DESIGN OF LOW COST ALTERNATIVE FUEL CHULHA

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Above all my acknowledgement to my parents who co-operated with me in whatever state I was.

Declaration

I declare that this written submission represents my idea in my own words and where other ideas or words have been included. i have adequately selected and referred the original source. I also declare that I have adhered to all principles of academic honesty and integrity and have not misinterpreted or fabricated or falsified any idea / data/ facts/ sources in my submission. i understand that any violation of above will be cause for disciplinary action by the institute and can also evoke penal action from the sources which have just not properly sighted or from whom proper permission has not been taken when needed.

Signature

Roll No.

Name

Date

Approval

Industrial Design Project 2

' Design of a low cost, alternative fuel chulha (stove) for rural regions. '

By: Siddhartha Mukherjee

M.Des, Industrial Design Batch 2012-14 is approved as a partial fulfillment of requirement of post graduate degree in Industrial Design

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Contents

Abstract

The project aims at improving the rural cooking scenario in India for the people who are dependant on firewood as the sole source of fuel for their daily cooking. The idea initially was considered for the dwellers of the Sunderban region who apart from being firewood users are inhabitants where transportation of coal and other fuels become difficult due to absence of well organized roads.

Apart from using some alternative fuel (crop refuse in this case), it is emphasized that the design be flexible enough so that it can be manufactured locally with available materials and existing technologies. It's not just about making the product and selling it to them, it's about incorporating it into their daily lifestyle. Replacing the hearth from someone's house is more than a design challenge. It calls for making the technology available and more importantly comprehendible so that it becomes adapted to a certain cooking culture. Also, it needs to accomplish by a device that is affordable to those living below the poverty line.

Introduction

Improving cooking technology in remote parts of India, which have over the years been ignored and are constantly struggling and adapting themselves to make ends meet, has a big potential to improve the economic and health conditions of the community. Initially the idea was to take the case of the dwellers of the Sunderban delta.

1.1 The Sunderban story

The Sunderban delta lies in the eastern part of India and a major 2/3rd part in Bangladesh, is the biggest halophytic mangrove forest in the world. The region is drained by super confluence of rivers, Brahmaputra, Padma and Meghna. The region is densely covered in mangrove forests and is one of the biggest reserves for the Bengal tiger.

1.2 Survival on bare minimum

Population density in Indian Sunderbans isover 900 per sq.km already (2001 census) which is Almost the entire population depend on the natural resource based livelihood patterns. The per capita electricity consumption is one fourteenth of the national average. A majority of households do not have any access to electricity. Only 57 out of 1076 villages are fully connected by land (Centre for Science and environment 2011) and 17 % households have grid connectivity. Although Sunderbans is prone to extreme weather events, grid is still being promoted in spite of its high running and maintenance cost.
Dependency on firewood as domestic fuel has created openings of newer natural hazards like aggravated soil erosions (the roots of the mangroves act as a binder against erosion and acts as a buffer for the cyclones and the heavy tidal waves. Apart from being home to a variety of flora and fauna, the forests act as a great carbon sink.

The Sunderban saga

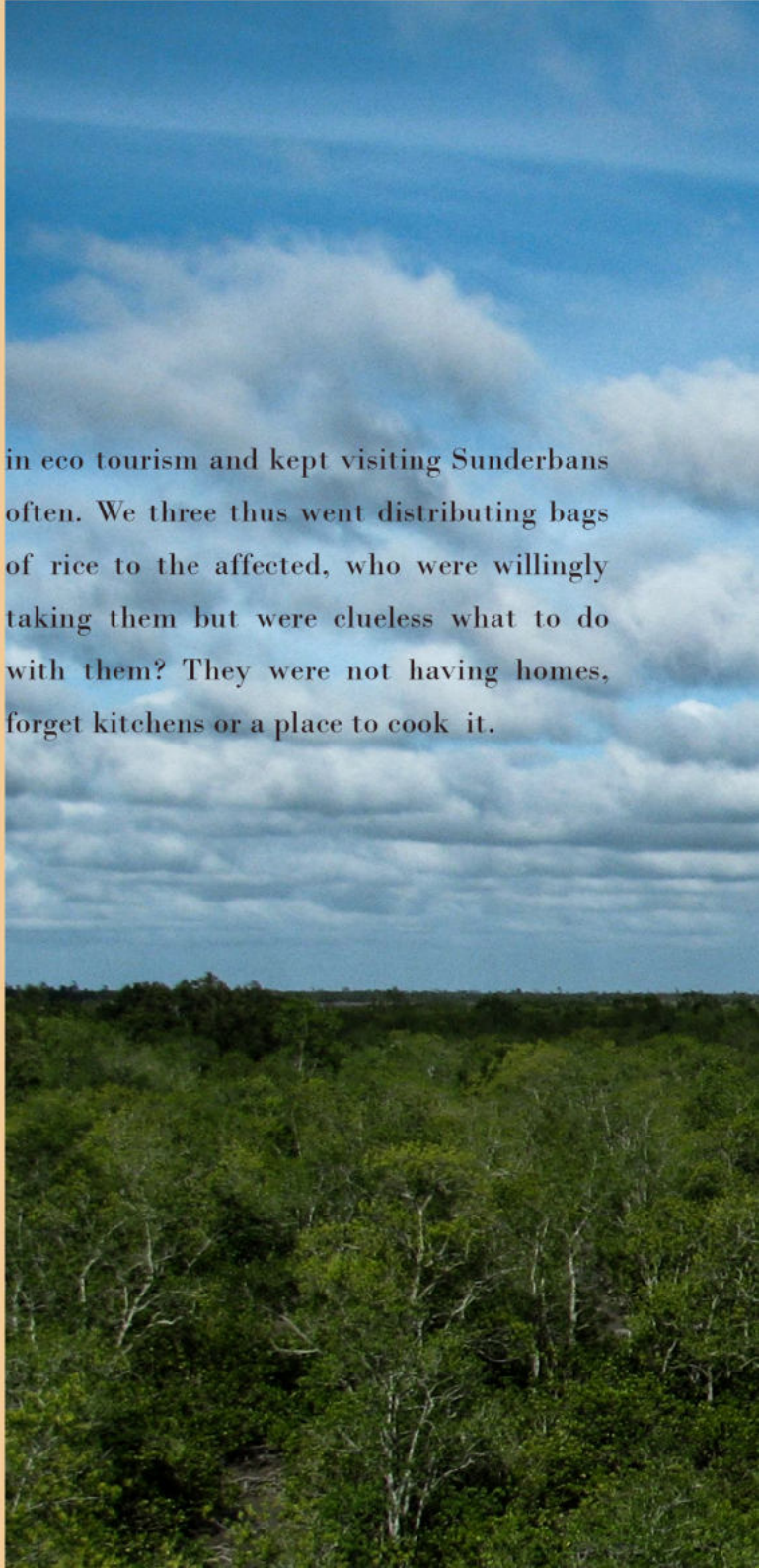
2.1 Depleting forests

According to a 2011 scientific paper, the forests of Sunderbans play a critical role as a carbon sink; trees and soils in forests can trap and store Carbon dioxide (CO2) from the atmosphere, a process known as carbon sequestration. Forests when destroyed, lead to release of the stored carbon: tropical deforestation is reportedly responsible for about 20 per cent of the world's annual CO2 emissions.

2.2 Dwindling resources

The sustenance of the forest thus determines better yields in agriculture and fishery, both of which generate the livelihood and survival of the people. About 44 per cent of the population lives below the the poverty line whereas 60 percent of the households don't have access to clean drinking water. (Centre for Science and environment 2011)

Over the last 120 years the probability of cyclones have increased by 26%. Aila, a devastating cyclone lashed through Bay of Bengal over Sunderbans in May 2009. 330 people were killed and at least 1 million were marooned in the middle of nowhere. A rendezvous with the plight and the extent of catastrophe brought by the storm opened eyes to a more personal level of the negligence at least in the matter of food and health security. A month later after the cyclone Aila caused it's havoc, me along with a friend of mine went to visit some islands of Sunderbans mainly Gosaba and Sajnekhali. Enroute we met a student of Jadavpur university who was pursuing studies in eco tourism and kept visiting Sunderbans often. We three thus went distributing bags of rice to the affected, who were willingly taking them but were clueless what to do with them? They were not having homes, forget kitchens or a place to cook it.



Design opportunities

3.1 What to change

The issues of deforestation, natural calamities, the poverty and helplessness of the people all seem to get connected somewhere, one way or the other all seems to be linked. The chopping down of trees for firewood (which is the only source of domestic fuel) is cause of soil erosion, insurgence of more heavy tidal waves, reduction in the size of the CO2 sink as well as the buffer for cyclone. Electricity never being option in a place devoid of grid and looking for another source of fuel means the families travel farther and pay more to be able to cook, and that too in poverty trodden community. There is significant gender disparity along with these problems: generally the women at homes and young girls bear the brunt of this i.e. collecting firewood, chopping and sizing them and often children who would otherwise be in school are required to collect fuel, size and chop them.

3.2 Hazards of open fire cooking

Open fire cooking in the typical chullah (stove) has its own health hazards too, and it is magnified more in a place with lack of medical facilities. Women more likely are to contract chronic obstructive pulmonary disease, develop lung cancer, asthma, cataracts and have miscarriages.

The Indian constitution stipulates that every citizen has the right to the highest attainable standard of physical and mental health. In this regard inhabitation in healthy living conditions, smoke free from burning of fuels

for cooking are a must, which are detrimental to the health of the womenfolk and children working in the house. energy source for cooking have important bearing upon the present as well as future quality of health and lifestyles among all households. (TERI 2010)

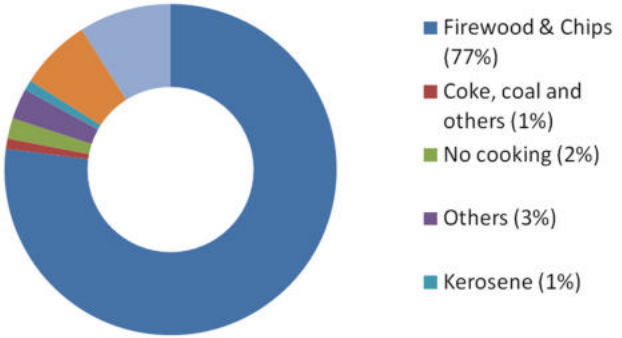


Figure 1 Percentage of households by primary energy source used for cooking in rural India (2007/ 08) **Source** (TERI 2010), (NSSO 2010)

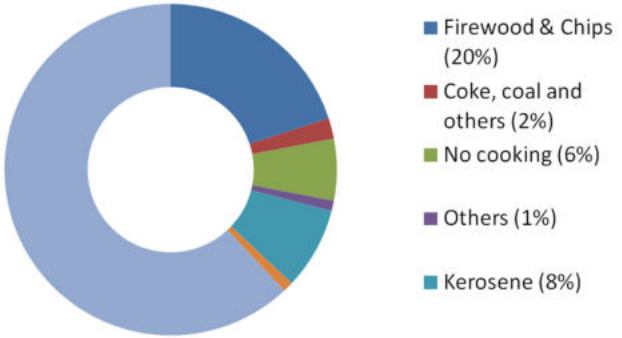


Figure 2 Percentage of households by primary energy source used for cooking in urban India (2007/ 08) **Source** (TERI 2010), (NSSO 2010)

(Left)Image copyright Matt withers (2011). Source http://educategirls.in/educateblog/wp-content/uploads/2011/02/%C2%A9Timi-5.jpg

Design Brief

To design and test the most appropriate cooking solution for rural people, where cooking is predominantly done in firewood.

4.1 Factors behind the design brief

The design challenge apart from being technical is cultural and social too. Since the area of work is chosen to be in a rural background, it is emphasized that the stove design should be flexible enough that it is manufactured locally, with available materials and manufacturing techniques. Cost cutting and making it affordable is a primary target.

It's not just about making the product and selling it to them, it's about incorporating it into their daily lifestyle..

Replacing the hearth from someone's house is more than a design challenge, for generations who have adapted themselves to the traditional chullah and firewood. Offering something as an alternative suddenly opens eyes of many skeptics. It calls for making the technology available and comprehendible so that it is adaptable to the cooking culture, the experience of daily meal preparation. And last but not the least; all these to be achieved must be accomplished with a device that can be used by those living below the poverty line.

4.2 Wishlist for the Design

What needs to be achieved and what guides the design brief are highlighted aside

Can be used in different seasons

Easily made, ease of maintenance and use and locally made by the people themselves.

Able to work both indoors and outdoors

Instead of selling the stove as a product, more focus is laid so that the product is locally made by some people there, which in turn generates livelihood

Environmental benefits

- Reduction in chopping down of trees for firewood, hence more green canopy
- Preservation of the carbon sink

Economic benefits

- Cheaper alternative to the conventional method of cooking.
- Locally made by people, encourages livelihood of people making and selling them.

Social benefits

- Less time spent collecting firewood and the tasks associated with it, more time for the womenfolk and the children who collect and split firewood.
- Less smoke emission means healthier families and lesser medical attention.
- Sustenance of people, majority of whom live below poverty line.

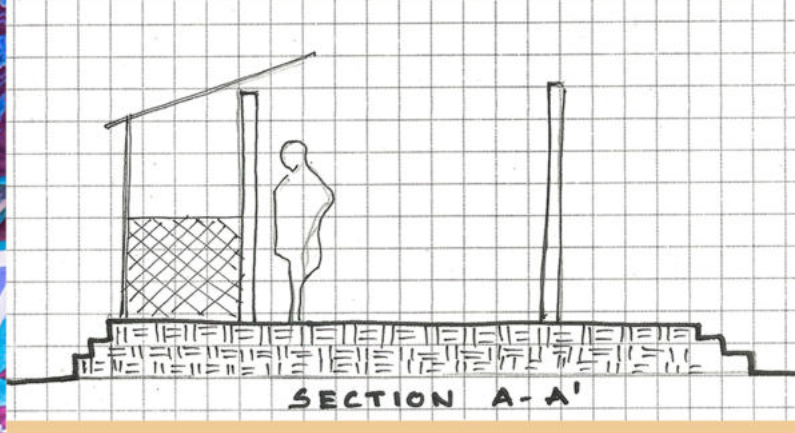
User studies

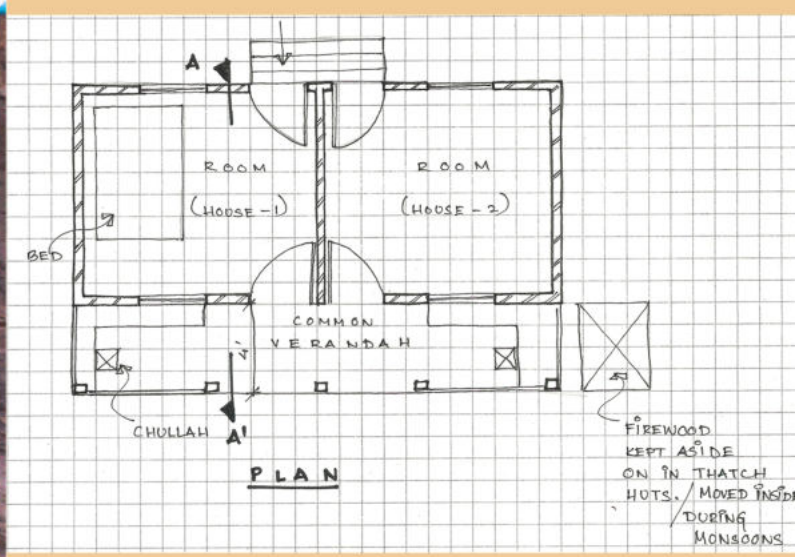
User studies involved identifying the users, their economic and social niche in the societal hierarchy. Identifying the behavioral and experiential issues connected with it.
For initial research, I contacted an agricultural engineer from ICAR Dapoli, Maharashtra, I later went to Raigad in Maharashtra, to get an insight on the rural cooking scenario where open fire cooking is predominant.

In areas where rice is major crop such as Raigad and Ratnagiri in Maharashtra and other parts of coastal India. The rice chaff (sticks of the plant after harvesting) is used as fuel too. This shows there is a lot of scope for using crop residues as fuel.

The first house I observed was a series of three rooms side by side with a common verandah on the front. The verandah served as the common interacting space as well as the kitchen. For a family of four, everyone the man of the house, the lady and their two children shared the same room. A chulha made from an old tin can was used as the hearth, burning firewood or crop chaff.

Verandah was the preferred location for cooking as indoor cooking was not problem due to smoke emissions as well as space constraints. The chulah is placed on the floor in case of the portable one and the lady sits in on the floor in a squatting position while cooking.





(Top) Plan and section of the household

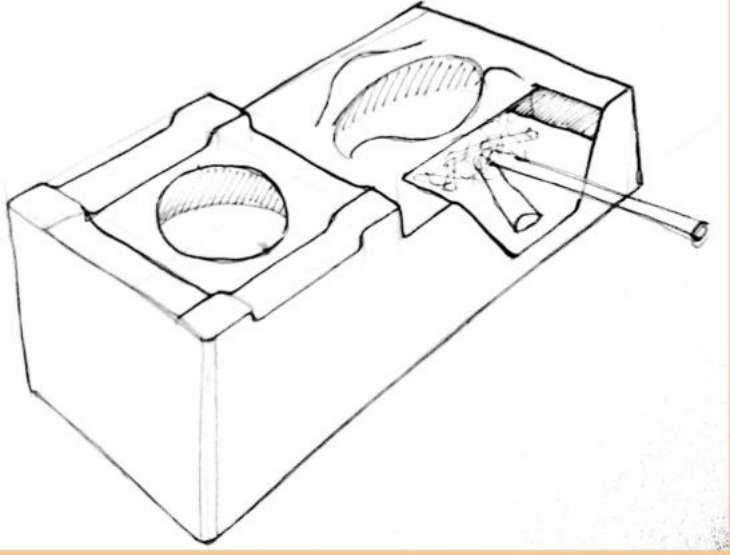
Scenario 1 : Household with a chullah made from old oil can and burning firewood or crop residue as fuel

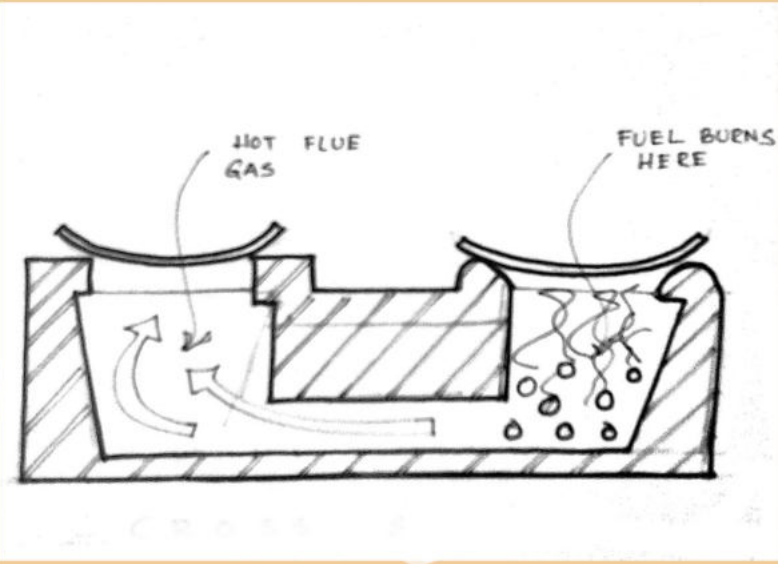
(Left) The version of the firewood chulha made from an old oil can

The chulha (stove) is made from mud and slurry of cowdung and moulded by hands on the ground. A chulha is often dignified as the abode of the fire god and considered sacred.

Some locals even talked how after a chulha is made, the first meal prepared on it is milk, in invocation of the fire god and how the overflowing of the milk is considered pious.
A chulha like the one shown on the right has two pot holders. The vessel receives heat from the burning of the firewood below it, while another vesel gets heat from the hot gases which tend to escape from the other burner and used for warming food. The chulha of this type is sold in the local weekly market and cost around Rs. 150.

(Right) A chulha for burning firewood made from clay and bricks having two potholders. One potholder is for active cooking while the other is used for warming food by the hot flue of the burnt wood.





(Top) View and cross section of the chulha

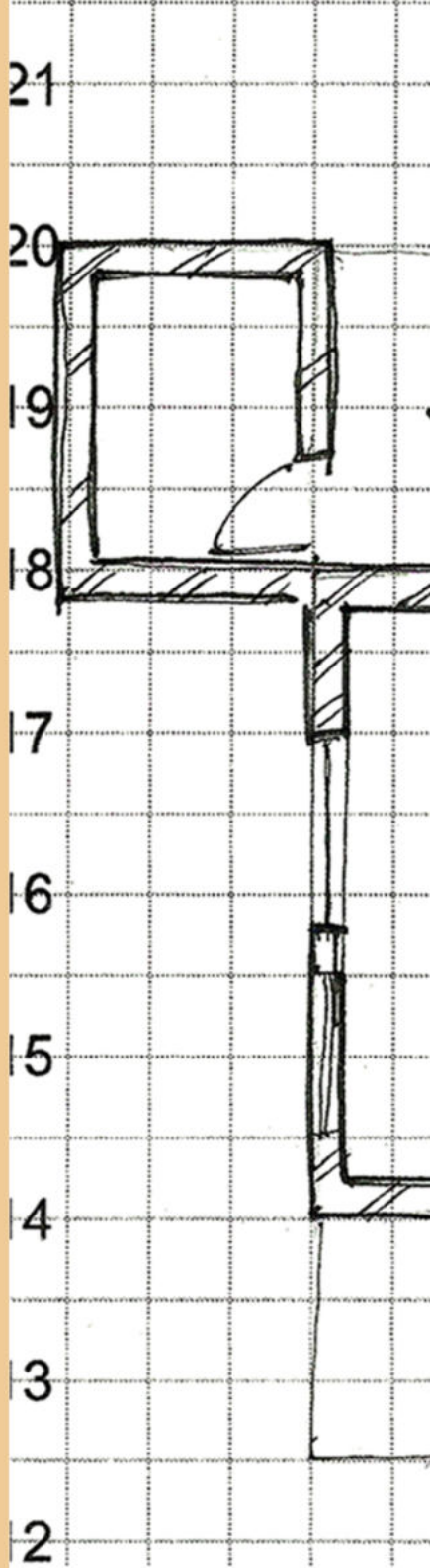
(Left) Firewood burning causes incomplete combustion and emits lot of smoke and soot, which can be seen as the blackening of walls and pots.

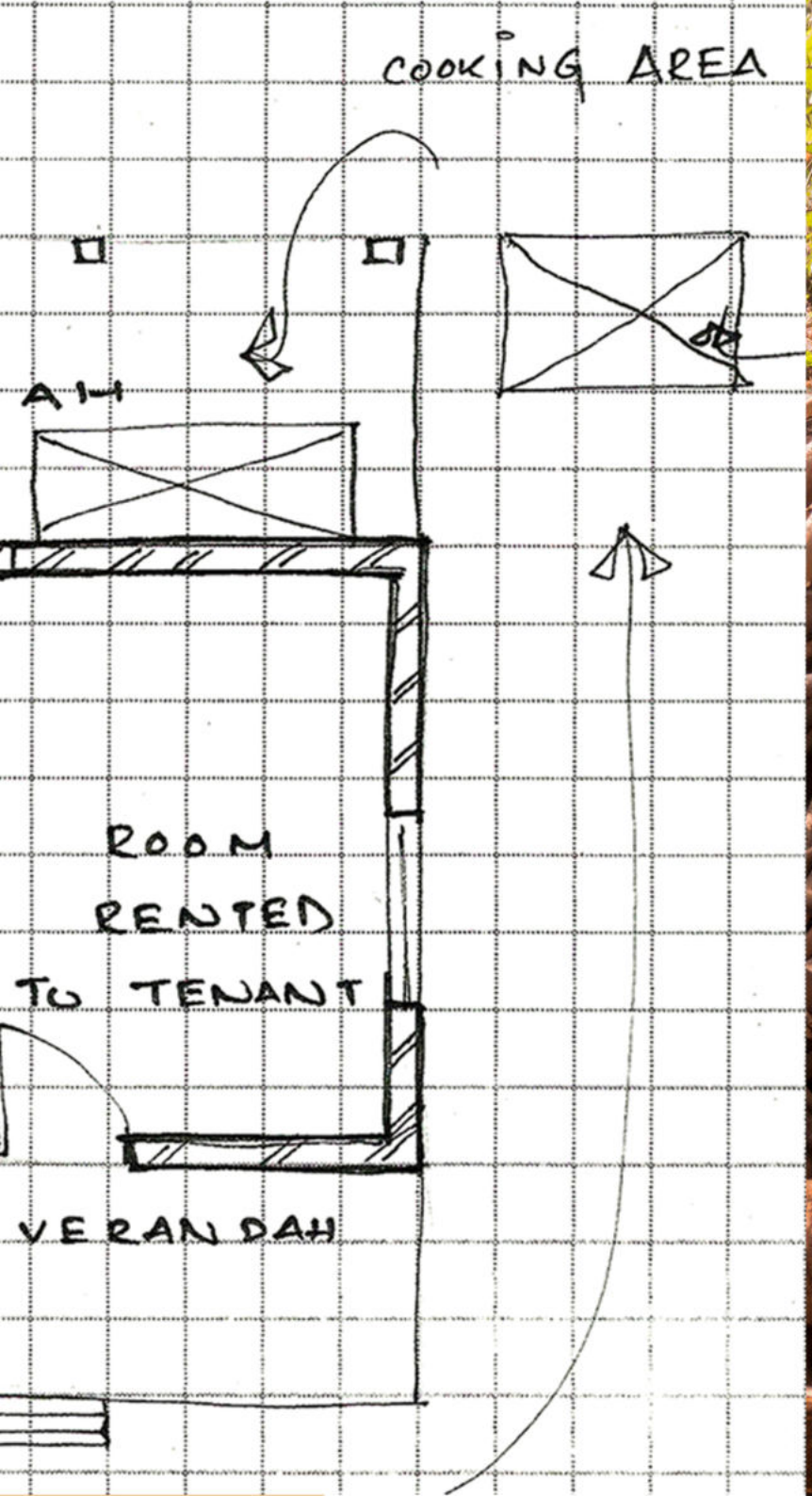
The plan of the house visited shows the position of the kitchen of the house as well as the fuel storage area. Cooking is generally done away from the living areas due to hazards of open fire and smoke problem due to fire-wood burning.

It is evident that firewood burning emits a lot of poisonous smoke, soot and ash. An example of it can be seen on the photograph on the left where the walls are blackened due to the soot.

Fuel is generally stored outside the house where the wood is in bigger chunks and not splitted. During mon-soons the firewood needs to be shifted inside.

Also in fields after harvesting is done small huts are made of crop residue are made to house chaff, rice husk etc,. A few of these were seen in some houses.





These huts are made from crop residues after harvesting and house crop residues, rice husk etc. which are meant for cattle fodder. However the same can be used for storing fuel.

Revised design brief

6.1 Insights from user studies

The user studies presented an overview of how and what people cook. Firstly it determined the logic behind the placing of the kitchen, so that they don't get affected by the smoke emissions from the chulha. Also the kind of stoves they used for cooking were very different from each other in terms of materials, construction and working in order to achieve the common task of cooking.

Storage of the fuel also seemed to be a primary concern. During rainy seasons or during unavailability of firewood stockpile of the same became necessary. People also used crop residues and chff which becomes available easily during harvest seasons at a cheaper cost too.

The people generally prefer making their own chulha instead of buying. But often the chulha such as the one with two pot holders are bought from the weekly market.

6.2 Activities during cooking

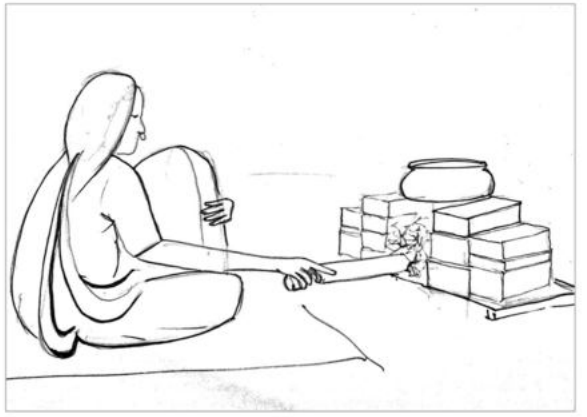
The lady of the house generally works on the floor. Some important activities which happen while cooking are mainly associated with the preparation before cooking. Mainly kneading of the dough for chapati, making of masala paste on Sil batta, cutting of vegetables are the activies which happen parallel to the cooking

So the design brief may be summarized as **" Designing a low cost chulha (stove) which burns alternative fuel and self made by the rural people."**

Collecting firewood

Kneading dough for chapati

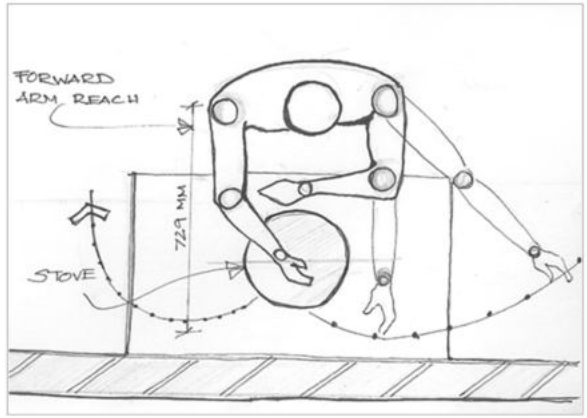
Lighting and tending the flame



Making chapati

Cooking atop the chulha

Forward arm reach



6.3 Design directions

The cooking postures and way of cooking on the floor determines the dimensions and the easy working height when cooking on floor.

Traditional vessels such as handi, kadhai and degchi are the most widely used utensils for cooking. The cook top dimensions should correspond with the vessel sizes.

The forward arm reach also determines the diameter of stove and also the access of the stove so that it doesn't interfere with the other ongoing activities.

One of the major problems with firewood cooking is the amount of smoke it produces while cooking which causes respiratory problems, nasal and eye irritation.

Indian cooking utensils : clockwise from top Kadhai, Pateela, Degchi and Tawa.
The diameters of these vessels determine the dimensions of the cooktop and also the shape of it, so that the heat distribution is even.

Vessels such as Kadhai and Degchi have a curved bottom and the bottom of it thus needs to be held in place proper so that heat is evenly distributed along the curved surface as well.

http://www.dsource.in/resource/kitchen-products/utensils-of-cooking

Exploring technologies

7.1 The technology

Being a task as old as the origin of mankind, cooking heat has always been a part of mankind along with development of cook stove design attributing to different needs, which has eventually developed a better understanding of the technological and the physical processes involved with heat transfer and combustion in different materials and different fuels.

Findings led to a variety of devices from low smoke stoves to camping stoves, rocket stoves and gasifiers

7.2 Gasification and gasifiers

Gasification is a thermo-chemical process in which carbonaceous (carbon rich) feedstocks such as coal, coke or biomass (cattle dung, crop residue) are converted into a gas consisting of hydrogen and carbon monoxide with traces of carbon dioxide and other trace gases under anaerobic (oxygen deficient) conditions, high pressure and temperature conditions. The gas produced is termed as Syngas.

Syngas is the direct end-product of the gasification process. Though it can be used as a standalone fuel, the energy density of Syngas is only about 50 percent that of natural gas. (Alternativefuelsabout.com 2013)

When carried in proper conditions gasification serves as an efficient energy extraction process.

7.3 Difference between combustion and gasification

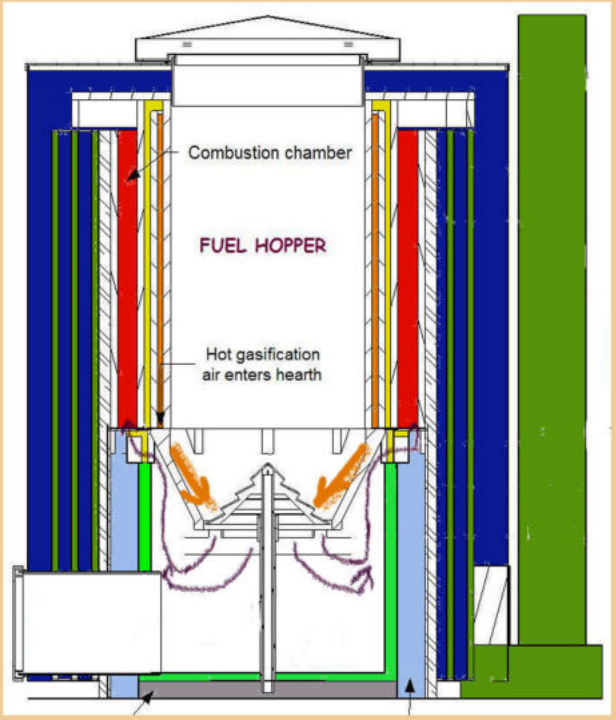
Combustion is an exothermic reaction between a carbonaceous fuel and oxidizer (supporter of combustion generally oxygen) in which the fuel is burned to produce heat.

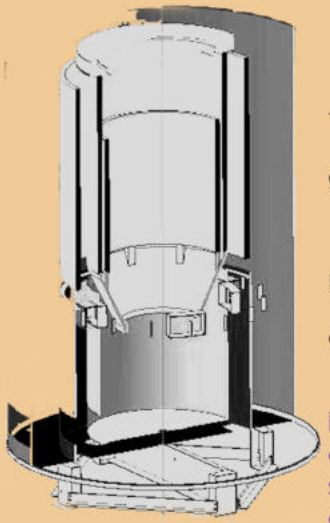
Carbon (Fuel) + Oxygen ⟶ Heat + Water + CO_2

Gasification is an exothermic(heat releasing) reaction between a carbonaceous fuel in a controlled chamber in limited supply of oxidizer, in which the burning of fuel yields Syngas (a mixture of hydrogen and carbon monoxide) which is flammable and an energy source.

Carbon (Fuel) + Oxygen ⟶ Hydrogen + CO + Water + CO_2(trace)

(Alternativefuelsabout.com 2013)





Top: Sectional view of a gasifier

Bottom: Cutaway view of a gasifier

http://powerityourself.com/wp-content/uploads/base_gasifier_cross.jpg

The 'chulha ' benefits those in the rice growing region, where rice husk is used as a mix for livestock feed. There are possibilities- where realization of rice husk as a domestic fuel is possible.

7.4 Why gasification ?

Gasification offers feedstock flexibility. Fuel rich in carbon content are suitable for gasification.

It can generate energy from what is discarded, in this case cop residues.

Complete combustion of the fuel without wastage.

Since energy is achieved from the combustion of the fuel as well as from the ignited syngas the efficiency is much higher.

Near zero emission of smoke.

7.5 Choice of fuel

Rice is one of the primary crops of India, and the staple food of Eastern and Southern India. India accounts for 20 per cent of the World's rice production. Rice being a tropical crop flourishes in hot and humid climate.

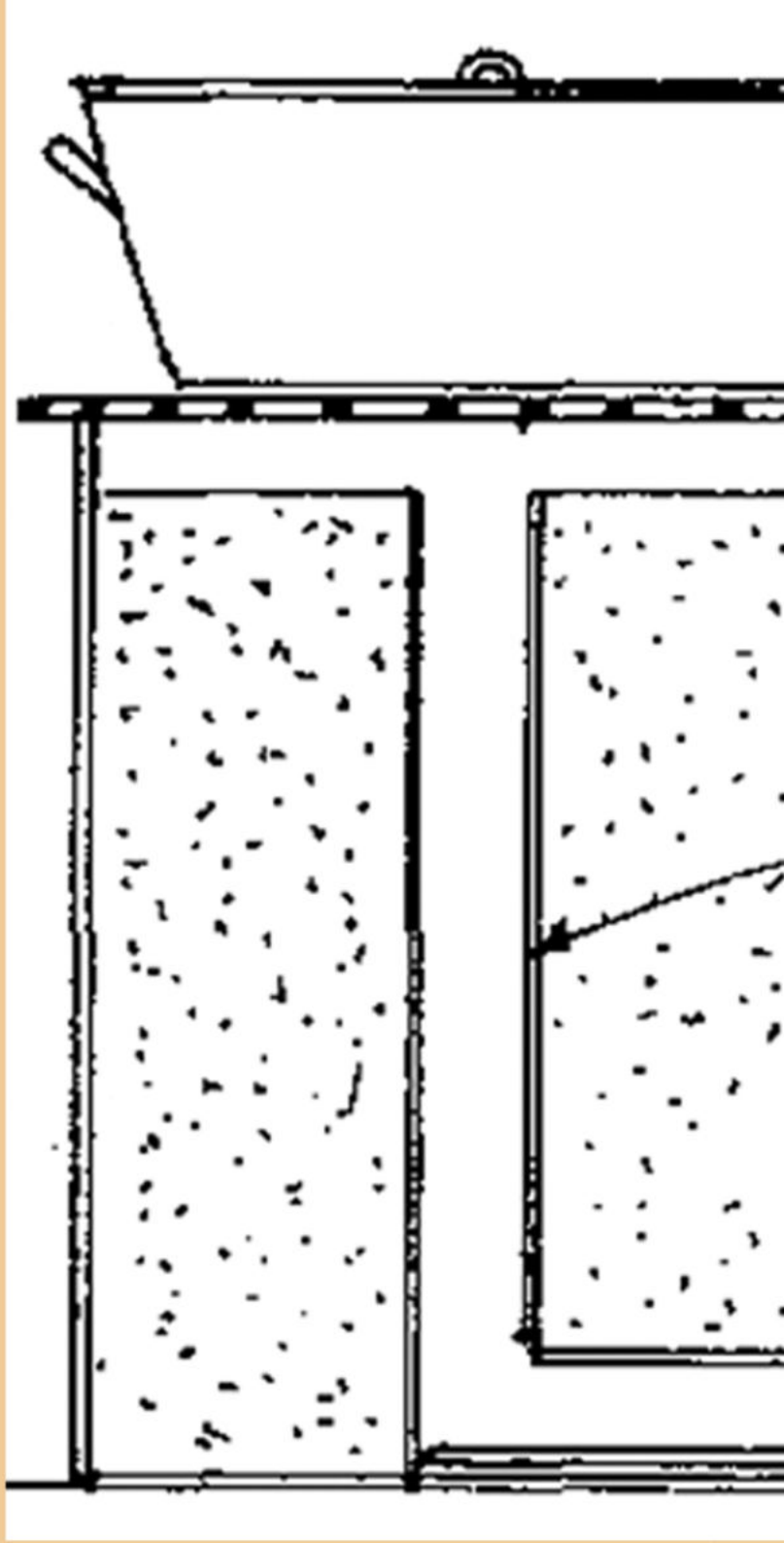
The major producers of rice in India are West Bengal, Bihar, eastern Uttar Pradesh, eastern Madhya Pradesh, northern Andhra Pradesh and Orissa. States such as West Bengal and Bihar raise two crops a year. Regions cultivating rice in India also indlude the Western coastal strip and the Eastern coastal strip, covering all the primary deltas. Assam plains and the surrounding foothills and Terai region.

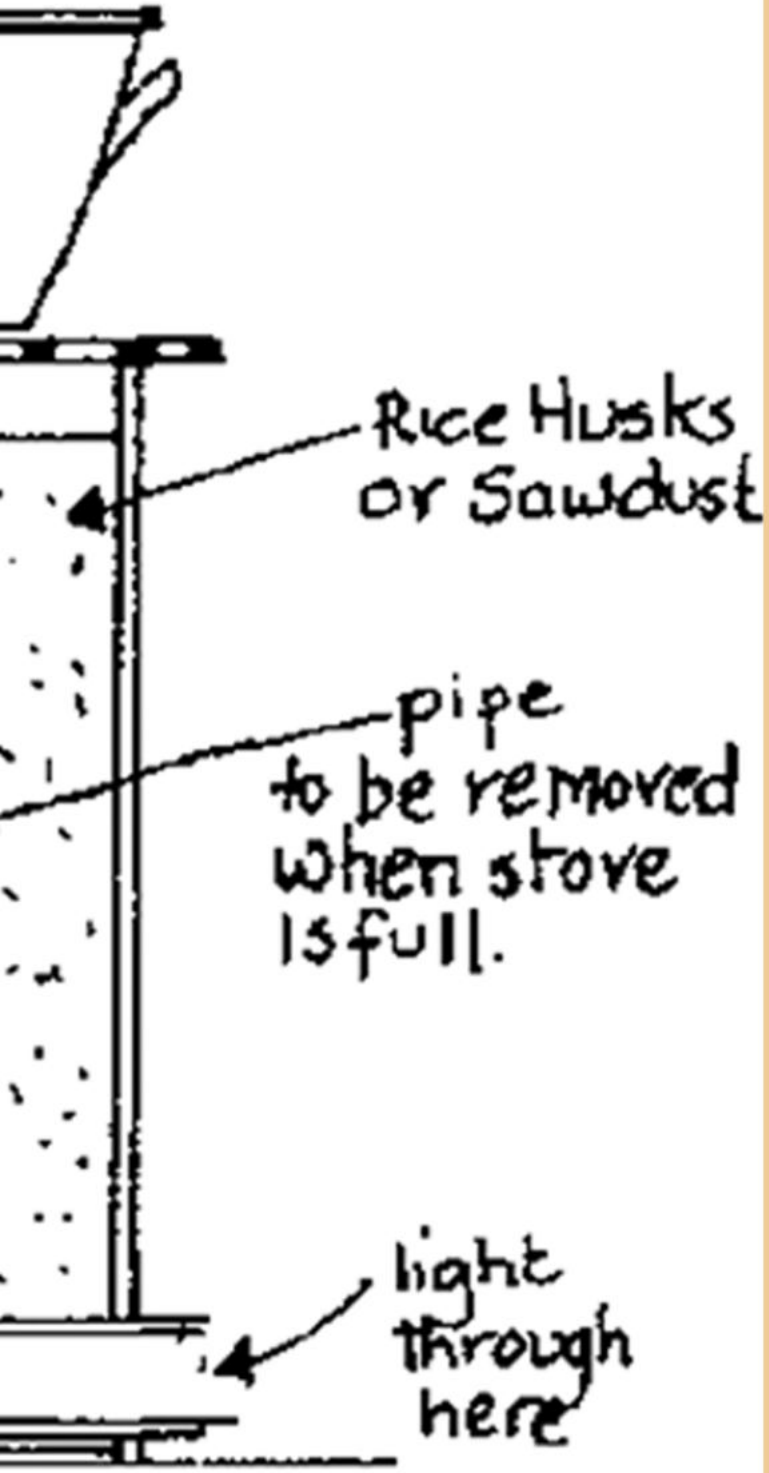
7.6 The rice husk stove

Direct combustion being the most earliest form of generating heat from rice husk. Rice husk is loaded in a container with a stick inserted in the middle. (Figure 1 and 2) .The container has holes for air and rice husk is poured and compacted in it. Once the container is full the stick is removed and the bottom lit. This process is difficult to control and results in a significant amount smoke, also the heat produced is less and the flame is uncontrollable.

This only works by the combustion of the rice husk, hence a lot of smoke is emitted when incinerating the husk. The process is less efficient too and results in unburnt fuel. Slow burning with deposition of ash on the bed reduces its performance.

Figure 2
http://3.bp.blogspot.com/_2AvHdMW2j_w/Sq5nfRkBg1I/AAAAAAAAAAw/Z0Qe3fi3Ep4/s320/Low+cost+rice+husk+stove.jpg





7.7 Gasification of rice husk

As discussed earlier the process of gasification has better performance, efficiency, lower emissions than direct combustion;

Gasification has also been adopted for crop residues such as rice husk in different countries in different ways. One of the relevant technologies focusses primarily on Tom Reed's work on TLUD (Top lit updraft sgasifier stoves), a patented technology by him. However Reed encourages research and development along his lines.

In another part of the world Dr. Alexis Belonio of Philippines worked on the possibility of burning rice husk with gasification.

When any carbonaceous (carbon rich) fuel such as wood pellets or rice husk is burnt, it starts disintegrating by heat into simpler molecules by a process called pyrolysis. When the gas released during pyrolysis is burned immediately, the process is termed quasi - gasification.

Existing products

8.1 Bottom lit, direct combustion stove

Direct combustion of fuel made up of small particles is possible by packing the fuel around a central air column then lighting it from the bottom. Depending on the supply of air in the stoves, it is also possible to achieve gasification.

Work has been done by the Kisangani Smith Group to build stoves for burning sawdust. Enterprise.

http://3.bp.blogspot.com/_2AvHdMW2j_w/Sq5nfRkBg1I/AAAAAAAAAAw/Z0Qe3fi3Ep4/s320/Low+cost+rice+husk+stove.jpg

8.2 Belonio rice husk gasifier stove

The rice husk gas stove was developed in the Philippines by Dr. Alexis T. Belonio. It operates on the principle of gasification. A fan at the bottom of

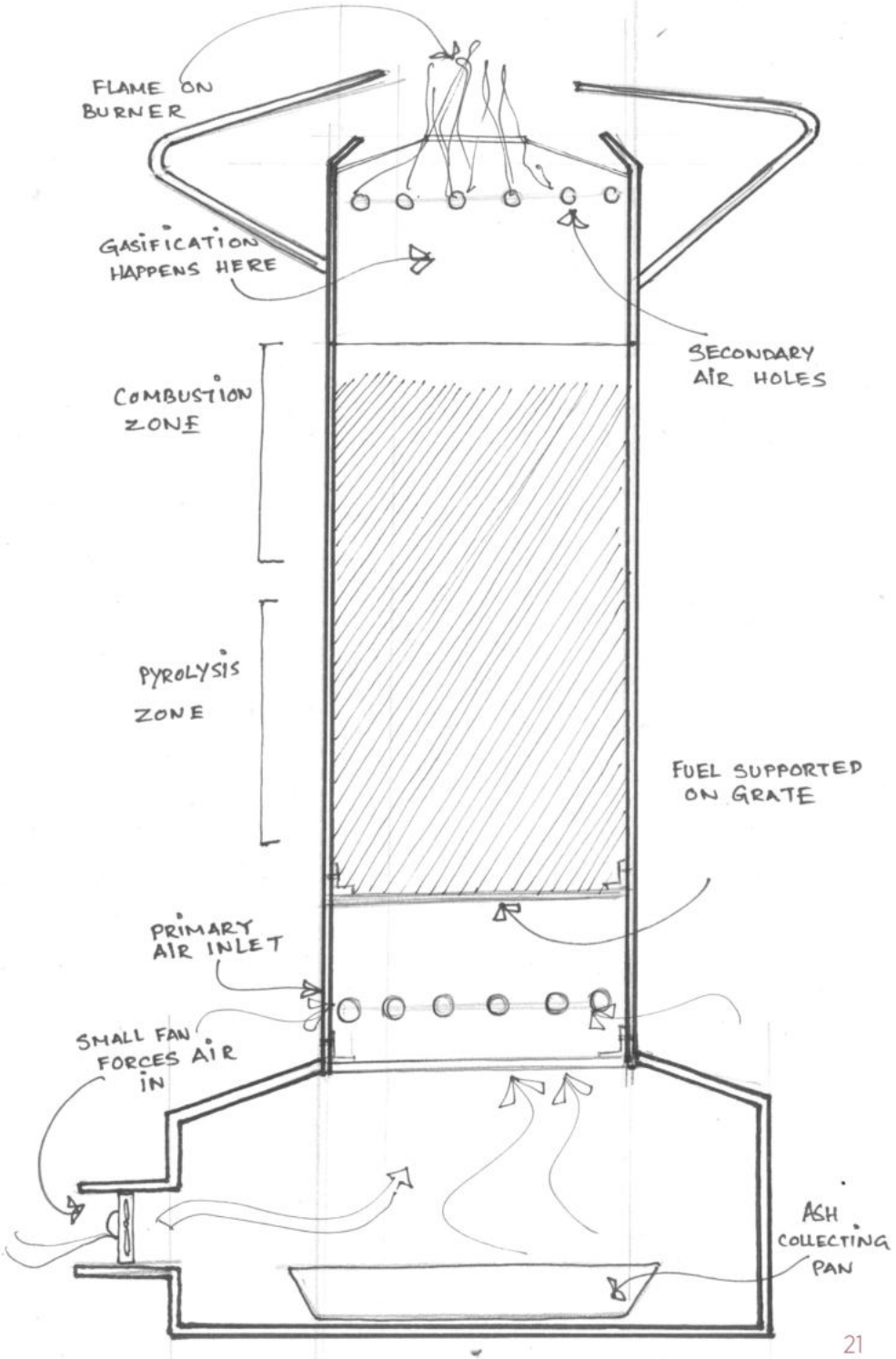
the reactor supplies primary air for the gasification reaction. The produced gas is forced through the bed of char, which results in a blue flame when it

is mixed with secondary air. It is capable of running for at least 30 minutes unattended. The relatively simple design makes the stove easy to manufacture. However, it requires a fan with appropriate power to force air through the column

of rice husk. This fan requires battery power, as well. One advantage of using forced air is that the power of the stove can be adjusted during operation by turning down the primary air.

The stove is extensively documented. It was also awarded the 2008 Rolex Award for Enterprise.

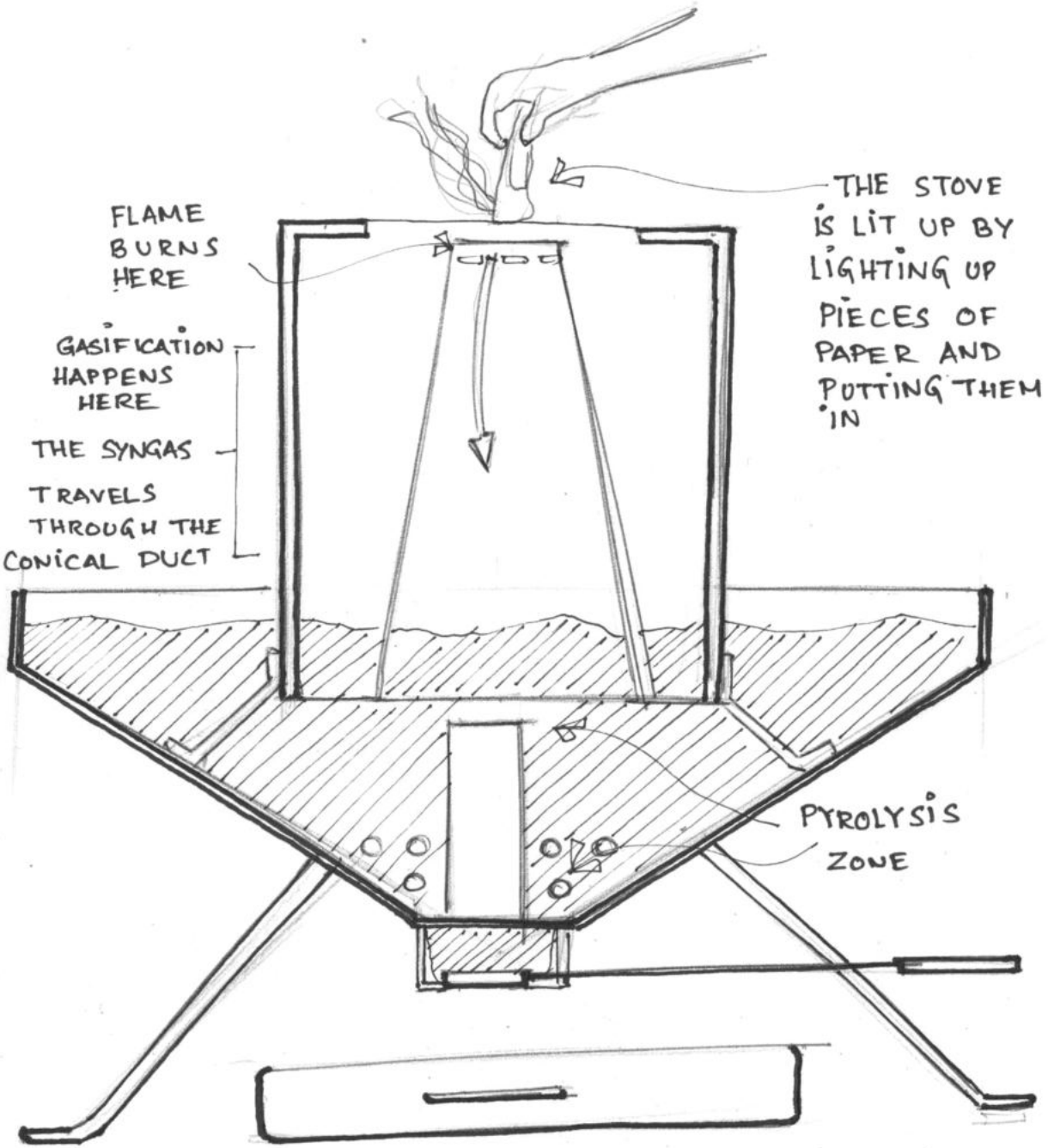
http://www.stoves.bioenergylists.org/files/t-hat_and_char_bowl_dampered_dsc_0305.jpg

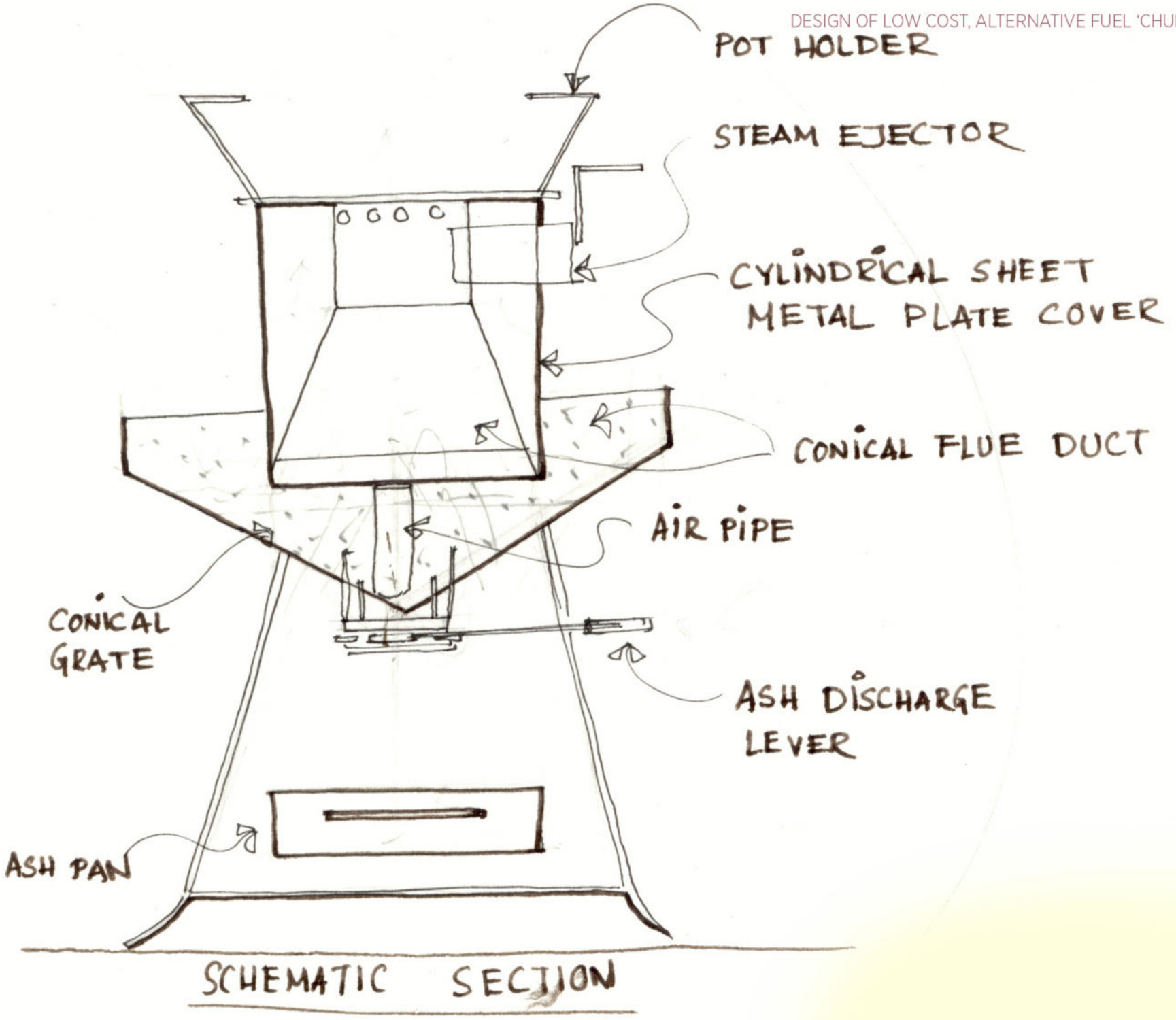


8.3 The conical grate stove

The conical grate stove was designed by Dr. Alexis Belonio. It is a quasi gasifier stove designed specifically for rice husk as fuel. It comprises of a conical hopper in which rice husk is fed, the two concentric cylinders which serve as the reactor. It is a continuous type rice husk stove in which the rice husk falls to the reactor as it is burnt gradually. The stove must be tended every few minutes to knock the char off the bottom grate into the ash pan. Versions of it exist with a steam injector and ejector. The steamejector is filled with water and remains in contact with the stove body. As the body gets heated the water changes into steam. The presence of steam enhances the gasification process and keeps the flame more steady.

http://www.e-pao.org/galleries/images/misc/2013/03/Stove_201303_2.jpg




POT HOLDER
STEAM EJECTOR
CYLINDRICAL SHEET METAL PLATE COVER
CONICAL FLUE DUCT
AIR PIPE
CONICAL GRATE
ASH DISCHARGE LEVER
ASH PAN
SCHEMATIC SECTION

The mock up rig

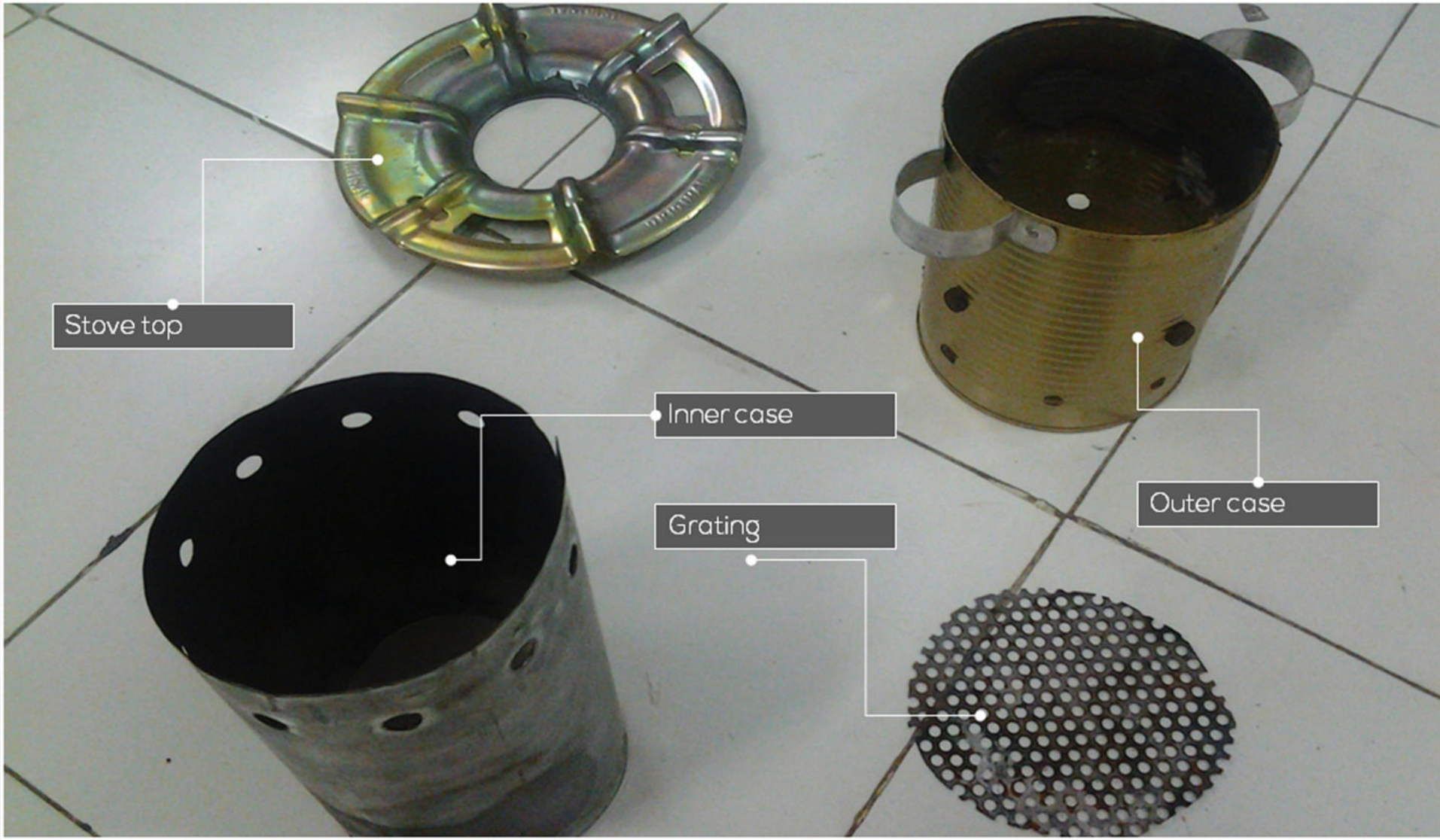
An initial mock up model was constructed to understand the working of gasifier stove. It comprised of an outer casing an inner burning chamber, and air holes to allow gasification.
It was not a continuous fuel supply stove, it needs to be loaded in batch for every use.
It performed fairly well in sustaining combustion and gasification.

Building a mock up stove was necessary to understand the process of gasification and get an hands on experience of how the fuel behaves exactly.

Initially the mock up rig was tested with wood chips and saw dust and on pyrolysis the sawdust started gasifying. On repeating the same experiment recently with rice husk, the experiment failed.

Rice husk tends to form a bed of fuel with very less air spaces. Even igniting the rice husk was difficult and when ignited the flame got choked due to the lack of air.

Thus passing air through a thick bed of rice husk was a near impossible task.


Stove top
Inner case
Outer case
Grating

Ideations and concepts

Concept 1

The idea was to make the stove as simple as possible with least number of parts. The idea of using a portable campfire stove with rice husk seemed an option.

The idea was to make and test a stove in which rice husk is loaded in batches and each batch capable of running for 20 to 30 minutes. After the batch of fuel is burnt out, the char and ash is disposed off and a fresh batch of fuel is loaded for further use.

The mockup of this was tested with wood chips and sawdust resulting in complete burning of the wood as well as the char produced. It only produced content of ash as the final residue.

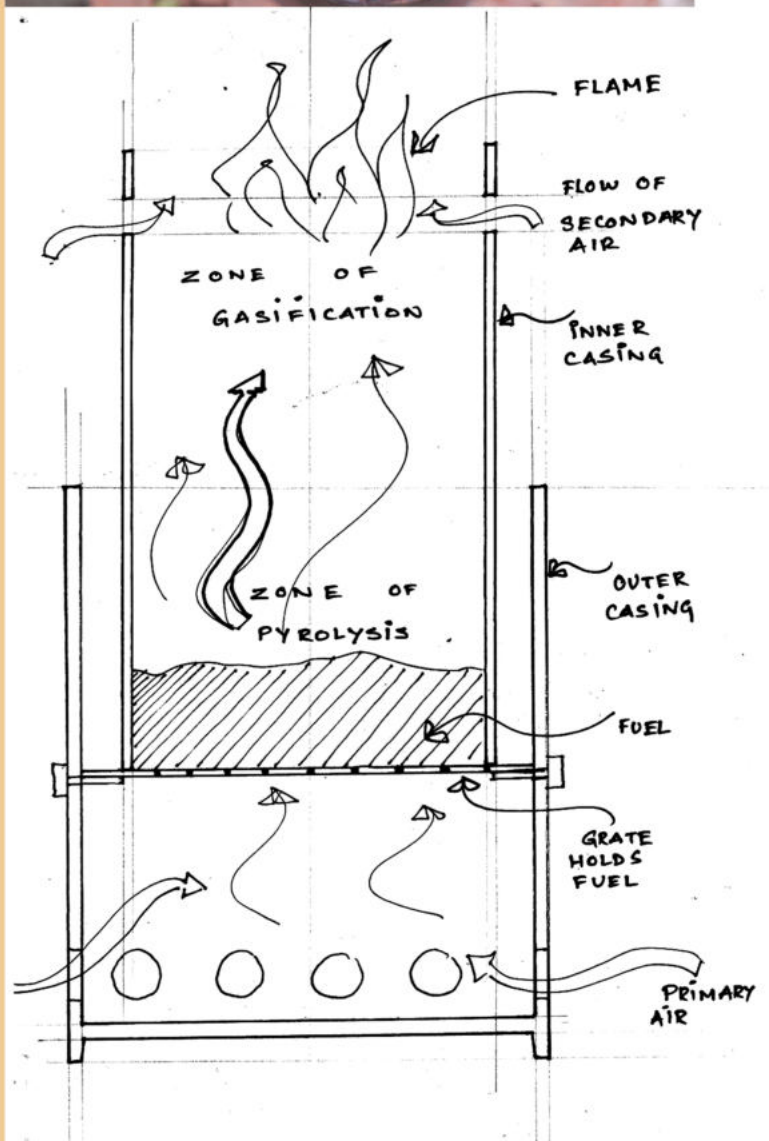
Why it was not chosen ?

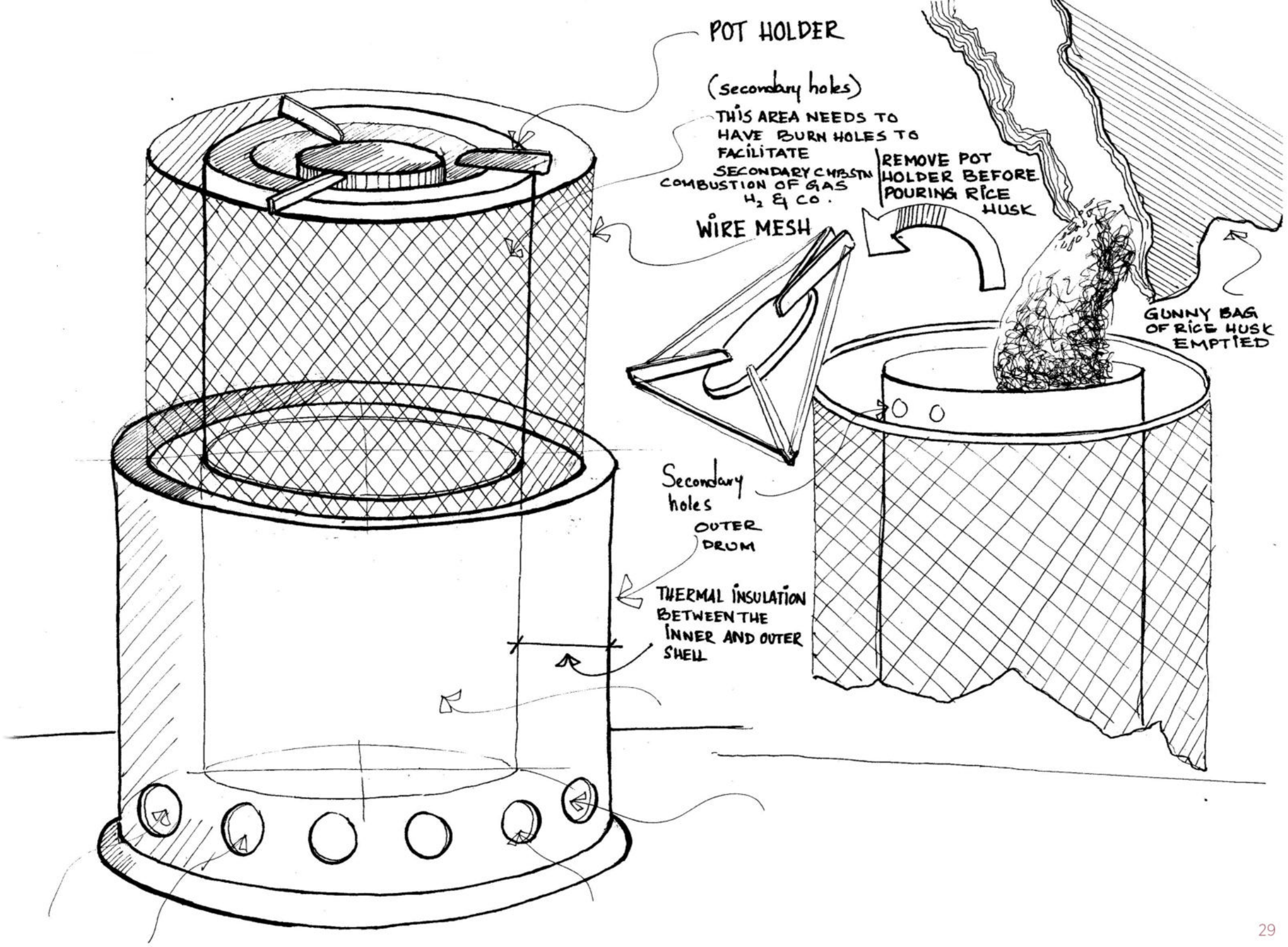
Although the idea seems simple and involves less number of parts and is also possible to be made entirely of sheet metal is not feasible when rice husk is the concerned fuel.

Rice husk unlike sawdust gets packet very tightly without any sir spaces between which reduces the flow of oxygen from the primary air holes necessary for combustion. The bed of ricehusk thus becomes impermeable to oxygen and chokes the flame out.

Insights from the experiment

Air supply to the rice husk particles need to be uniformly spread throughout the volume it is spread from intermediate levels, or smaller quantities of rice husk be used for



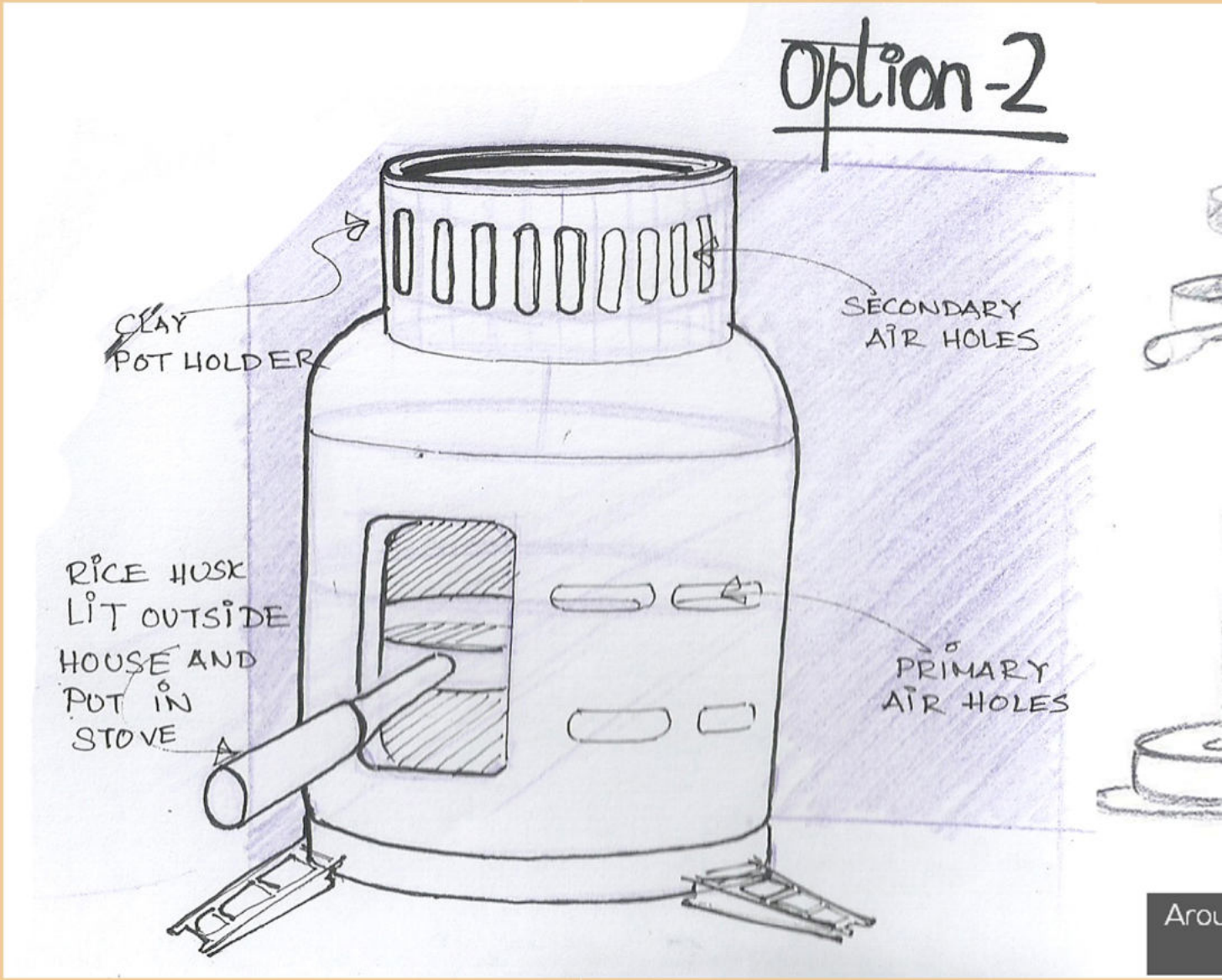

POT HOLDER
(secondary holes)
THIS AREA NEEDS TO HAVE BURN HOLES TO FACILITATE SECONDARY COMBUSTION OF GAS H_2 & CO.
CHIMNEY
REMOVE POT HOLDER BEFORE POURING RICE HUSK
WIRE MESH
GUNNY BAG OF RICE HUSK EMPTIED
Secondary holes
OUTER DRUM
THERMAL INSULATION BETWEEN THE INNER AND OUTER SHELL

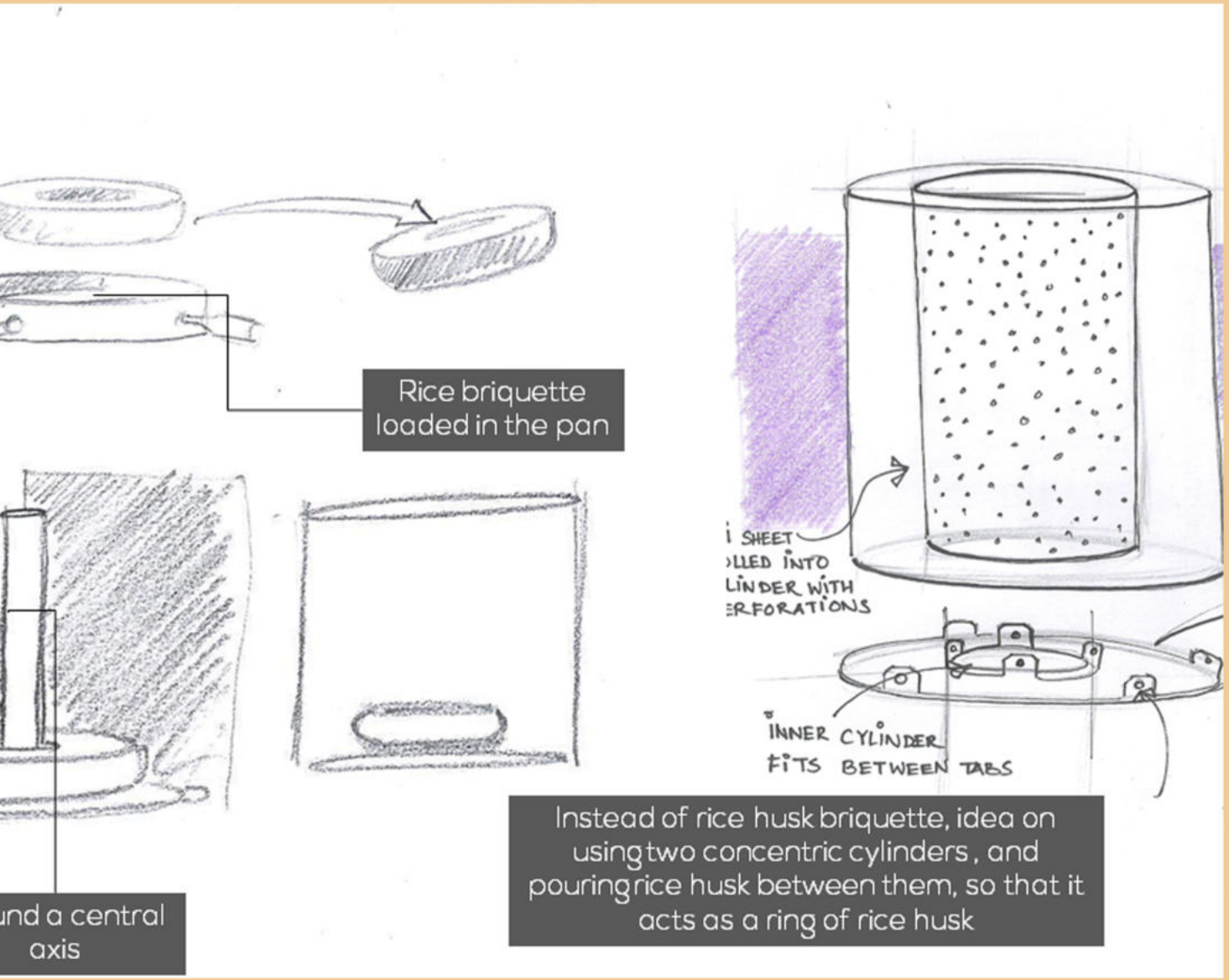
Concept 2

Rice husk can be made into small circular briquettes, using a briquette making machine. This idea uses the possibility of using rice husk briquette as the fuel.
As briquette rice husk occupies less storage space and is more convenient to light, similar to biomass cakes.

Briquetting Process

In briquetting rice husk, the rice husk is grounded to a semi fine powder form. Rice husk briquettes are produced using 2 different binders (gum Arabic and starch); two sets of briquettes were produced at the ratio 6:1 (Rice husk: gum Arabic paste wt/wt and rice husk: starch paste, wt/wt). These mixtures were loaded into a fabricated mould and compressed by weight to the mould for sometime and sun dried. (Ibrahim 2012)





Concept 3

The idea is to provide two concentric perforated cylinders with rice husk in between them. The cylinders are made from perforated GI sheet and rolled locally and riveted.

The idea draws itself from the circular briquettes of rice husk, this idea uses plain husk and burns it as if it were a ring of rice husk.

A base plate attaches to the outer cylinder providing tabs in its centre for holding the inner cylinder.

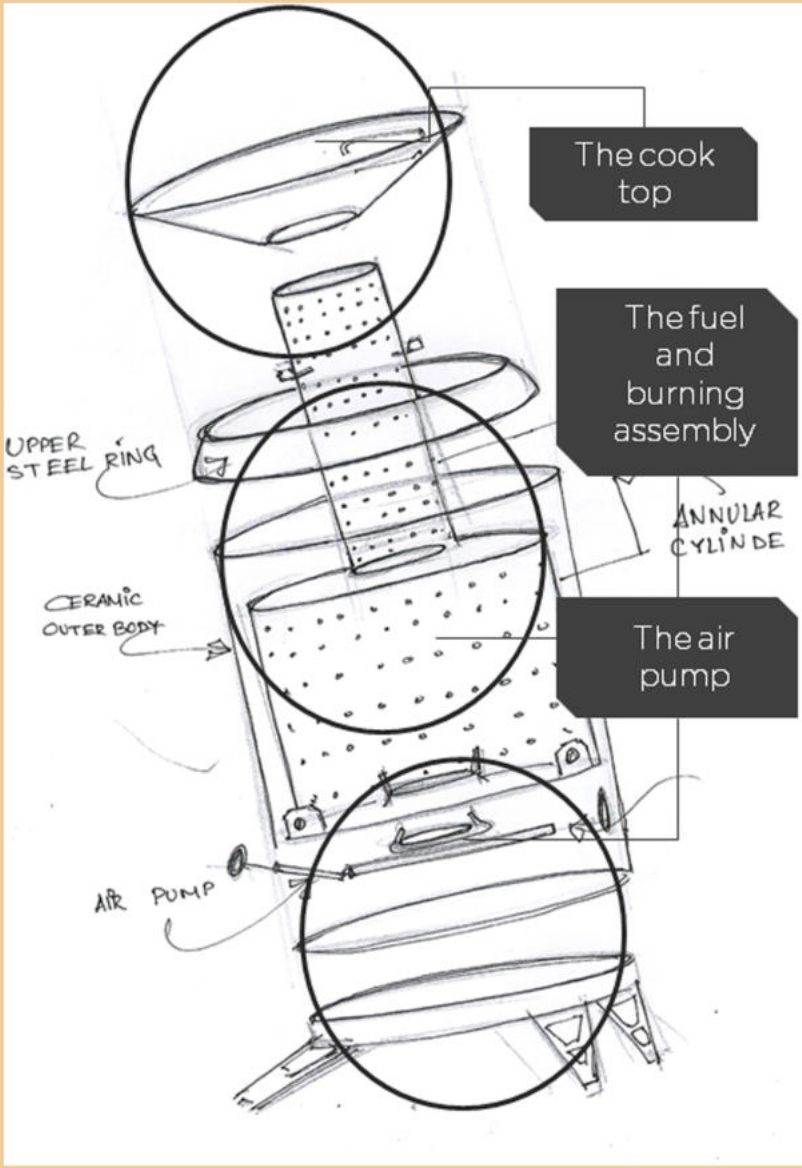
Below it is the forced air assembly.

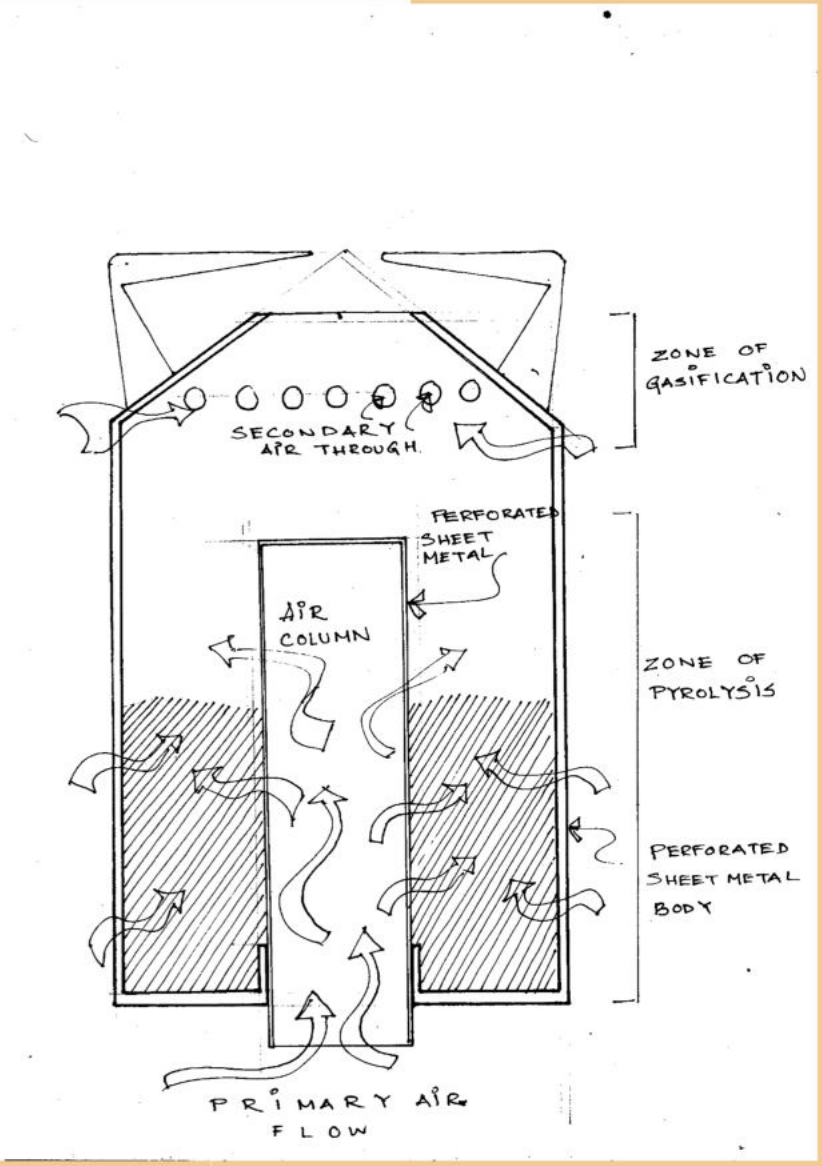
The chulha is divided into three parts

The fuel and burning assembly

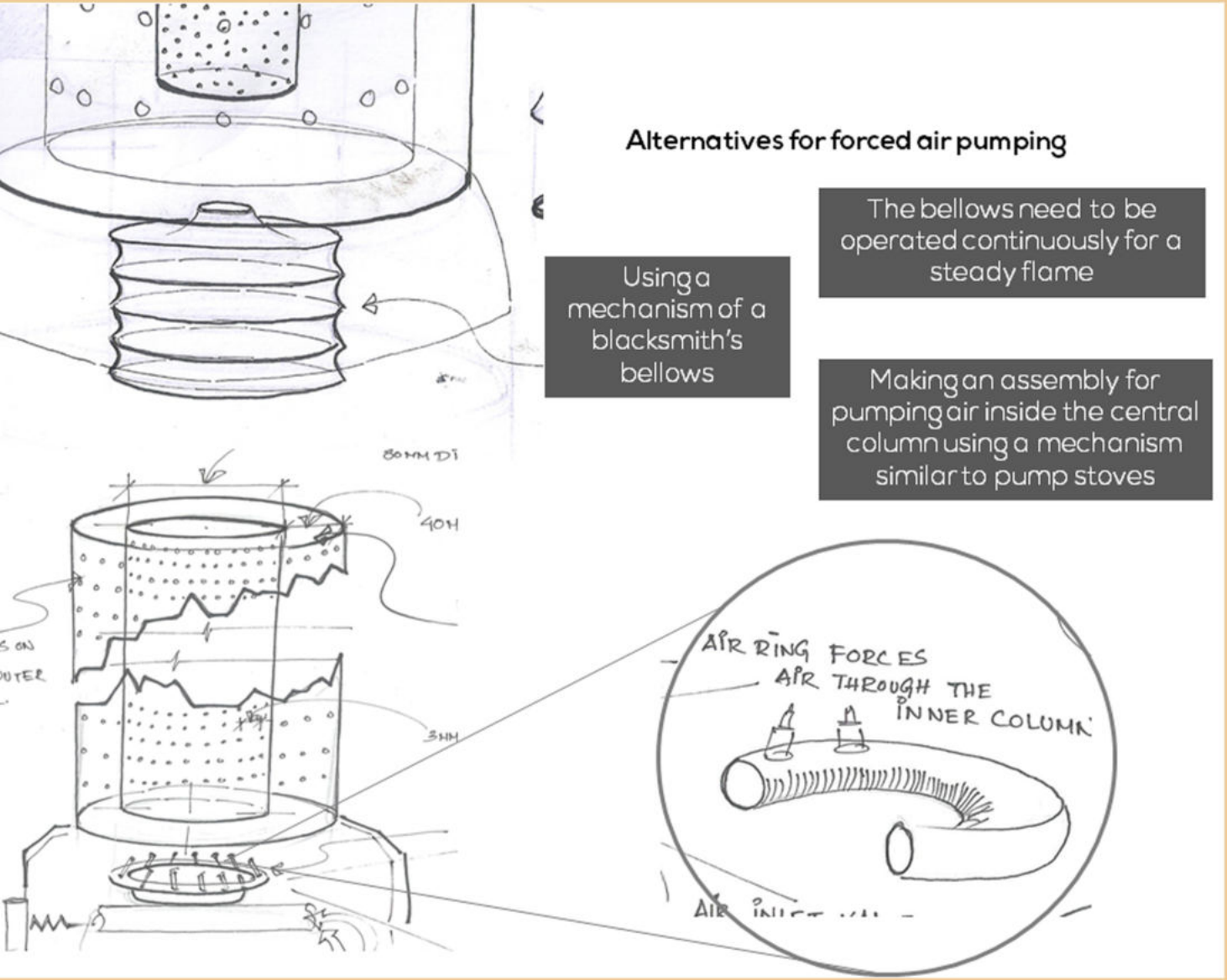
The cook top

The air pump


The cook top
The fuel and burning assembly
The air pump
UPPER STEEL RING
ANNULAR CYLINDE
CERAMIC OUTER BODY
AIR PUMP


ZONE OF GASIFICATION
SECONDARY AIR THROUGH
PERFORATED SHEET METAL
AIR COLUMN
ZONE OF PYROLYSIS
PERFORATED SHEET METAL BODY
PRIMARY AIR FLOW

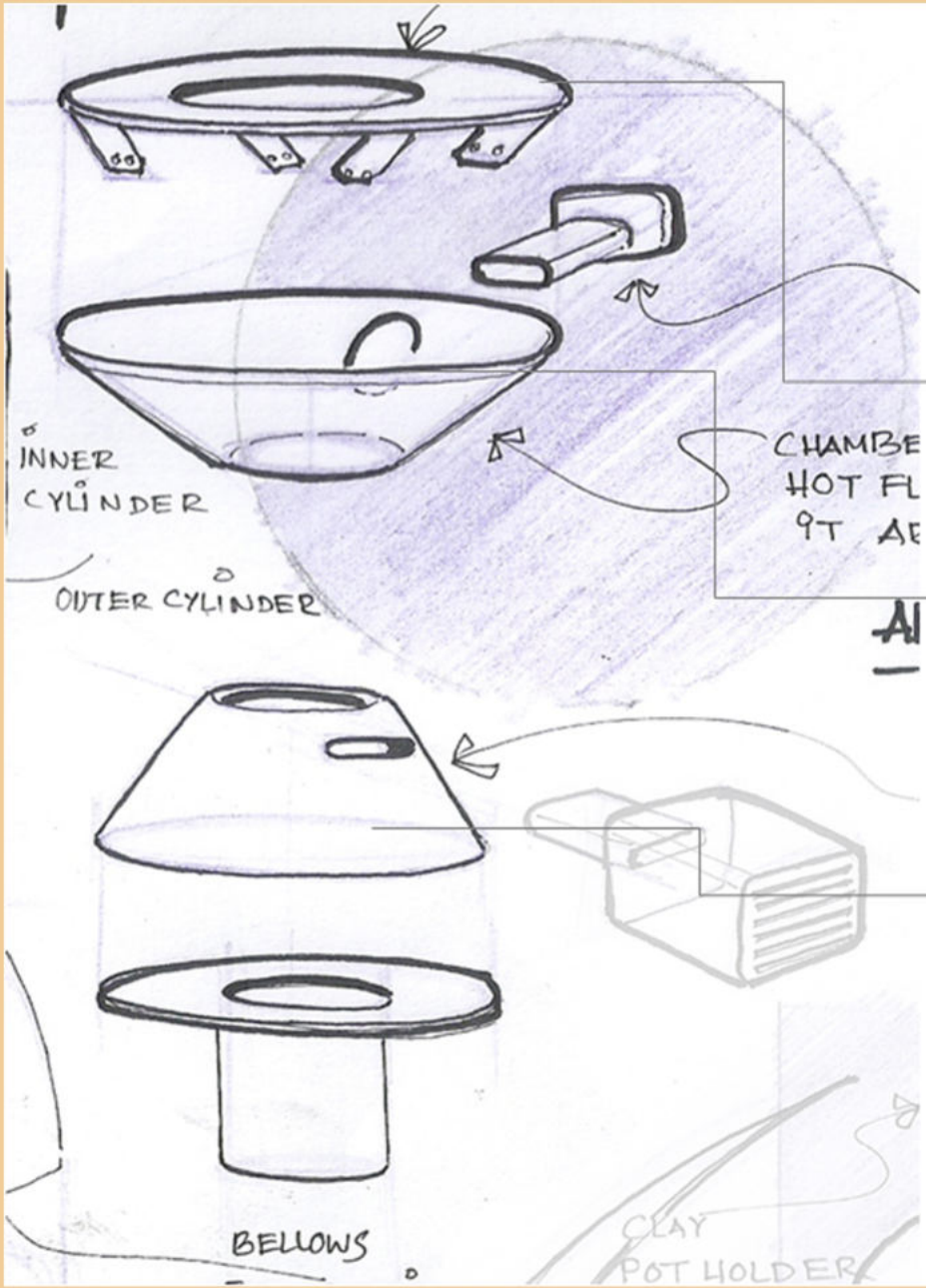

PLUNGER OPERATED BY HAND



Batch loading gasifier stove

Having a stove on the lines of what Dr. Alexis Belonio designed had its own problems. Firstly the tending of flame every 10 minutes was not a task everybody enjoys while cooking. Secondly it has a number of components which increase the complexity of usage and cleaning.

So an idea was to suggest an option where the fuel is loaded in batches for a round of cooking and the stove emptied out after use. Since gasification was desired, some kind of mechanism for pumping air was needed.



Cook top details

The circular cook top is made such it encloses the vessel from the bottom in all directions preventing the loss of hot flue gases

The part fits on top of the inner annular ring, it has a area for eject of the flue gases

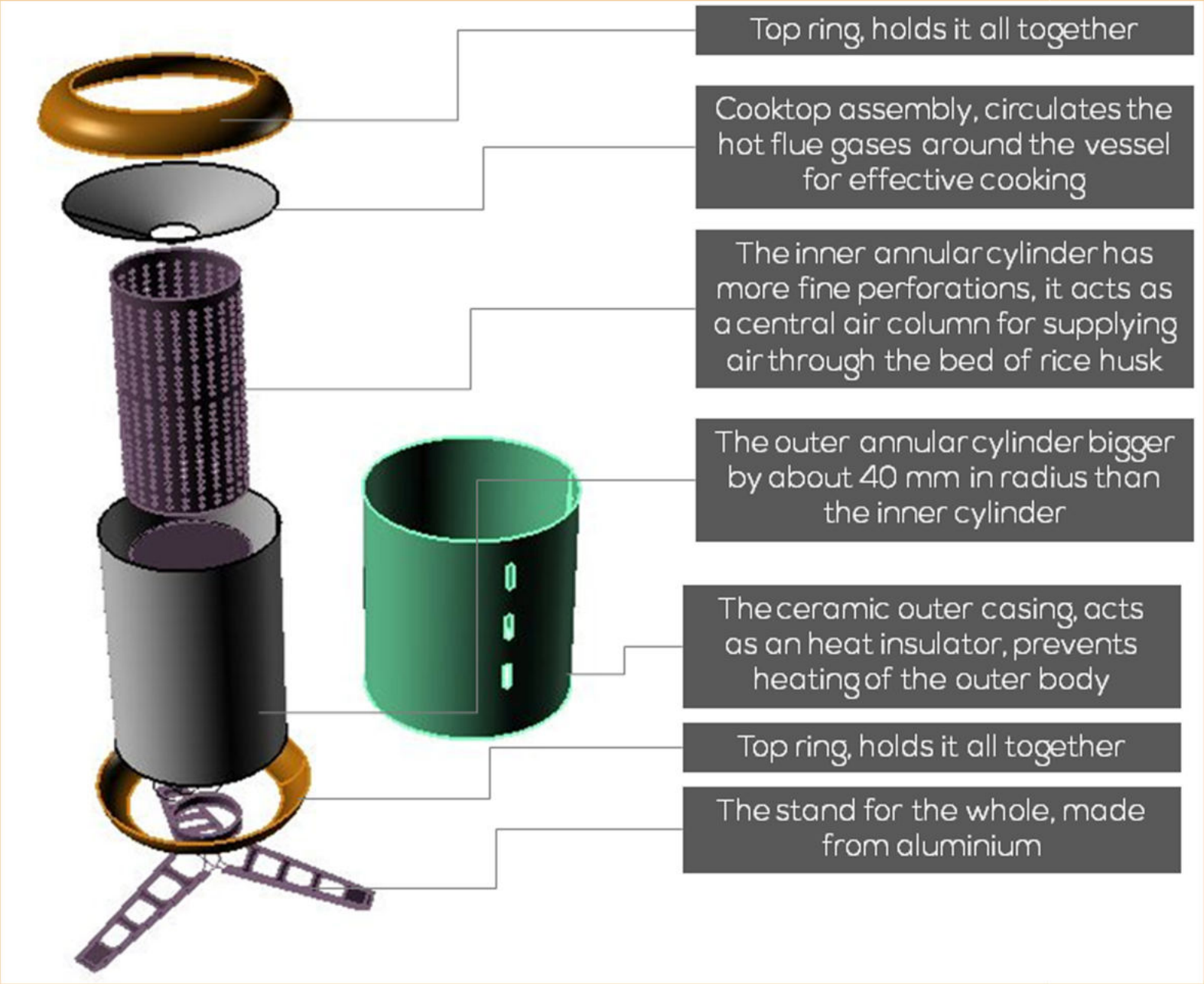
By theory if the area of cross section decreases pressure in fluid increases, so to enhance the up draft action, if this part is reverses as shown in top, the functioning is improved

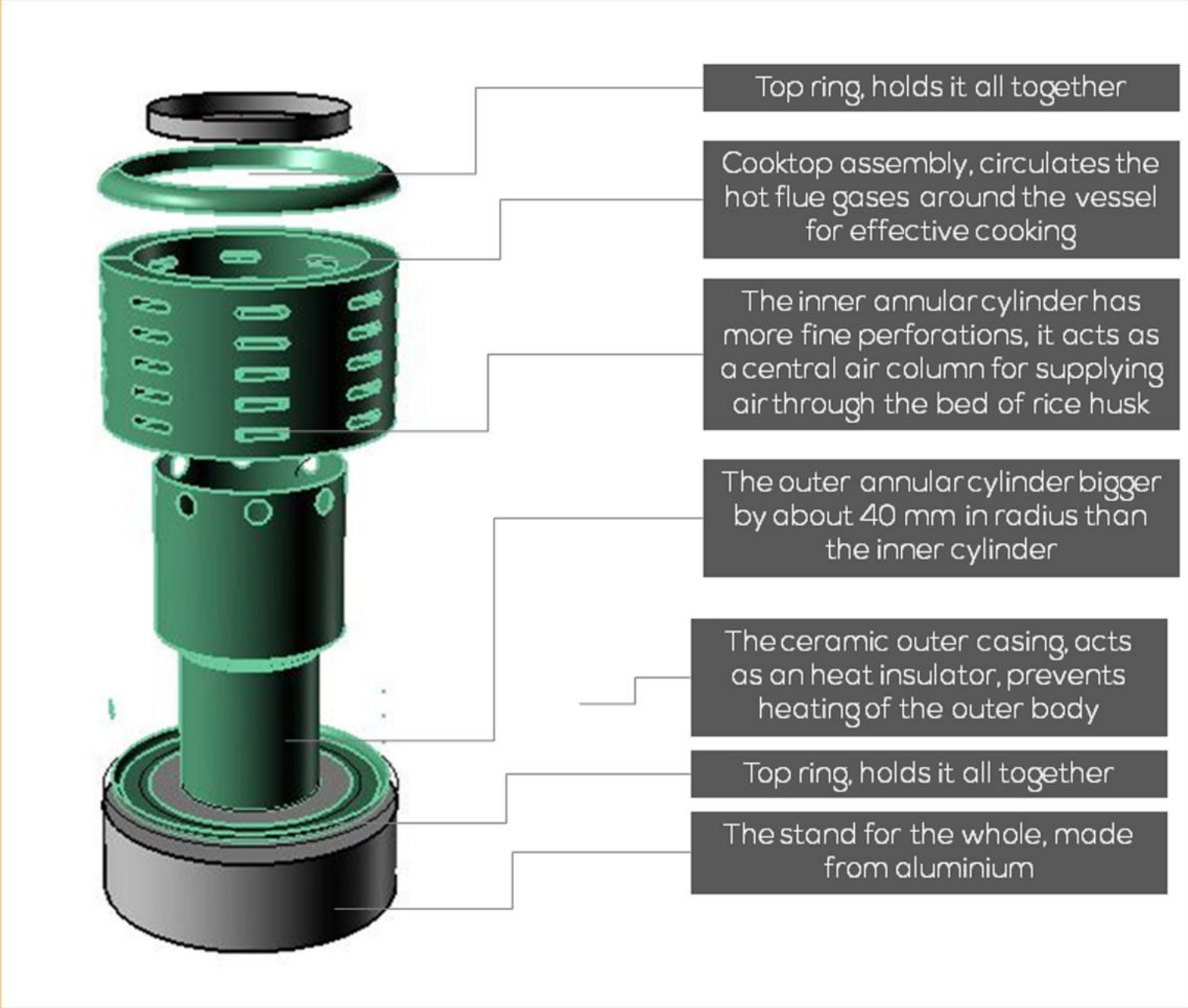
Explorations on the styling


HUSK


RICE HUSK
STOVE
SCALE 1:8


RICE HUSK
STOVE
SCALE 1:8


Top ring, holds it all together
Cooktop assembly, circulates the hot flue gases around the vessel for effective cooking
The inner annular cylinder has more fine perforations, it acts as a central air column for supplying air through the bed of rice husk
The outer annular cylinder bigger by about 40 mm in radius than the inner cylinder
The ceramic outer casing, acts as an heat insulator, prevents heating of the outer body
Top ring, holds it all together
The stand for the whole, made from aluminium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The stand for the whole, made from aluminium

Batch loading gasifier stove

Another mock up model to test the concept was made out of aluminium sheet.
The stove was lit up and allowed to run for 20 minutes and a test was conducted to boil water. Again the char formed choked out the flame and the technique of adding an inner tube for air did not work out.

Why it was not chosen ?

In the idea of the batch operated gasifier stove, the biggest problem was the formation of char at the top. Again if wood chips or sawdust is used they get oxidised due to their loose packing. But in case of rice husk this does not work out.

Since rice husk does not form ash easily and most of the burnt fuel remains in the char state, it became necessary to look into alternatives where two things are satisfied.

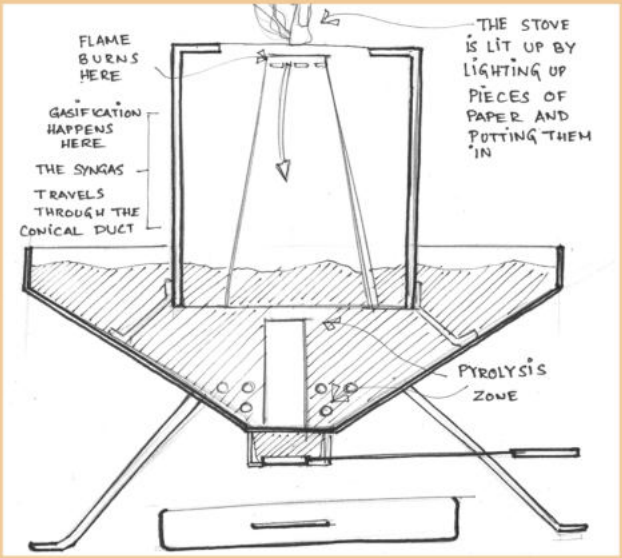
1. The bed of rice husk is thin enough to be permeable to the air outside.

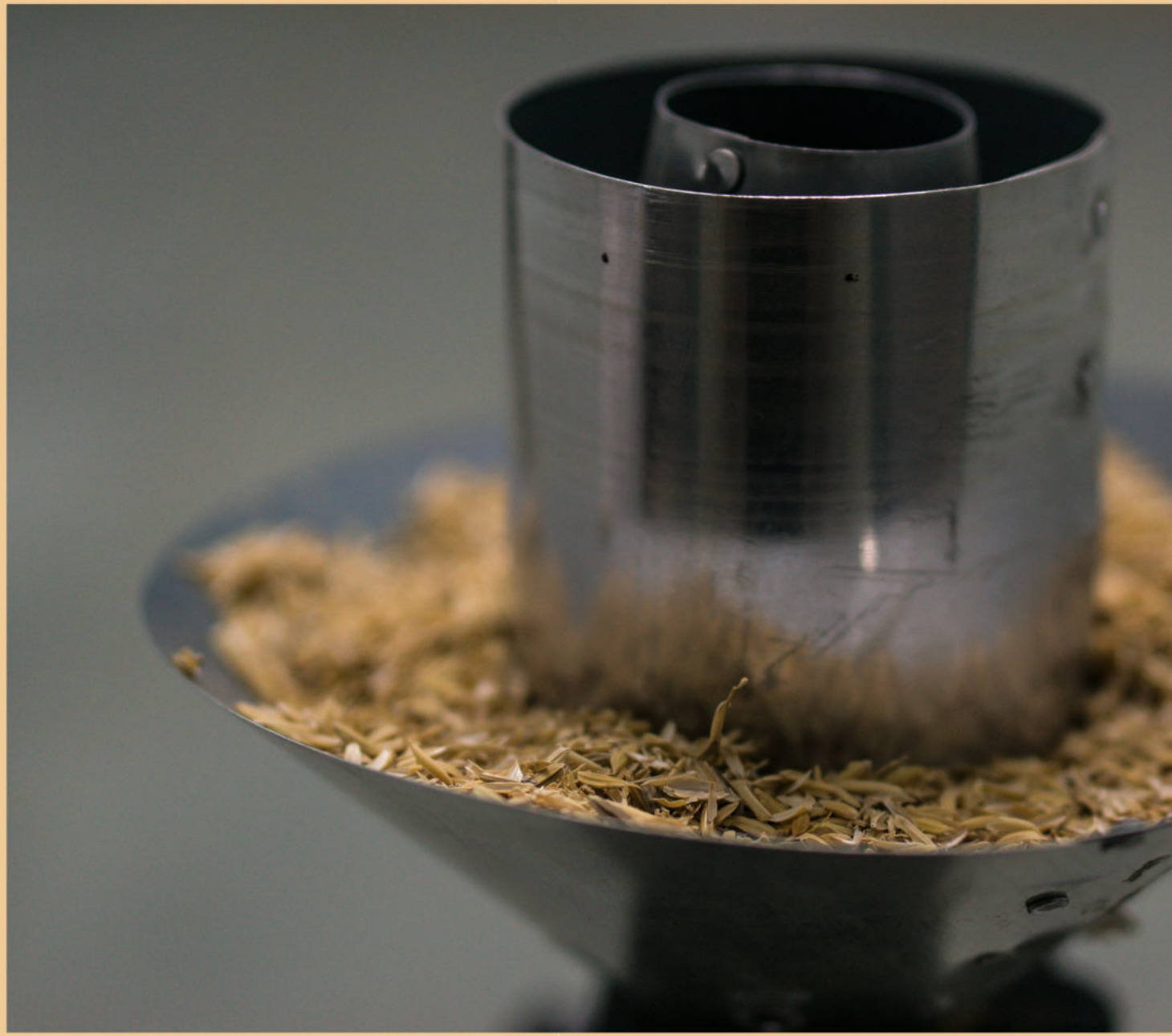
2. No char should be formed at the top where the burning happens.

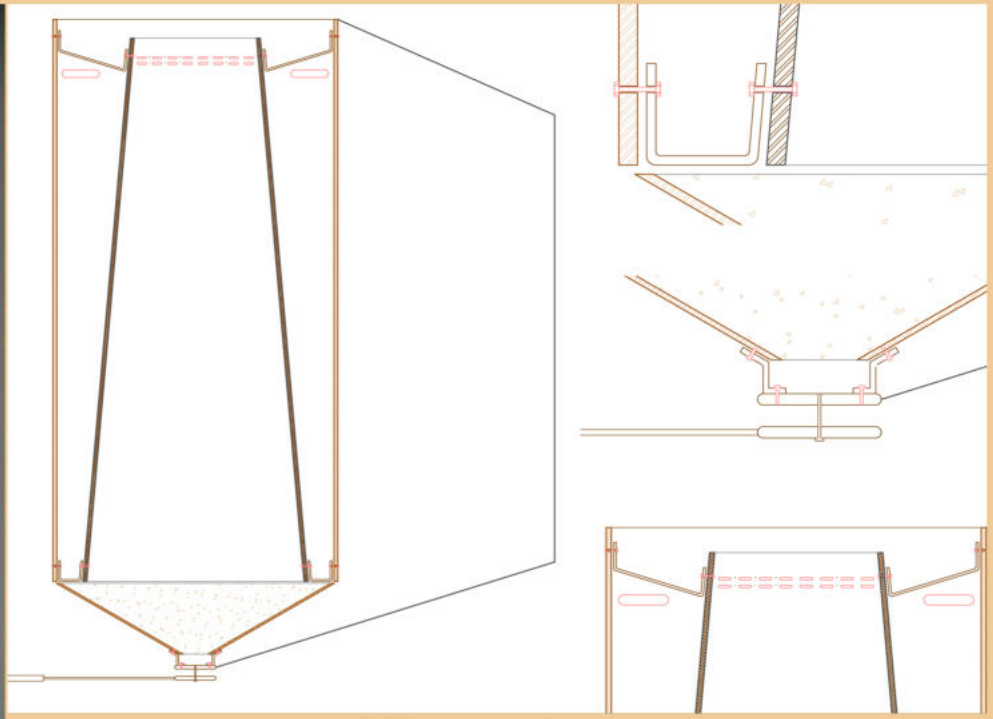
Concept 4

A half scale model of the conical grate stove was made to understand why it performs in case of rice husk.

In the conical grate stove rice husk falls down due to gravity into the narrow conical section which means only a small amount of the rice husk falls down into the reactor, the thickness of the rice husk bed thus being small allows the air outside to flow through it and support combustion



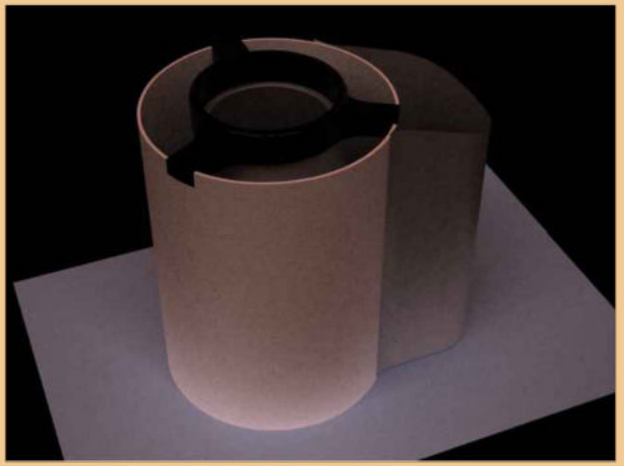


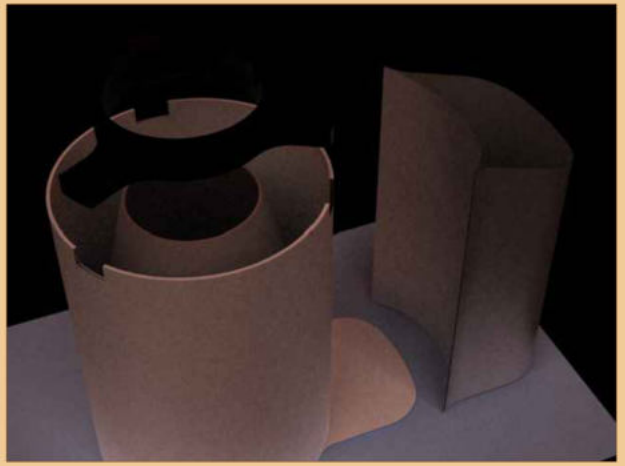


What now ?

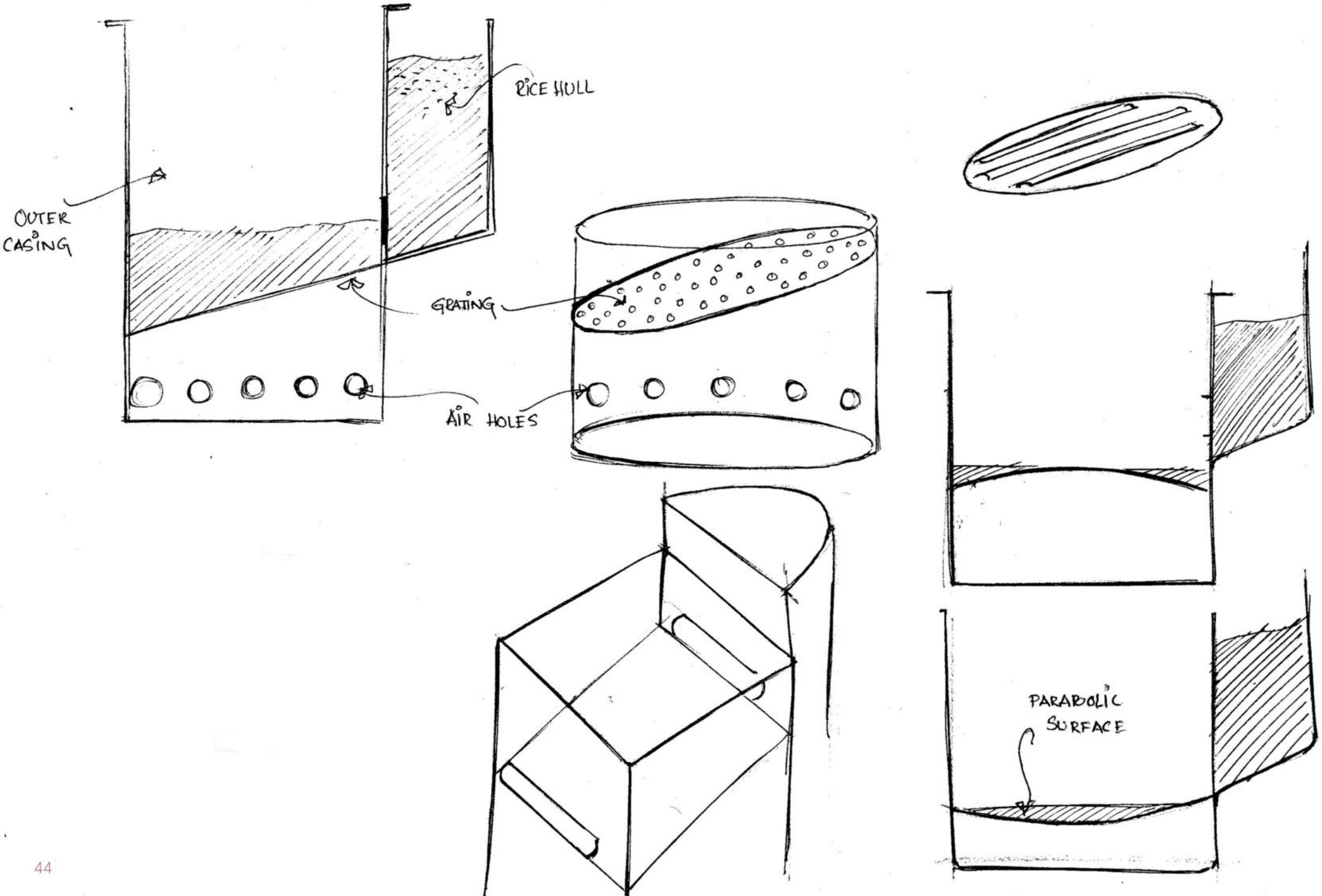
The idea now is to have a reactor with a conical section and a conical hopper below it. The hopper collects fuel from the fuel container at the side of the stove and gradually as more fuel is burnt, fresh fuel falls on its own accord due to gravity and replenishes the fire.

a char disposinglever is provided below the hopper to dispose off the char.



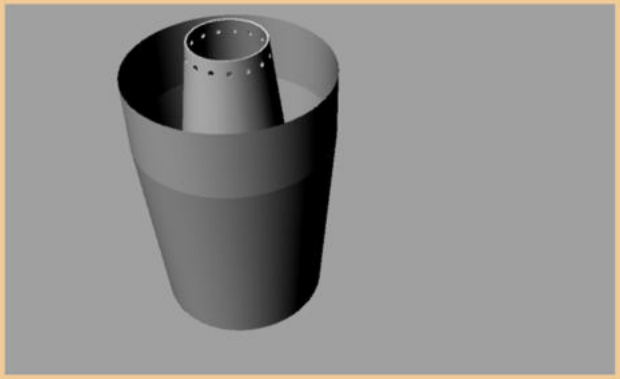


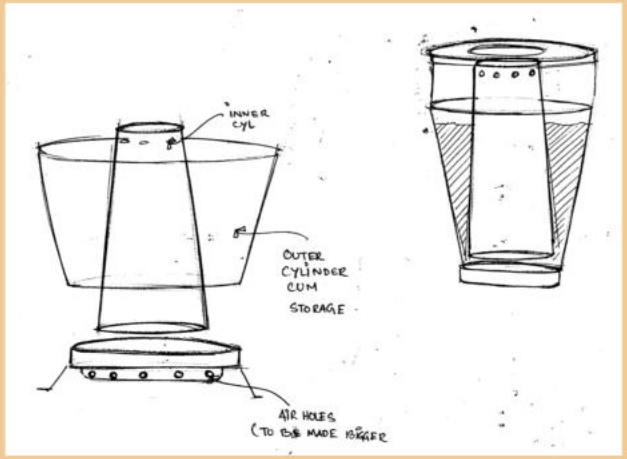
The render above shows the stove body with the side fuel storage attached

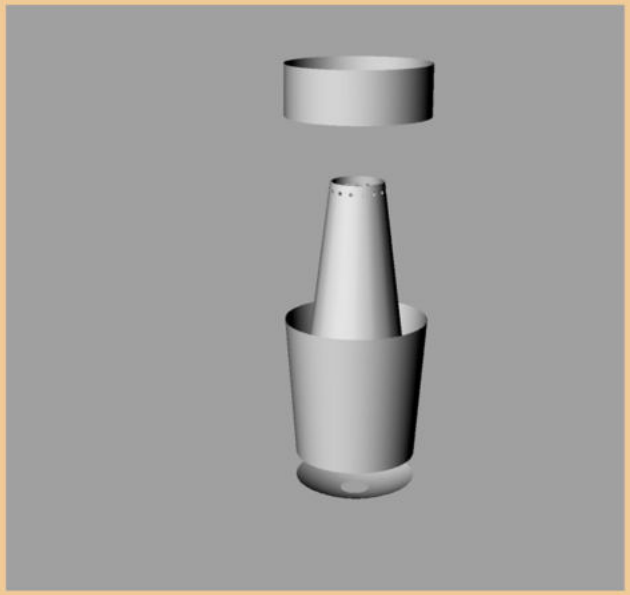

RICE HULL
OUTER CASING
GRATING
AIR HOLES
PARABOLIC SURFACE

Concept 5 (The final concept)

An extension of the concept 4, it is more emphasized on increasing the surface area of the rice husk burning yet maintaining a shallow depth of the rice bed







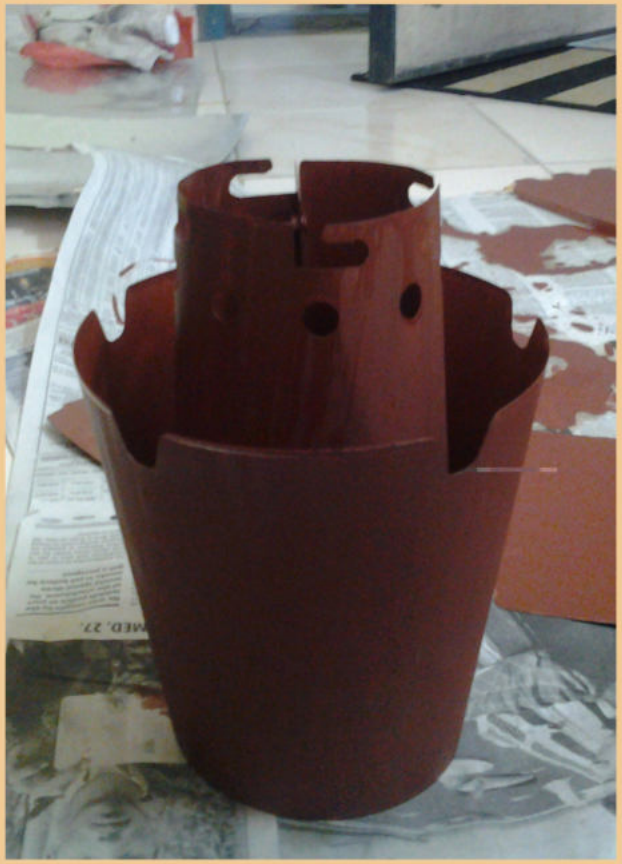
Why this was chosen ?

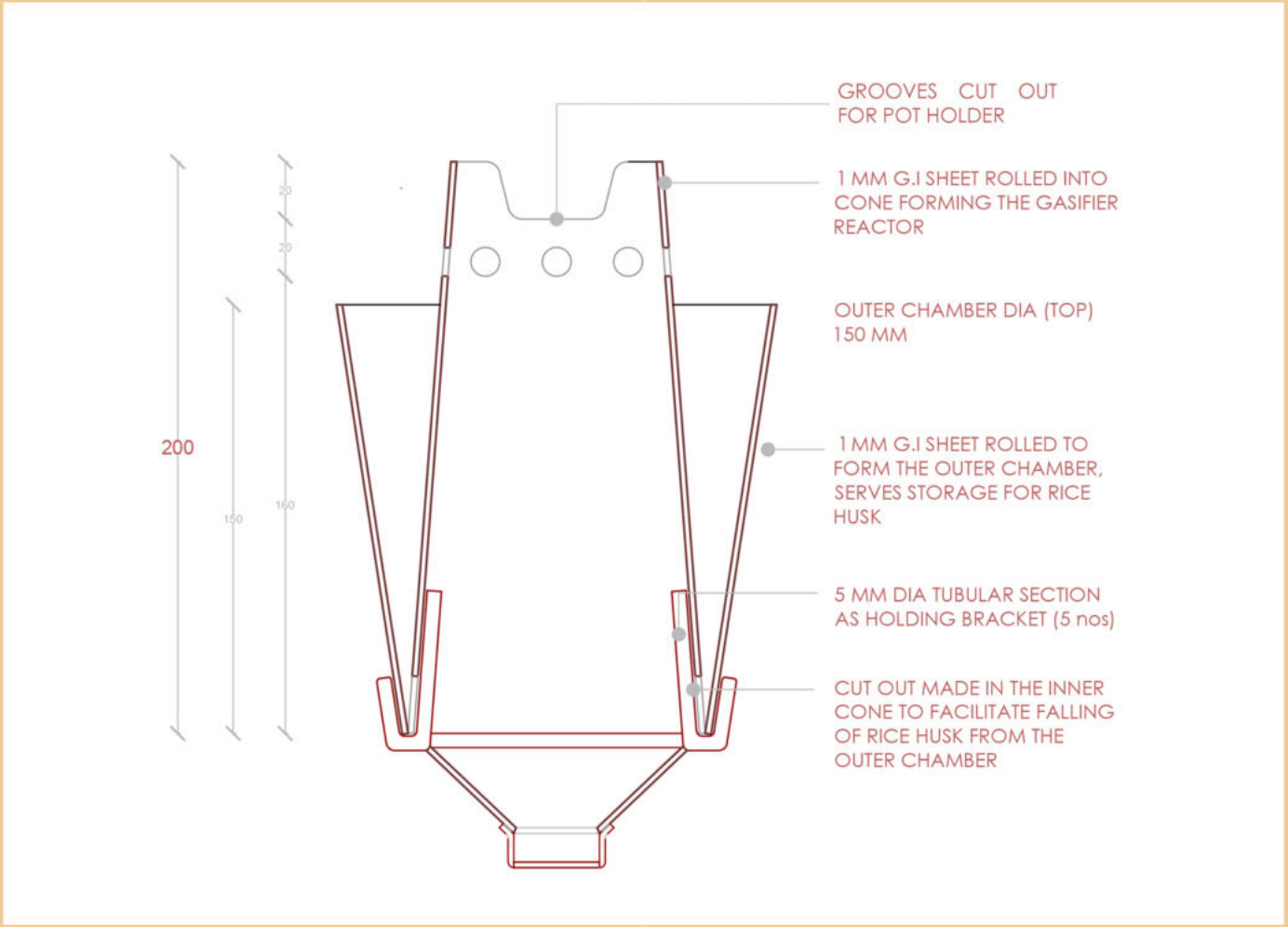
This really solves the problem of the permeability of the rice husk layer to air. Also the outer cylinder itself serves as the storage for the rice husk and feeds it to the hemispherical hopper below. Unlike the batch loading gasifier, this is a coninuous gasifier which ensures that fuel is replenished automatically when needed.

The outer cylinder serves two purposes. Firstly it acts as the storage of the rice husk, Secondly it renders the need of a heat shield layer useless. The rice husk between the reactor cone and the storage zone acts as an insulator against. Also the constant contact of the rice husk with the reactor cone keeps it warm and makes it easier to burn.

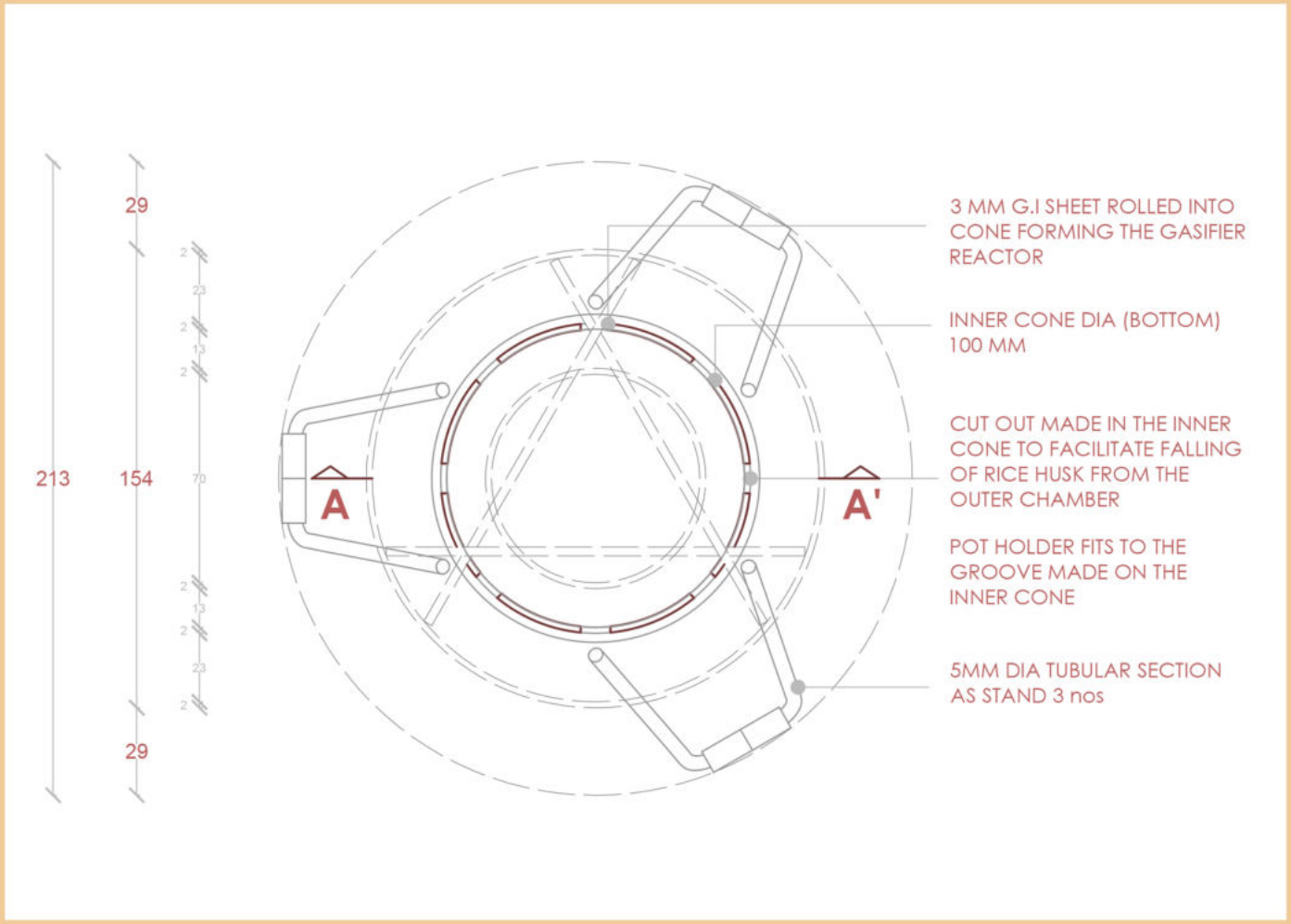
The body

The inner and outer cylinders are made of 1mm thick Galvanized iron sheet since it is cheap and can withstand heat too. The sheet is rolled as per the desired shape and riveted or clipped to keep it in shape.





The cylinders are fitted to the stand made of 5mm rod or pipe section. Rice husk falls by gravity into the conical part at the bottom fitted to the stand.



The stand

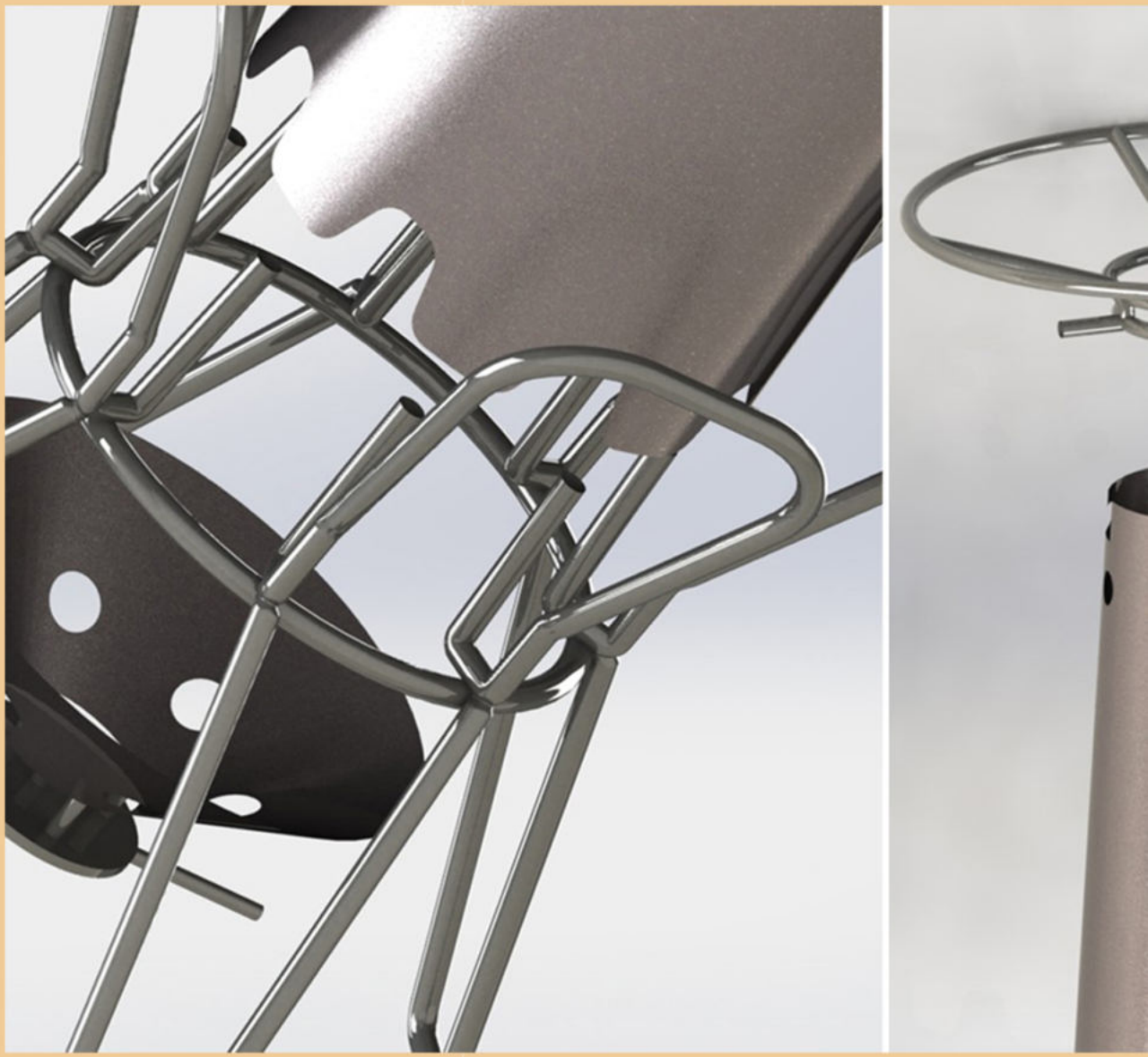
The stand made of 5mm steel rods or tubular section form the skeleton to which the other parts attach.

The cooktop

The cooktop is made from 5mm dia steel rods and made to follow the curved bottom profile of the Indian utensils, which provides more contact area to the vessel and the stove.
The cooktop fots on top of the inner cylinder which is provided with grooves on which it locks onto.

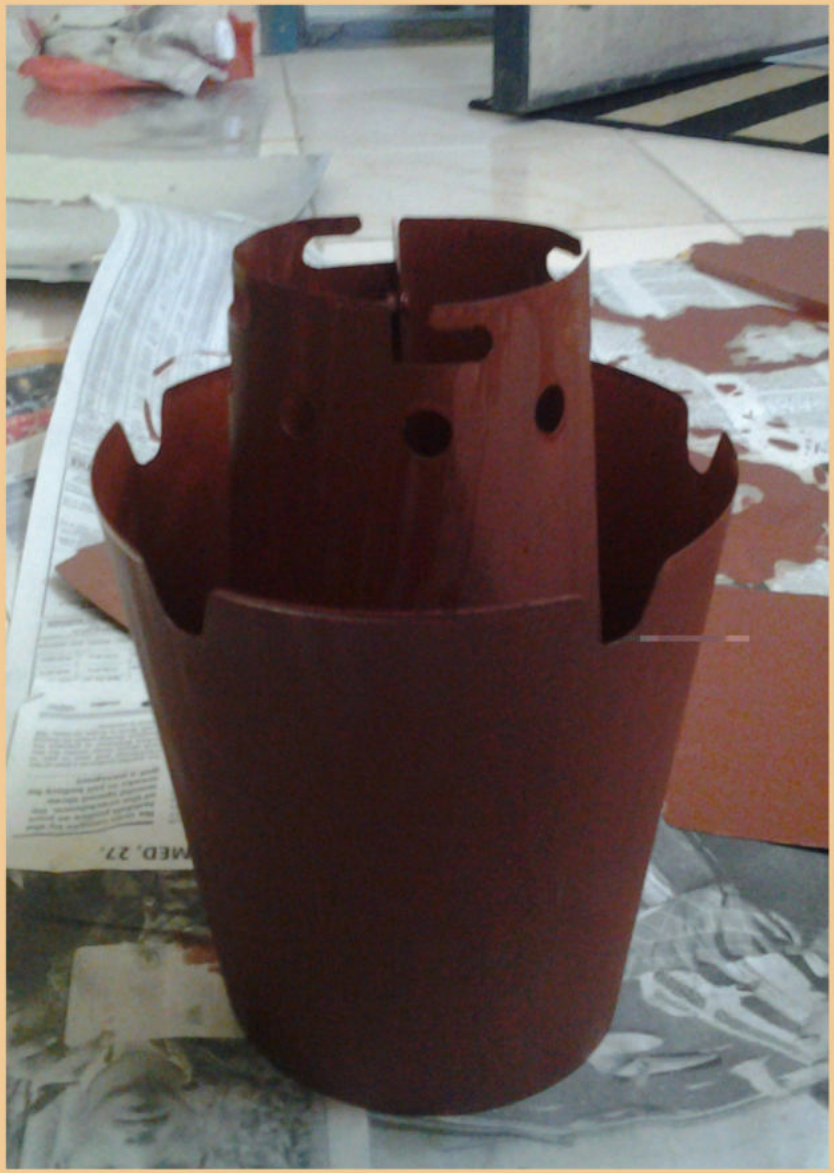
The lower cone and ash discharge lever

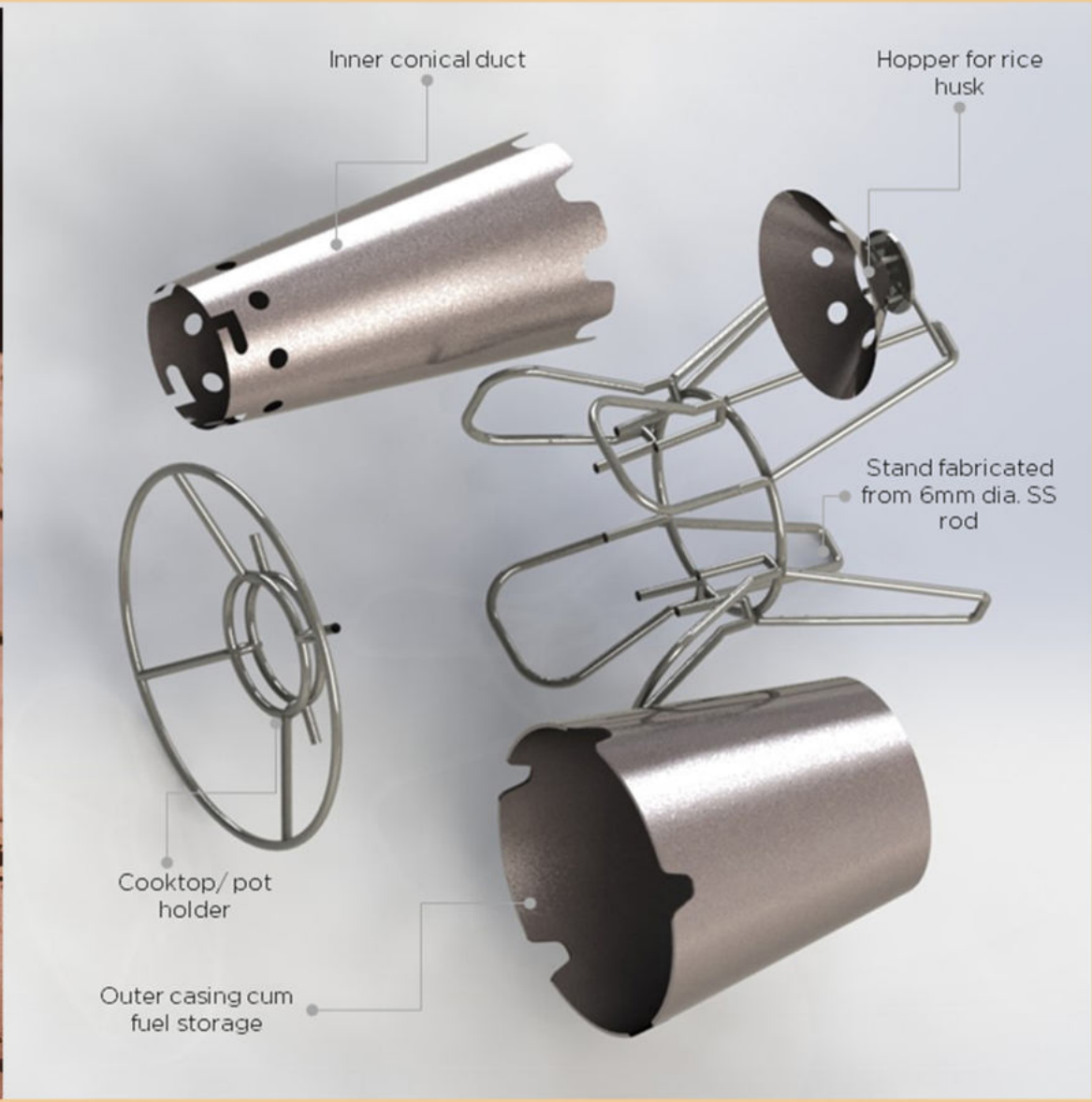
The lower cone is the zone where the rice husk undergoes pyrolysis. It is provided with air holes and an ash discharge lever for tapping out the ash. The ash discharge lever works in a manner similar to a corkscrew, where it can be turned in either direction to dispose off ash. The slits present in the inner cone allow the stored rice husk in the outer cone to fall into the lower cone.



The stove

The computer generated image below shows the completed stove.




Inner conical duct
Hopper for rice husk
Stand fabricated from 6mm dia. SS rod
Cooktop/ pot holder
Outer casing cum fuel storage

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All images have been referenced wherever used from other sources