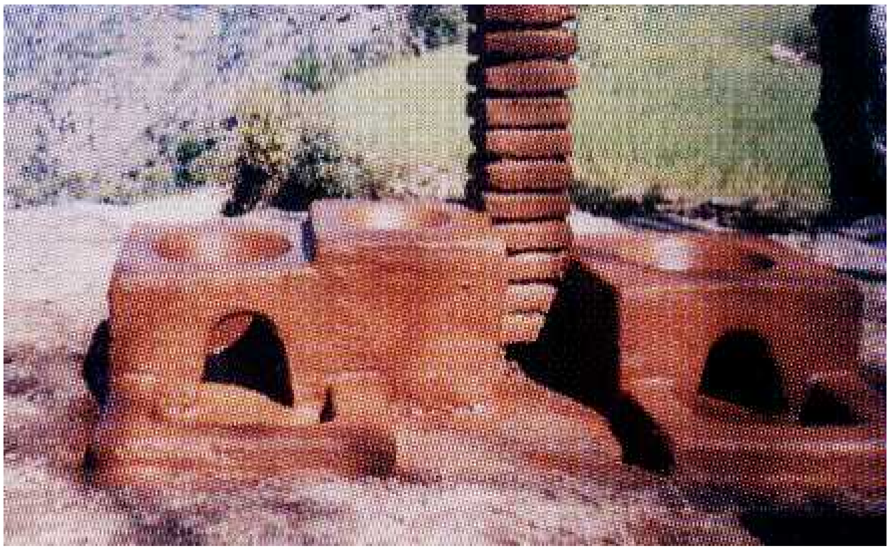
Appendix VI
Different Designs of Woodfuel Stoves



Double-Burner, Parallel-Fired, with Chimney Stove

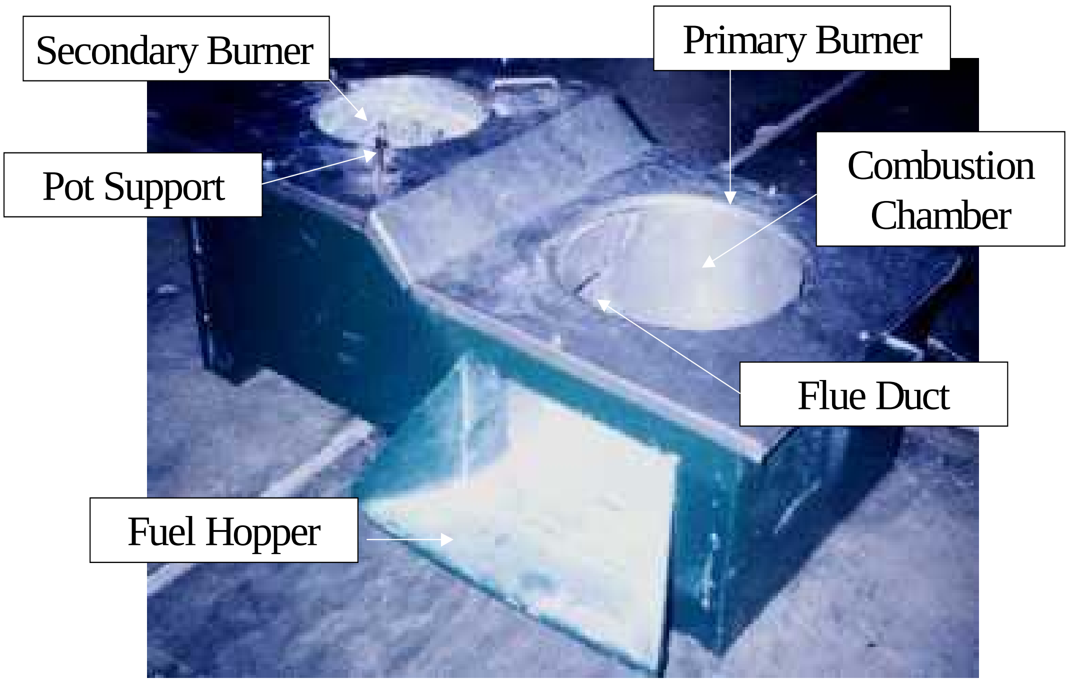
Triple-Burner, Perpendicularly-Fired, with Chimney Stove

Double-Burner, Perpendicularly-Fired, and Chimneyless Stove

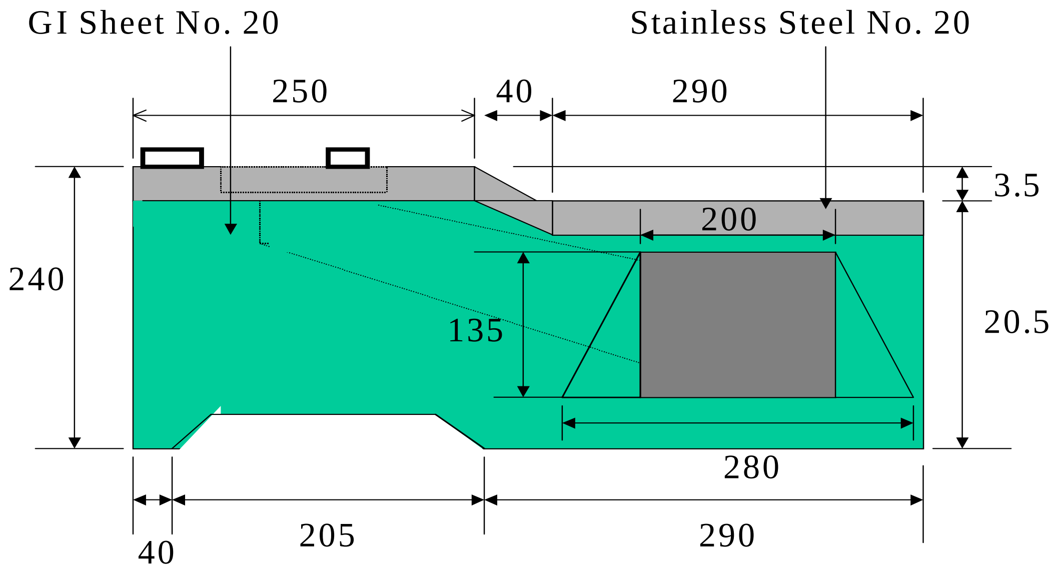


Double-Burner, Perpendicularly-Fired, with Chimney Stove

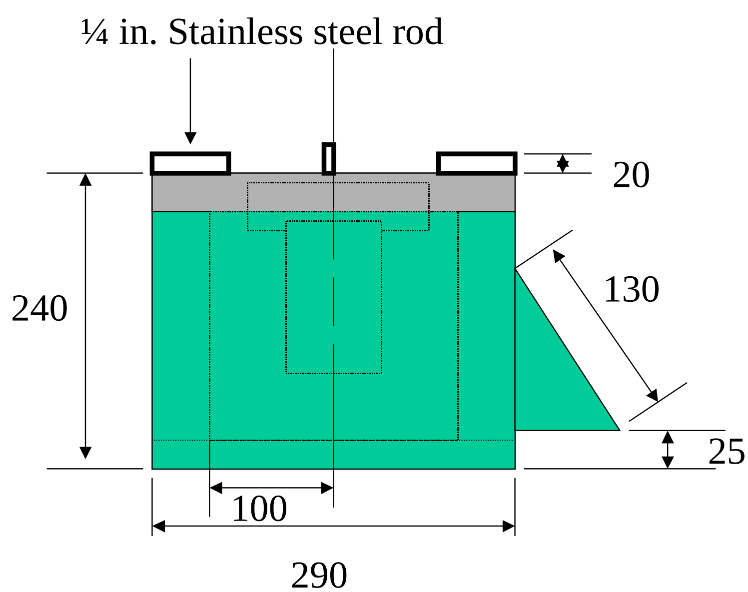
Appendix VII
Design Drawing of Two-Burner Stainless Steel Wood fuel Stove



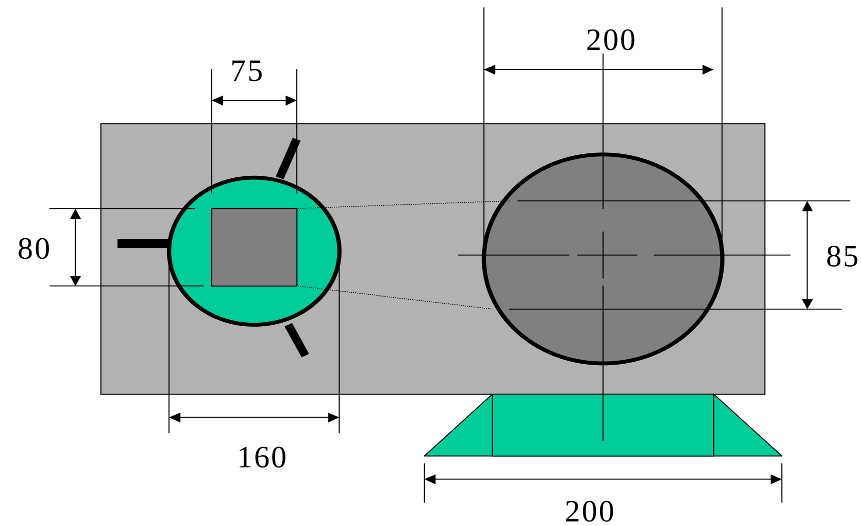
Basic Parts of the Stove



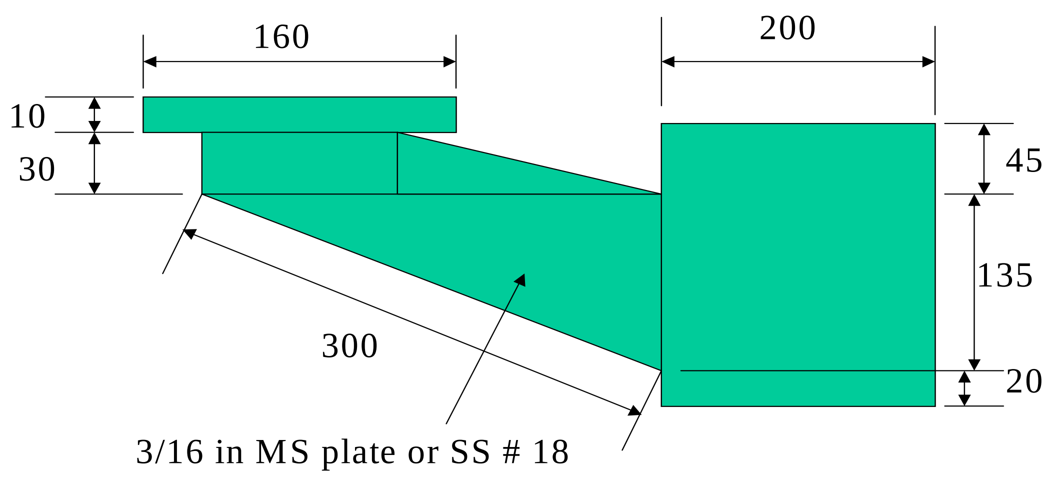
Detailed Drawing of the Stove



Side View of the Stove



Top View of the Stove



Detail of the Flue Duct