DESIGN AND DEVELOPMENT OF RICE HUSK GASIFYING CHAMBER FOR PADDY RICE PARBOILING

BY

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MATRIC. NO, 2005/21598EA

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

JANUARY, 2011.

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B, ENG) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

JANUARY, 2011.

CERTIFICATION

This is to certify that the project entitled "Design and Development of Rice Husk Gasifying Chamber for Paddy Rice Parboiling" by Eluwa, Joseph Chigozie meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

Engr.Dr. Gbabo Agidi Supervisor	25/01/2011 Date
Engr. Dr. A.A. Balami Head of Department	26-01-11 Date
External Examiner	13/01/2011 Date

DEDICATION

This Project is dedicated to Almighty God the author and finisher of my faith because of his love, care, support, strength, wisdom, guidance, provision, protection, safety and for seeing me through my degree program. I also dedicate it to my parents Mr and Mrs M.U Eluwa and to all beloved Brothers Uchechi, Chidiebere, Chukwuma, Uzoije and to my Sisters Oluchi, Amarachi and Iheanyichukwu

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thank the Ancient of days for his love, grace, mercy and compassion, for he is the one who gave me life, wisdom and understanding to be able to carry out this project. Glory and honour be o His name.

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will also acknowledge with thanks the effort of all those who helped me in making my undergraduate program a success.

My sincere gratitude goes to my parents Mr. & Mrs M U. Eluwa, my sisters Mrs H A. Jayeola and her Husband, Mrs C.I. Sunday and brothers Uchechi, Chidiebere, Chukwuma, and Uzoije may the God continually bless, uphold and enrich you. Thank you.

also wish to acknowledge the effort of my friends Ediri, Tinia, Gabriel and Ifeanyi.

Finally I will like to thank all my well wishers, and others too numerous to mention, I appreciate you for all your support. Thank you and may God bless you.

ABSTRACT

this study, a rice husk gasifier machine was designed, developed and tested. Following andard engineering principles the machine was designed and developed. Due to the ıvironmental pollution resulting from the indiscriminate dumping of by-product of milling in igeria, the machine was developed to proffer solution to the problem caused by rice husk. The achine comprises of a hopper, burner, reactor cylinder, char chamber and the fan housing. The ısification process of the machine follows the principle of forced air provided by the fan which ıvolves the rotation of the fan blade by an electric motor or a diesel engine at a speed of about 450rpm through pulley and belt. The husk is lighted with fire, air is blown into the reactor ırough the fan to the husk which is in a whole form and it is gasified through the air forced into by the fan and the atmospheric air from the secondary holes around the burner for proper xygenation. The performance of the machine was evaluated after it was tested the result shows ıat the machine is 65% efficient. The product from this machine could be used as a raw material ı cement and fertilizer processing industries. The machine can be employed to reduce nvironmental pollution by enhancing the process of burning of rice husk. The efficiency of the eactor or gasifier could be increased, if connected to a continuous flow of rice husk source that ill enhance faster loading and eases the operator from the stress of manual loading.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Energy is considered the basis for the progress and prosperity of any nations and society. It is also the cornerstone of economic development. The combustion of coal and biomass fuel can decrease emission of fossil CO_2 in order to meet an increasing Demand for energy, alternative energy sources like biomass must be use effectively. In Nigeria. Fuel wood is by far the most widely used household and industries as in other developing countries. Report shows that about 80 - 90% Nigeria's population, most especially the rural and the semi urban dwellers greatly rely on wood for their cooking and heating.

A huge quantity of agro-residues is produced in the country but they are used In-efficiently causing extensive pollution to the environment. The major residues are rice husk, rice straw, sawdust, bagasse; groundnut shells, etc. Apart from the problems of transportation, storage and handling, the direct burning of loose biomass in the enviroment is greatly associated with a very low thermal efficiency low bulk density. Higher moisture content and widespread in pollution. Report shows that in developing Countries energy from biomass continues to be the main source of energy, mostly in its traditional forms designed to meet demands of domestic use. With regard to energy shortage and environmental issues, it is widely accepted that renewable energy will play a major role in the foreseeing year. It has been reported that over 33 percent of energy consumption for developing countries can be supplied from this kind of rice husk. (Markson,2007).

Rice husk is a by-product of milling paddy. It is produced after the paddy passed through the husker and conveyed outside the mill through an aspirator. The amount of rice husks produced in a rice mill depends on the capacity of the milling plant. Large capacity mill usually produces a lot of rice husks per unit hour.

Rice husks may either be whole or ground, depending on the type of husker used. For rice husk gasifier, whole rice husk is better to use in attaining proper gasification. In addition, ground rice husk may require a higher-pressure blower. A kilogram of paddy can produce about 200 grams of rice husks. about 20% of the weight of paddy and this may vary in few percent, depending on the variety of rice. Therefore, a 1-ton paddy per hour rice mill is capable of producing 200 kg of rice husks per hour. For a day long operation of 10 hours, a total of 2 tons of rice husks can be produced. Several reports have shown that rice husks leaving the mill energy source (Alexis, 2005.)

1.2 Objectives of the Study

The objectives of this project include the following:

1) To construct a machine that will substitute the use of firewood thus aiding forest preservation.
2) To construct a machine that will substitute the use of electricity and gas for rice parboiling in rural areas.
3) To construct a machine that will aid waste management using rice husk and other agricultural waste.
4) To construct a machine that is not bogus and will reduce losses.

1.3 **Justification of the Study**

A successful agricultural processing requires optimum cleaning of the crop for consumption and proper handling of its wastes. The construction of this gasifier is to help manage the waste of agricultural produce within the surrounding where they are processed and to help solve the problem of rice parboiling. Some methods of heat sources for rice parboiling include : the use of electricity, gas, coal and firewood. The use of this machine will help to improve electricity supply in rural and urban areas, save cost of electricity payment and gas purchase as well as coal, above all to solve the problem of deforestation in the country by reducing the level of felling of forest trees and using rice husk in place of firewood in rice parboiling.

1.4 **Scope of the Study**

The project scope covers the design, fabrication and testing of a gasifier for agricultural waste management and solving the problem of deforestation through the interchangeability of wood with rice husk gasifier to improve rice parboiling.

CHAPTER TWO

2.0 LITERATURE REVEIW

2.1 COAL

Coal is the world's most plentiful fossil fuel. It is a mineral formed from the remains of land-based plants buried hundreds of millions of years ago and subjected to tremendous heat and pressure. Coal consists of a complex range of materials and varies greatly in quality from deposit to deposit, depending on the varying types of vegetation from which the coal originated, the temperatures and pressures exerted on the deposit, and the length of time the coal has been forming.

Coal is a dark, combustible material formed, through a process known as coalification, from plants growing primarily in swamp regions. Layers of fallen plant material accumulated and partially decayed in these wet environments to form a spongy, coarse substance called peat. Over time, this material was compressed under sand and mud, and heated by the earth to be transformed into coal. Some scientists refer to coal as sedimentary rock. Coal is primarily composed of carbon, hydrogen, oxygen and nitrogen.

There are several classifications of coal, which are rated according to their carbon content and heating value. The heating value of coal is expressed in BTUs per pound

2.2 Coal as fusil fuel

Fossil fuels are derived from plant and animal matter. They formed naturally over millions of years. These energy-producing fuels are the remains of ancient life that have undergone changes due to heat and pressure. The primary fossil fuels are coal, petroleum and natural gas. Together they account for 85% of the world's energy consumption

2.3 How we get Energy from Coal

The energy in coal originally came from the sun. Millions of years ago plants used this energy for chemical transformations necessary to growth, and carbon dioxide from the air was built into carbon compound that become coal.

The way we release this energy from the coal is by means of heat. Heat makes atoms and molecules move faster and faster, until some of the electrons jump out of them. When coal is burned, it supplies heat energy. The energy was there all the time in a form we call potential energy. The heat releases the stored energy and changes it into kinetic, or working energy. This is the energy that is used to drive the engines and generators that work for us.

2.4 Releasing Coal's Energy

The process of converting coal into electricity has multiple steps and is similar to the process used to convert oil and natural gas into electricity:

1. A machine called a pulverizer grinds the coal into a fine powder.
2. The coal powder mixes with hot air, which helps the coal burn more efficiently, and the mixture moves to the furnace.
3. The burning coal heats water in a boiler, creating steam.
4. Steam released from the boiler powers an engine called a turbine transforming heat energy from burning coal into mechanical energy that spins the turbine engine.

5. The spinning turbine is used to power a generator, a machine that turns mechanical energy into electric energy. This happens when magnets inside a copper coil in the generator spin.
6. A condenser cools the steam moving through the turbine. As the steam is condensed, it turns back into water.
7. The water returns to the boiler, and the cycle begins again

2.5 Coal Uses

Coal is used to generate heat, produce electricity, and make steel and industrial products. It is used worldwide as a fuel, second only to petroleum as the most consumed energy resource. Simple burning of coal produces heat for homes and industries. Coal is a major fuel for producing electricity. The coal is burned to turn water into steam. The steam turns the blades of a turbine, which drives a generator to produce electricity.

Coal is used for approximately 50% of the U.S. electricity production and 40% of the world's electricity.

2.6 Direct Combustion of Biomass

Most biomass is in solid form and can be burned (combusted with oxygen in air). The combustion process results in the generation of heat (thermal energy) the same way that burning coal gives off heat. The heat generated by the burning of biomass can be used for space heating (e.g., heating of buildings), for cooking, and for heating water. It can also be used to boil water to generate steam, which in turn is used to run a turbine and electric generator to produce electricity in the same way that coal is used to generate electricity in a coal-fired power plant. The biomass may need a certain amount of processing before burning (e.g., sorting, drying, and size reduction). It may also be mixed with coal or other types of fuel in the furnace.

2.7 Charcoal Production from Biomass and Combustion

2.7.1 WOOD

Wood is a tough substance found under the bark of trees and shrubs. There are two main categories for wood classification, hard wood and soft wood. Hard woods are deciduous trees or wide leafed trees, while soft woods are coniferous trees, which are cone bearing evergreens. Soft woods are used for construction and making paper products, while hard woods are used for producing furniture and housing materials. Hard woods are normally denser than soft woods. Every species of wood has a different pattern or design by which to distinguish it by. Wood consists of many things, 50% cellulose, 15%-30% hemicelluloses, 15%-30% lignin, and 5%-30% ash and other extractives. Denser hard woods are more likely to burn slower and hotter than less dense soft woods. Another thing is that hard woods are more likely to be more difficult to ignite because of they contain less oxygen.

Wood normally contains chemicals that volatilize when they are heated. During the combustion of wood in air, most of this volatile matter oxidizes and contributes to the energy being released in the combustion process. However, when wood is heated in the absence of air or oxygen, the volatile matter is driven off of wood in a process called pyrolysis, and the remaining matter is called charcoal. Charcoal is almost pure carbon, with about twice the energy content per unit mass as the original wood. Therefore, it can burn at much higher temperatures than wood. However, it takes about 4 to 10 kg of wood to make 1 kg of charcoal. In addition, if the volatile gases driven off from the wood during pyrolysis are not collected and used, they contribute to greenhouse gas emissions.

2.8 Charcoal Briquette

2.8.1 Background

Charcoal is a desirable fuel because it produces a hot, long-lasting, virtually smokeless fire. Combined with other materials and formed into uniform chunks called briquettes, it is popularly used for outdoor cooking in the United States. According to the barbecue Industry Association, Americans bought 883,748 tons of charcoal briquettes in 1997.

Basic charcoal is produced by burning a carbon-rich material such as wood in a low-oxygen atmosphere. This process drives off the moisture and volatile gases that were present in the original fuel. The resulting charred material not only burns longer and more steadily than whole wood, but it is much lighter (one-fifth to one-third of its original weight).

2.9 History

Charcoal has been manufactured since pre-historic times. Around 5,300 years ago, a helpless traveller perished in the Tyrolean Alps. Recently, when his body was recovered from a glacier, scientists found that he had been carrying a small box containing bits of charred wood wrapped in maple leaves. The man had no fire-starting tools such as flint with him, so it appears that he may have carried smoldering charcoal instead.

As much as 6,000 years ago, charcoal was the preferred fuel for smelting copper. After the invention of the blast furnace around 1400 A.D. , charcoal was used extensively throughout

Europe for iron smelting. By the eighteenth century, forest depletion led to a preference for coke (a coal-based form of charcoal) as an alternative fuel.

Plentiful forests in the eastern United States made charcoal a popular fuel, particularly for blacksmithing. It was also used in the western United States through the late 1800s for extracting silver from ore, for railroad fuelling, and for residential and commercial heating.

Charcoal's transition from a heating and industrial fuel to a recreational cooking material took place around 1920 when Henry Ford invented the charcoal briquette. Not only did Ford succeed in making profitable use of the sawdust and scrap wood generated in his automobile factory, but his sideline business also encouraged recreational use of cars for picnic outings. Barbecue grills and Ford Charcoal were sold at the company's automobile dealerships, some of which devoted half of their space to the cooking supplies business.

Historically, charcoal was produced by piling wood in a cone-shaped mound and covering it with dirt, turf, or ashes, leaving air intake holes around the bottom of the pile and a chimney port at the top. The wood was set afire and allowed to burn slowly; then the air holes were covered so the pile would cool slowly. In more modern times, the single-use charcoal pit was replaced by a stone, brick, or concrete kiln that would hold 25-75 cords of wood (1 cord = 4 ft x 4 ft x 8 ft). A large batch might burn for three to four weeks and take seven to 10 days to cool.

This method of charcoal production generates a significant amount of smoke. In fact, changes in the color of the smoke signal transitions to different stages of the process. Initially, its whitish hue indicates the presence of steam, as water vapors are driven out of the wood.

Basic charcoal is produced by burning a carbon-rich material such as wood in a low-oxygen atmosphere. This process drives off the moisture and volatile gases that were present in the

DECLARATION

I hereby declare that this project work is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

Eluwa, Joseph Chigozie

26/07/2011

Date

original fuel. The resulting charred material not only burns longer and more steadily than whole wood, but it is much lighter (one-fifth to one-third of its original weight).

Resins and sugars burn, the smoke becomes yellowish. Finally the smoke changes to a wispy blue, indicating that charring is complete; this is the appropriate time to smother the fire and let the kiln's contents cool.

An alternative method of producing charcoal was developed in the early 1900s by Orin Stafford, who then helped Henry Ford establish his briquette business. Called the retort method, this involves passing wood through a series of hearths or ovens. It is a continuous process wherein wood constantly enters one end of a furnace and charred material leaves the other; in contrast, the traditional kiln process burns wood in discrete batches. Virtually no visible smoke is emitted from a retort, because the constant level of output can effectively be treated with emission control devices such as afterburners.

2.10 Raw Materials

Charcoal briquettes are made of two primary ingredients (comprising about 90% of the final product) and several minor ones. One of the primary ingredients, known as char, is basically the traditional charcoal, as described above. It is responsible for the briquette's ability to light easily and to produce the desired wood-smoke flavor. The most desirable raw material for this component is hardwoods such as beech, birch, hard maple, hickory, and oak. Some manufacturers also use softwoods like pine, or other organic materials like fruit pits and nut shells. The other primary ingredient, used to produce a high-temperature, long-lasting fire, is coal. Various types of coal may be used, ranging from sub-bituminous lignite to anthracite.

Minor ingredients include a binding agent (typically starch made from corn, milo, or wheat), an accelerant (such as nitrate), and an ash-whitening agent (such as lime) to let the backyard barbecuer know when the briquettes are ready to cook over.

2.11 The Manufacturing Process

The first step in the manufacturing process is to char the wood. Some manufacturers use the kiln (batch) method, while others use the retort (continuous) method.

2.12 Charring the wood

1. (Batch process) It takes a day or two to load a typical-size concrete kiln with about 50 cords of wood. When the fire is started, air intake ports and exhaust vents are fully open to draw in enough oxygen to produce a hot fire. During the week-long burning period, ports and vents are adjusted to maintain a temperature between about 840-950° F (450-510° C). At the end of the desired burning period, air intake ports are closed; exhaust vents are sealed an hour or two later, after smoking has stopped, to avoid pressure build-up within the kiln. Following a two-week cooling period, the kiln is emptied, and the carbonized wood (char) is pulverized.
2. (Continuous process) Wood is sized (broken into pieces of the proper dimension) in a hammer mill. A particle size of about 0.1 in (3 mm) is common, although the exact size depends on the type of wood being used (e.g., bark, dry sawdust, wet wood). The wood then passes through a large drum dryer that reduces its moisture content by about half (to approximately 25%). Next, it is fed into the top of the multiple-hearth furnace (retort). Externally, the retort looks like a steel silo, 40-50 ft (12.2-15.2 m) tall and 20-30 ft (6.1-9.14 m) in diameter. Inside, it contains a stack of hearths (three to six, depending on the

desired production capacity). The top chamber is the lowest-temperature hearth, on the order of 525° F (275° C), while the bottom chamber burns at about 1,200° F (650° C). External heat, from oil-or gas-fired burners, is needed only at the beginning and ending stages of the furnace; at the intermediate levels, the evolving wood gases burn and supply enough heat to maintain desired temperature levels. Within each chamber, the wood is stirred by rabble arms extending out from a centre shaft that runs vertically through the entire retort. This slow stirring process

(1-2 rpm) ensures uniform combustion and moves the material through the retort. On alternate levels, the rabble arms push the burning wood either toward a hole around the central shaft or toward openings around the outer edge of the floor so the material can fall to the next lower level. As the smoldering char exits the final chamber, it is quenched with a cold-water spray. It may then be used immediately, or it may be stored in a silo until it is needed. A typical retort can produce approximately 5,500 lb (2.5 metric tons) of char per hour.

2.13 Carbonizing the coal

3. Lower grades of coal may also be carbonized for use in charcoal. Crushed coal is first dried and then heated to about 1,100° F (590° C) to drive off the volatile components. After being air-cooled, it is stored until needed.

2.14 Briquetting

4. Charcoal, and minor ingredients such as the starch binder are fed in the proper proportions into a paddle mixer, where they are thoroughly blended. At this point, the

material has about 35% moisture content, giving it a consistency somewhat like damp topsoil.

5. The blended material is dropped into a press consisting of two opposing rollers containing briquette-sized indentations. Because of the moisture content, the binding agent, the temperature (about 105° F or 40° C), and the pressure from the rollers, the briquettes hold their shape as they drop out the bottom of the press.
6. The briquettes drop onto a conveyor, which carries them through a single-pass dryer that heats them to about 275° F (135° C) for three to four hours, reducing their moisture content to around 5%. Briquettes can be produced at a rate of 2,200-20,000 lb (1-9 metric tons) per hour. The briquettes are either bagged immediately or stored in silos to await the next scheduled packaging run.

2.15 **By-products/Waste**

During the late nineteenth and early twentieth century's, recovery of acetic acid and methanol as by-products of the wood-charring process became so important that the charcoal itself essentially became the by-product. After the development of more-efficient and less-costly techniques for synthesizing acetic acid and methanol, charcoal production declined significantly until it was revitalized by the development of briquettes for recreational cooking.

The batch process for charring wood produces significant amounts of particulate laden smoke. Fitting the exhaust vents with afterburners can reduce the emissions by as much as 85%, but because of the relatively high cost of the treatment, it is not commonly used.

Not only does the more constant level of operation of retorts make it easier to control their emissions with afterburners, but it allows for productive use of combustible off-gases. For example, these gases can be used to fuel wood dryers and briquette dryers, or to produce steam and electricity.

Charcoal briquette production is environmentally friendly in another way: the largest briquette manufacturer in the United States uses only waste products for its wood supply. Wood shavings, sawdust, and bark from pallet manufacturers, flooring manufacturers, and lumber mills are converted from piles of waste into useful briquettes.

Rice is the staple food crop and its annual production in India and the world is about 90 and 400 MT respectively. For every paddy processed, about 0.25 ton of paddy husk is generated as a by-product in milling operation (Baruah & Jain, 1998). Its heating value is about 15 MJ/kg which supports its application as an energy source. Thus paddy husk is an important agricultural crop residue having potential as renewable energy source. It can be used via combustion route, alternatively be used via gasification where it can be used to run engines and connecting equipment. Use of paddy husk via gasification will provide efficient and environment friendly use of rice husk as fuel energy. Some references on design of large as well as small capacity rice husk gasifiers are documented in the literature (Jain & Bhatnagar, 1990). However, little attention is paid towards the development of systematic reactor scaling factors or design parameters for a small (3 to 30 kW) as well as large capacity rice husk gasifier systems. The performance data for these gasifiers is also not properly reported. Down draft gasifiers with throat (Imbert type) is known to generate best quality producer gas for engines having minimum tar. An extensive literature review conducted by Kaupp and Goss (1984) failed to find any reference on rice husk gasification in a down draft gasifier with throat. Jain & Bhatnagar 1990 and Pathak & Jain, 1985 also reported that rice husk can not be used as a feed stock in Imbert type gas producers due to material flow problems. It is therefore, necessary that a suitable gasifier for rice husk gasification is developed which is capable of producing clean gas for running IC engines. The gasifier coupled to engine could be used for farm irrigation water lifting and for electricity generation in developing countries.

2.16 Historical Background of the Rice Husk Gasifier Development

The rice husk gas stove development in the Philippines started way back in 1986 when the Department of Agriculture – International Rice Research Institute (DA-IRRI) Program for Small Farm Equipment, headed by Dr. Robert Stickney, developed and introduced the first downdraft rice husk gasifier stove. The potential of this technology as a replacement to the use of wood 184 fuel and wood charcoal for domestic cooking stoves led the Department of Agricultural Engineering, College of Agriculture, Central Philippine University, Iloilo City (DAE-CA-CPU) to further develop a similar technology in 1987. With some problems encountered, especially in the excessive tar produced from the gasification of rice husks, the rice husk gas stove technology was left on hold for a moment. In 2000, with the establishment of the Appropriate Technology Centre (ATC) under the Department, different designs of cooking stoves were developed utilizing rice husk as fuel. Through a collaborative program with The Asian Alliance of Appropriate Technology Practitioner Inc. (APROTECH ASIA) and the Asia Regional Cook stove Program (ARECOP), the Author was given an opportunity to attend the Training on Wood Gasifier Stove at the Asian Institute of Technology in Thailand in 2003. In this training, an Inverted Down-Draft (IDD) or Top-Lit Updraft (TLUD) wood gasifier was demonstrated by a Sri Lankan participant was found promising to be used for rice husks as fuel without experiencing the problems encountered in the previous designs of rice husk gasifier. In the late 2004, a proto-type rice husk gasifier stove following the IDD/T-LUD concept was fabricated as a student project. Performance test and evaluation which were carried out in early 2005, showed that rice husk fuel for IDD/T-LUD gasifier was proven to be a good alternative technology for the conventional LPG stoves. After six months of continued development, a commercial model of the gasifier stove was introduced in the market for utilization.

2.17 EXISTING DESIGNS OF RICE HUSK AND OTHER BIOMASS FUEL GAS STOVE (Alexis 2005)

So far, there are only few designs of rice husk gas stove that were developed in the Philippines and even abroad. The various stoves presented below are the designs that were developed utilizing rice husks and other biomass fuel.

Rice Husk Gasifier Stoves

1. DA-IRRI Rice Husk Gasifier Stove

This stove was developed sometime in 1986 during the DA-IRRI collaborative program on small farm equipment in the Philippines by Dr. Robert Stickney, Engr. Vic Piamonte, as the Author. The stove adopted a double-core downdraft type reactor where rice husks are burned and are gasified starting from the bottom. The gasified fuel is allowed to cool and to condense on a coil inside a water-pipe heat exchanger before it is introduced to the burners. During the process, air is sucked from the reactor and is blown to the burner using an electric blower which is positioned between the reactor and the burner.

The stove has an inner reactor diameter and an outer reactor diameter. A square wire mesh is used to hold the rice husk fuel. The stove is operated by placing first a layer of rice husk char on top of the grate. The DA-IRRI Rice Husk Gasifier.

Has a blower which is switched ON to suck the air needed for combustion of fuel. When all the fuel is completely burning, additional amount of rice husks is fed into the reactor until it is fully filled. Tests have shown that flammable bluish gas is produced from the stove. Emptying and reloading of rice husks in this stove only take less than 5 minutes.

2. CPU Single-Burner Batch-Type Rice Husk Gasifier Stove

This stove was developed in 1989 at CPU basically to provide individual households a technology for domestic cooking using rice husks as fuel. It is a double-core downdraft type gasifier and is an improved version of the DA-IRRI rice husk gasifier stove. Similarly, this stove follows the principle of a double-core down-draft gasifier where burning of fuel starts from the bottom of the reactor. Rice husks are burned inside the reactor starting from the bottom and the combustion zone moves upward until it reaches the top most end of the reactor. Rice husk fuel is continuously fed in the reactor until the combustion zone reaches the topmost portion of the fuel. The principle of operation

of this stove is downdraft-type where air passes through the column of burning char. A 90-watt electric motor is used to suck the air and gas from the reactor. This type of stove adopts an LPG-type burner for simplicity of fabrication. The amount of gas in the stove is regulated by means of a gate valve. A chimney was also provided for the stove to discharge raw and excess gases, if desired.

Rice Husk Stove.

Results of the performance testing on this type of stove showed that the stove operates for a total period of 0.98 to 1.25 hrs per load. The amount of fuel consumed per load is 1.96 to 2.72 kg producing from 0.53 to 1.04 by char. Boiling and cooking tests showed that 1.2 to 4.0 litres of water can be boiled in the stove within 10 to 34 minutes, and 0.7 to 1.0 kg of rice can be cooked in the stove within16 to 22 minutes.

3. *CPU Proto-Type IDD/T-LUD Rice Husk Gas Stove*

These models of the stove were the prototype models of the commercially available IDD/T-LUD rice husk gas stove described. These are entirely different from the Sri Lankan model in terms of the burner design, char grate, and fan speed control mechanism.

The ash chamber is directly beneath the reactor. The fan is attached to the door of the ash chamber, and switching it ON and OFF is done with the use of a rotary switch. The stove can accommodate 600 grams of rice husks per load. The time required to produce combustible gas at the burner of the stove is about 32 to 35 seconds. The total time required before all the rice husk fuel is consumed ranges from 15 to 20 minutes, depending on the amount of air supplied by the fan to the reactor during cooking. After all the rice husks are burned, the amount of char and ash produced range from 122 to 125 grams. The CPU Proto- Type IDD/T-LUD Rice Husk Stove Model 1.

The computed power output of the stove ranges from 0.237 to 0.269 kW. Fuel consumption rate ranges from 0.33 to 0.43 kg of rice husk per minute. The time required for the combustion zone to travel from the top to the bottom of the reactor ranges from 1.74 to 2.27 cm per min. Thermal efficiency was found to be at the range of 12.28 to 13.83%.

Boiling test also showed that a litre of water, with initial temperature of 32 °C, boils to 100 °C within 9.0 to 9.5 minutes. During the test, no smoke and fly ashes were observed coming out of the stove.

4. ***CPU Cross-Flow Type Rice Husk Gasifier Stove***

This stove (Fig. 21) was patterned after the AIT Wood Gasifier Stove. This was designed as an attempt to gasify rice husks in a continuous mode so that operation of the stove can be done continuously, as desired. The stove uses a 3-watt DC motor to provide the needed air for gasification into a 15-cm column of rice husks inside the gasifier. The rice husks fuel flow inside the gasifier reactor in a vertical mode while the air moves into the layer of burning rice husk in a horizontal mode. The CPU Proto-Type IDD/TLUD Rice Husk Gas Stove Model 2. The CPU Cross- Flow Rice Husk Gasifier Stove.

The burner, which is located on one side of the stove, burns the gasified fuel and it is here where cooking is done. Smoke emission is quite evident in this type of stove. Water sealing is provided on the top of the fuel chamber and at the bottom of the ash chamber to properly direct the smoke to the burner. Results of performance tests have shown that the stove requires two kilos of rice husk per load. Operating time per load ranges from 37 to 47 minutes. One litre of water can be boiled in the stove within 8 to 11 minutes.

6. ***San San Rice Husk Gasifier Stove***

As reported in the internet, this stove was developed by U. Tin Win, under the guidance of Prof D. Grov of the Indian Institute of Technology and by Dr. Graeme R. Quick. The stove burns rice husks directly by allowing the air to pass through the perforated bottom of the stove going to the top. The primary air flows directly in the producer gas burning zone is at the bottom of the stove. A hinge shutter allows the removal of ash as necessary. The secondary air passes through the four zones of the stove. The stove can also be fuelled with a mixture of chopped kitchen wastes, leaves and fresh biomass, and rice husks. The problem of frequent tapping of the ash in the stove is minimized and the smoke emitted was found to be negligible and less polluting as reported. The San San Rice Husks Gasifier.

2.18 Other Biomass Fueled Gas Stove

1. CPU IDD/T-LUD

Wood Gasifier Stove

This stove was developed similar to the IDD/T-LUD rice husk gas stove. However, instead of using rice husks, chunks of wood are used as fuel. Fuel wood, cut into pieces of about an inch, is placed inside the reactor where it undergoes gasification. The reactor has a diameter of 15 cm and a height of 35 cm. A small fan is used to start the fuel. During the operation, the fan is totally turned off. Ash is collected in a chamber located beneath the reactor, where a small fan is installed for the start-up of fuel. On top of the reactor is an improved burner where gasified fuel is injected and mixed with combustion air. The flame emitted from the gasifier is yellowish orange with traces of blue colour.

Test results have shown that the stove can successfully generate gas for cooking. Two kilos of wood chunks can sustain 56 to 75 minutes operation. Boiling time of 1.5 litres of water is from 4 to 9 minutes. Thermal efficiency of this gas stove model
ranges from 10 to 13 percent.

2. NERD Forced Draft Smokeless Wood Gas Stove

This stove design came from Sri Lanka and was demonstrated at AIT, Thailand during the 2003 Training Seminar on Wood Gasifier Stove sponsored by ARECOP. The stove technology follows the principle of IDD/T-LUD where wood chunks are burned inside the reactor and firing of fuel starts from the top.

The CPU IDD/TULD

Wood Gas Stove, the reactor. Air is supplied to the wood chunks by forcing it into the fuel column using a small electric fan. In this stove, as reported in the internet, wood is converted into gas and burn on top of the burner. Report showed that 555 grams of wood fuel, or any biomass chips, are burned inside the reactor for 30 min. The stove is smokeless during operation. It is handy and portable which can be easily transferred from one place to another, as desired. According to the report, the stove does not emit so much heat during operation. It is claimed that the stove's overall efficiency is 34%.

Two watts D.C. micro fan is used to supply air for gas generation and combustion. The stove has AC main plugs terminals for battery and battery charger serving as accessories for the unit. It was also reported that the residue after each operation is only a few grams of ash.

The stove has a total weight of 10 kg with a height of 50 cm.

3. CPC Turbo Wood Gas Stove

This stove is an Inverted Down Draft (IDD), and now called T-LUD) type wood gas stove originally developed by Dr. Tom

The Sri Lanka Wood Gas Stove.

The Turbo Wood Gas Stove.

Foundation in the US. As reported from the internet, this stove combines especially designed gasification chamber, mixer, and burner to provide a 3-kW high- intensity heat using only 10 grams of fuel per minute. A 2-watt micro blower provides a fully variable amount of air just where and when needed to achieve the stove's very high performance level. The stove can be easily adjusted in terms of cooking intensity and time needed for frying, boiling, or simmering for up to two hours on a single charge of fuel.

The stove uses small pieces of wood and other biomass fuel such as nut shells, corn cobs, and others. As claimed, it is extremely clean stove that can be used indoors even with only minimal ventilation. It can cook fast just as modern gas or electric stove.

Report shows that the stove can boil a tea pot of water within 3 to 4 minutes. It can simmer up to 2 hours for slow cooking to save fuel and preserve food nutrients. It can be easily started and is ready for high intensity cooking in less than a minute. It has high efficiency of about 50%. It produces extremely low emissions that will virtually eliminate respiratory and eye diseases due to smoke inhalation.

4. Juntos T-LUD Gasifier Stoves

The Juntos brand of Top-Lit Updraft (T-LUD) gasifier stoves are developed by Dr. Paul Anderson of Illinois State University. Using as fuel various types of dry chunky biomass including wastes such as yard wastes, locust tree pods, and briquettes mainly from paper pulp and sawdust operate the stove.

An early Juntos Gasifier Stove, by natural convection. Early versions in 2002 were made from tin can with the top removed and covered with another metal serving as outer jacket with an annular space of 1 cm to pre-heat the air, thereby improving the combustion of burning gases. A 2-cm diameter air pipe is installed at the bottom of the stove reactor to provide primary air to the burning fuel.

An improved version of this stove, the Juntos Model B, has two chambers: (1) the pyrolysis chamber, and (2) the combustion chamber. The pyrolysis chamber is the bottom part of the stove that is basically made of a metal container in which air enters the central fuel area from underneath a grate that supports the fuel. As reported from the internet, the pyrolysis chamber has a diameter of 10 cm to 15 cm and can be made into various heights as long as the flow of primary air is not obstructed. The fuel is ignited on top of the column of fuel, creating smoke via the process of pyrolysis. The second chamber is where the hot flammable pyrolysis gases receive the flow of secondary air. The combustion chamber acts as an internal chimney so that gases are completely combusted before reaching the cooking pot.

The Juntos Model B

T-LUD gasifier won an award for cleanest combustion of nine natural draft biomass stoves.

T-LUD gasifiers are batch-fed and can yield charcoal equalling approximately 25% by weight of the load of biomass fuel. An improved Juntos

Model B T-LUD gasifier stove, including chimney needed for altitudes above 1000 meters,

Where secondary air is regulated. Fuel containers, internal chimney for combustion Skirt around pot directs exhaust gases to chimney Chimney (optional at low elevations with outdoor cooking.)

Air base for primary air

5. AIT Wood Gasifier Stove

This stove was developed at the Asian Institute of Technology, Bangkok, Thailand. This stove was demonstrated and presented during the 2003 Training on Gasfiier Stove. While rice husk briquette can be used as fuel, this stove is primarily designed for wood chunks. The stove consists of a cone-shaped fuel chamber, a reaction chamber where fuel is gasified and a combustion chamber where the gasified fuel is burned by natural convection mode. During gasification, air passes through the layer of fuel and escapes at the other end of the reaction chamber through a producer gas outlet. Flow of air and of gases in the stove is facilitated by the draft created by the combustion chamber.

Ash is discharged from the reaction chamber to the ash pit door of the stove.

Reports have shown that the stove can be operated continuously for 24 hours.

Operation is smokeless with average thermal efficiency of 17% when using rice husk briquettes, 27% with wood chips, and 22% with wood twigs as fuel. The stove is reported to be promising for community type cooking, particularly for institutional kitchens and traditional cottage industries.

6. Chinese Gasifier Stove

This stove is an improved version of a centre-tube type stove that uses crop residues as fuel. It consists of holes on its upper and middle portions to provide the needed air for stove to operate. The Chinese Gasifier Stove.

The AIT Gasifier, gasification of fuel. As reported from the internet, the stove was claimed to have an efficiency of about 60% that is 3 to 4 times higher as compared with other stoves utilizing crop residues as fuel.

7. Special-Purpose Straw Gas Cooker

This stove was introduced by Kevin Chisholm of Wattpower in the internet. It is used to change agricultural and forestry wastes into fuel gas. It is claimed that the stove has the following characteristics:

It is small enough for household use, it operates well, and it can be recharged with fuel material easily and conveniently. Gas can be produced in this stove in 1 to 2 minutes and can be operated continuously without the need of shutting down when adding fuel. According to the report, it can gasify materials such as corncobs, corn stokes, wheat straw, rice straw, peanut husks, wood chips, and others. The stove can produce 6 to 12 m3/hr of gas and is operated by an 80-watt, 220-volt AC blower. The gas produced contains 18% CO, 6 to 10% H2, and 2% CH4 with calorific value of 4,600 to 5,200 kJ/m3. (17)

8. CRESSARD Gasifier Stove

This stove as reported in the internet was designed in Cambodia by CRESSARD. The stove was constructed out of materials from a junk yard. The stove runs on a downdraft mode having an inner sleeve of 30 cm. It has a rolled flange at one end and support

The Special-Purpose Straw Gas Cooker the CRESSARD Gasifier Stove cross pieces in the other end. The throat is constructed by cementing an ordinary fired clay cooking stove available in the local market. The bottom cover of the cooking stove is provided with holes so that ash could fall to the bottom of the 55-gallon drum during operation. The top of the drum was cut in a circle, which matched the stainless steel sleeve.

9. Pellet Gasifier Stove

This stove as reported in the internet is a gasifier type that uses pellet grass. It is claimed that this stove is capable of burning moderately high ash pellet agricultural fuels at 81 to 87% efficiency. According to the REAP's report, switch grass pellets are used like wood pellets in this stove and provide fuel combustion efficiencies and particulate emissions in the same range as modern oil furnaces.

10. Holey Briquette Gasifier Stove

This stove as reported in the internet was designed specifically for biomass based low pressure briquette that is made manually by rural poor or urban producers. The stove is made from refractory ceramics having a height of 23 cm, a diameter of 14 cm, and a wall thickness of 25

25% of the entire household of families will use rice husk gas stove,

3.3.1 To determine the quantity of heat required to boil water both for soaking and parboiling of the above given quantity of rice

Using the formula $Q_H = M_W.C_W.DT$

Where

Q_H = Quantity of heat required for boiling of water (J)

M_W = Mass of water required (kg)

C_W = Specific heat capacity of water (J/Kg/K)

DT = Change in Temperature (Degree Kelvin)

3.3.2 To determine the mass of water required by using the relationship between the amount of paddy and the amount of water required,

1000kg of paddy requires 13000kg of water (Wimberly 1983)

From the statement above it can be interpolated to get the mass of water needed for both parboiling and soaking of 200kg of rice

1000kg of paddy rice requires 1300kg of water

200kg of paddy rice will require $= 200 \times \frac{1300}{1000} = 260kg$

Therefore, if 200kg of paddy requires 260kg of water for parboiling.

Addition of 50% excess water, 40% of water for parboiling of the paddy rice to be heated in other to produce steam used for parboiling, 10% of water is to be left in the boiler after soaking and parboiling of the paddy rice.

Adding 50% Excess water

$\frac{50}{100} \times 260 = 130kg$

Adding up the required amount of water and the excess

Total mass of water needed is 260 + 130 = 390kg

Where

260kg is the actual mass of water required

130kg is the excess mass of water added to actual mass.

3.3.3 To determine the quantity of heat required to heat total mass of water which is 390kg

Using $Q_H = M_W.C_W.DT$

Data

Q =?

M = 390KG

C = 4200J/KG/K

DT = (T2-T1)

T_1 = 4 Initial temperature of water at room temperature

T_2 = 100 final temperature of water after heating

The temperatures T_1 and T_2 are both in degree Celsius and have to be converted to degree Kelvin we add 273k

$T_1 = 4 + 273 = 277^0k$

$T_2 = 100 + 273 = 373^0k$

Applying the formula $Q = M.C.(T_2 - T_1)$

Q = 390 x 4200 x (373 - 277)

Q = 390 x 4200 x 96

Q = 157248000J

Plus addition of 20% excess heat, this is because of heat loss during the process of generating the heat energy and to make the generated very effective,

Adding 20% expected heat loss

$\frac{20}{100}$ x 157248000J = 31449600J

31449600J is the expected heat loss

Now, actual heat required equal expected heat loss plus heat generated,

Actual heat = Expected heat loss + Heat generated,

Actual heat required = 31449600 + 157248000 = 188697600 J

Therefore Q_{max} = 188697600 J

3.3.4 To calculate the quantity of rice husk to be burnt in order to produce or generate the amount of heat stated above.

For every ton of paddy processed about 0.25 ton of paddy husk is generated as a by-product in milling operation (Baruah & Jain, 1998).

Its heating value is about 15 MJ/kg which supports its application as an energy source. (Jain et al; 1997)

From the statement above, if

1 ton of paddy rice generate 0.25 ton of rice husk and the heating value of 0.25 ton of rice husk is 15MJ/kg, then converting tones to kilogram

1ton equals 1000kg

0.25ton equals 0.25 x 1000 = 250kg

Therefore 0.25tones of rice husk is equivalent to 250kg of rice husk.

Since, 0.25tones of rice husk generate 15MJ/kg of heat,

Therefore, 250kg of rice husk will also generate 15MJ/kg of heat as well because 0.25ton of husk equals 250 kg of rice husk.

To know the heat value of 1kg of rice husk

Since

250kg of rice husk gives 15MJ/kg of heat

1kg of rice husk will give $1 \times \frac{15 \times 10^6}{250} = 0.06MJ/kg$

Therefore 1kg of rice husk will generate 0.06MJ/kg of heat.

3.3.5 To determine the amount of rice husk that will be required to generate the actual heat required, actual heat is 188697600j.

Since,

1kg of rice husk generates 0.06×10^4

X kg of rice husk generates 188697600j

X kg = $1 \times 188697600/6 \times 10^4$

X kg = 3144.96kg.

Therefore, 3144.96kg of rice husk will generate the actual heat required which is 188697600j.

3.3.6 To determine the volume of rice husk that generate the actual heat required for the gasification process having known the mass and the density of rice husk.

Bulk density of both compacted and non-compacted rice husk ranges from 100 to 120kg/m^3

Mass of required rice husk = 3144.96kg

Density of rice husk = 100kg

Using the formula

Density = $\frac{\text{mass}}{\text{volume}}$

Making the volume subject of formula, we have

Volume = $\frac{\text{mass}}{\text{Density}}$

Volume = $\frac{3144.96kg}{100kg/m^3}$

Volume = $31.45m^3$

Therefore, the volume rice husk needed to generate the quantity heat for parboiling the selected quantity of rice is $31.45m^3$

3.3.7 Diameter of the shaft

The diameter of the shaft is obtained as follows

From equation 3.5

$$d^3 = \frac{16}{\pi S_a}\sqrt{(k_b M_b)^2 + (k_t M_t)^2}$$

$S_a = 40MN/m^2$ *for shaft with key-way*

$k_b = 2$

$k_t M_t = 0$, *for a case of pure bending*

M_b = *Maximum bending moment* = $M_{b2} = 12.91Nm$

$$d = \left(\frac{16}{\pi S_a}\sqrt{(k_b M_b)^2 + (k_t M_t)^2}\right)^{\frac{1}{3}} = \left(\frac{16}{\pi \times 40 \times 10^6}\sqrt{(2 \times 12.91)^2 + (0)^2}\right)^{\frac{1}{3}} = 14.87mm$$

Pulley and Belt selection

Design of the Pulley and the Belt

This is done in order to know the equivalent ratio of between the size of the motor pulley and that of the shaft pulley. This can be determined as follows,

$N_1 d_1 = N_2 \times d_2$ (Khurmi and Gupta, 2005)

Where,

N_1- is the speed of the motor pulley = 1500 rpm

N_2- is the speed of the shaft pulley = 500 rpm

d_1- is the diameter of the motor pulley = 900 mm

d_2- is the diameter of the shaft pulley = ?

(Adewumi and Igbeka, 1998) gave the average speed of blowers as 500 rpm.

$d_2 = \frac{N_1 \times d_1}{N_2} \frac{1500 \times 900}{500} = 2610$ mm approximately 26.1cm

This shows that the ratio between the sizes of the shaft pulley to the motor pulley is 3:1

Determination of the Total Length of Belt

The length of the belt needed to drive the motor pulley and the shaft pulley can be determined by using the expression below,

$l = 2c + \frac{\pi}{2}(d_1 + d_2) - \left(\frac{d_2 - d_1}{4c}\right)$ (Khurmi and Gupta, 2005)

3.3.8 Power Demand at Shaft

$$P = \tau\omega \tag{3.7}$$

$$\omega = \frac{2\pi N}{60} \tag{3.8}$$

$$\omega = \frac{2 \times 3.142 \times 1450}{60} = 151.86$$

$$P = 51.1879 \times 151.86 = 7773.565W$$

3.3.9 Determination of Speed of rotating Shaft

$$\frac{D_1}{D_2} = \frac{N_1}{N_2} \tag{3.9}$$

D_1 Diameter of motor pulley = 12cm

D_2 = Diameter of shaft pulley = 25cm

N_1 Speed of electric motor = 1450rpm

N_2 speed of rotating Shaft. = ?

12/25 = 1450/N2

N_2 x 12 = 25 x1450

N_2 = 25 x 1450/12

N_2 = 3020.83m/s

Where,

C- Is the center distance between the motor pulley and the shaft pulley =120 mm

d_1- is the diameter of the motor pulley = 900 mm

d_2- is the diameter of the shaft pulley = 2610mm

$$\therefore l = (2 \times 120) + \frac{\pi}{2}(900 + 2610) - \left(\frac{2610-900}{4\times 120}\right)$$

$$l = 240 + 1.571\ x\ (3510) - \ 3.563$$

$$l = 5750.7mm$$

Determination of the Speed of the Belt

The speed of the belt can be determined by using the expression below,

$v = \frac{\pi \times N_1 x d_1}{60}$ (Khurmi and Gupta, 2005)

Where,

N_1- is the speed of the motor pulley = 1500 rpm

d_1- is the diameter of the motor pulley = 60 mm = 0.06 m

$$v = \frac{\pi \times 1450 \times 0.9}{60} = 683.39m/s$$

Speed of Shaft 3020.83m/s

3.4.0 MACHINE COMPONENTS

1. The Gasifier Reactor
2. The Char Chamber
3. The Fan Assembly
4. The Burner

3.4.1 The Gasifier Reactor

The gasifier reactor is the component of the machine where rice husks are placed and burned with limited amount of air. This reactor is cylindrical in shape having a diameter of 50 to 60 cm. depending on the power output needed for the gasifier. The height of the cylinder varies from 60 to 80 cm. depending on the required operating time. The cylinder is made of an ordinary milled steel iron sheet gauge no. 16 on both the outside and the outside. This is provided with an annular space of 10 cm. where the burned rice husks or any other materials is placed to serve as insulation in order to prevent heat loss in the reactor. At the lower end of the reactor is a fuel grate made of iron rod which is used to hold the rice husks during gasification. This grate is positioned such that balances in the inner reactor

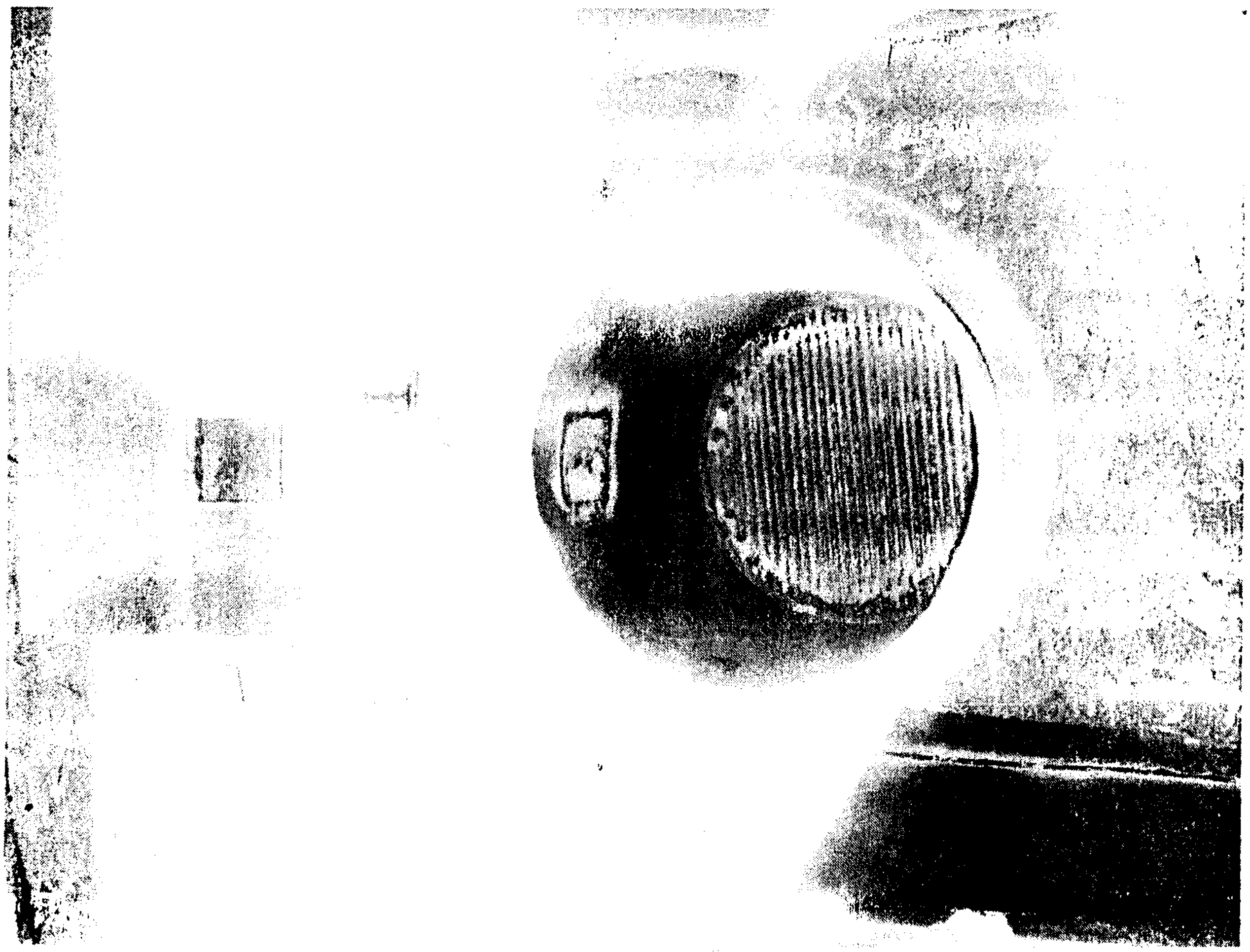

plate. 3.1: The reactor with the Grate placed inside it with the loading funnel

3.4.2 The Char Chamber

The char chamber serves as the storage for char produced after each operation. It is located beneath the reactor to easily catch the char that is falling from the reactor. This chamber is provided with a door that can be opened for easy disposal of char and it must be kept always closed when operating the gasifier. The char chamber is tightly fitted in all sides to prevent the air given off by the fan from escaping the chamber hence, minimizing excessive loss of draft in the system in gasifying the fuel. Four (4) support legs are provided beneath for the chamber to support the entire reactor.

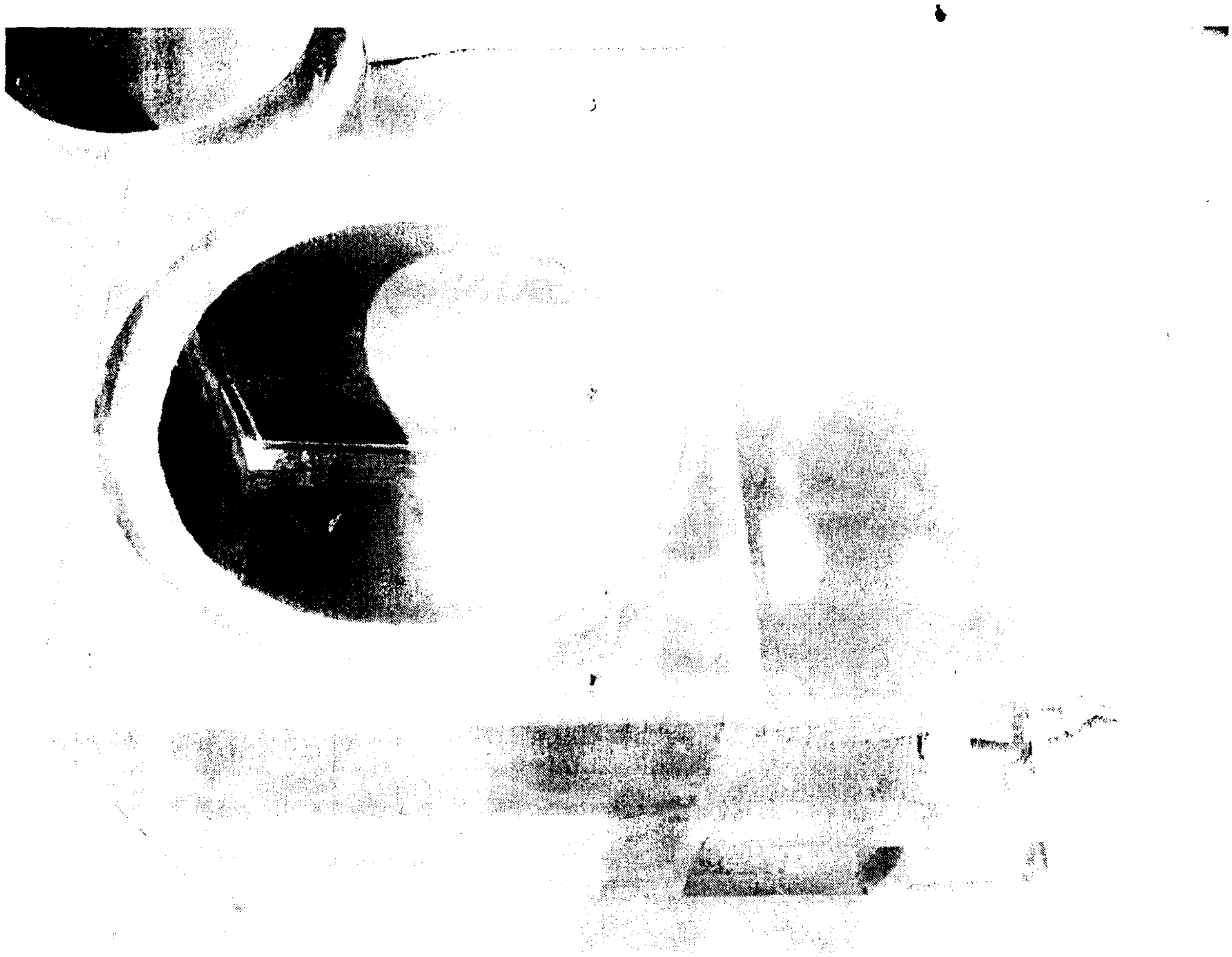

plate. 3.2: The char chamber

3.4.3 The Fan Assembly

The fan assembly is the component of the reactor that provides the air needed by the fuel during gasification. It is usually fastened on the

Char chamber, either at the door or at the chamber itself, to directly push the air into the column of rice husks in the reactor. Inside the fan assembly is the fan blade which is being held by a shaft to enable the blade supply the air needed for the gasification process. The fan is being rotated by an electric motor connected with the aid of a pulley and belt from the electric motor to the fan shaft for the rotation of the fan.

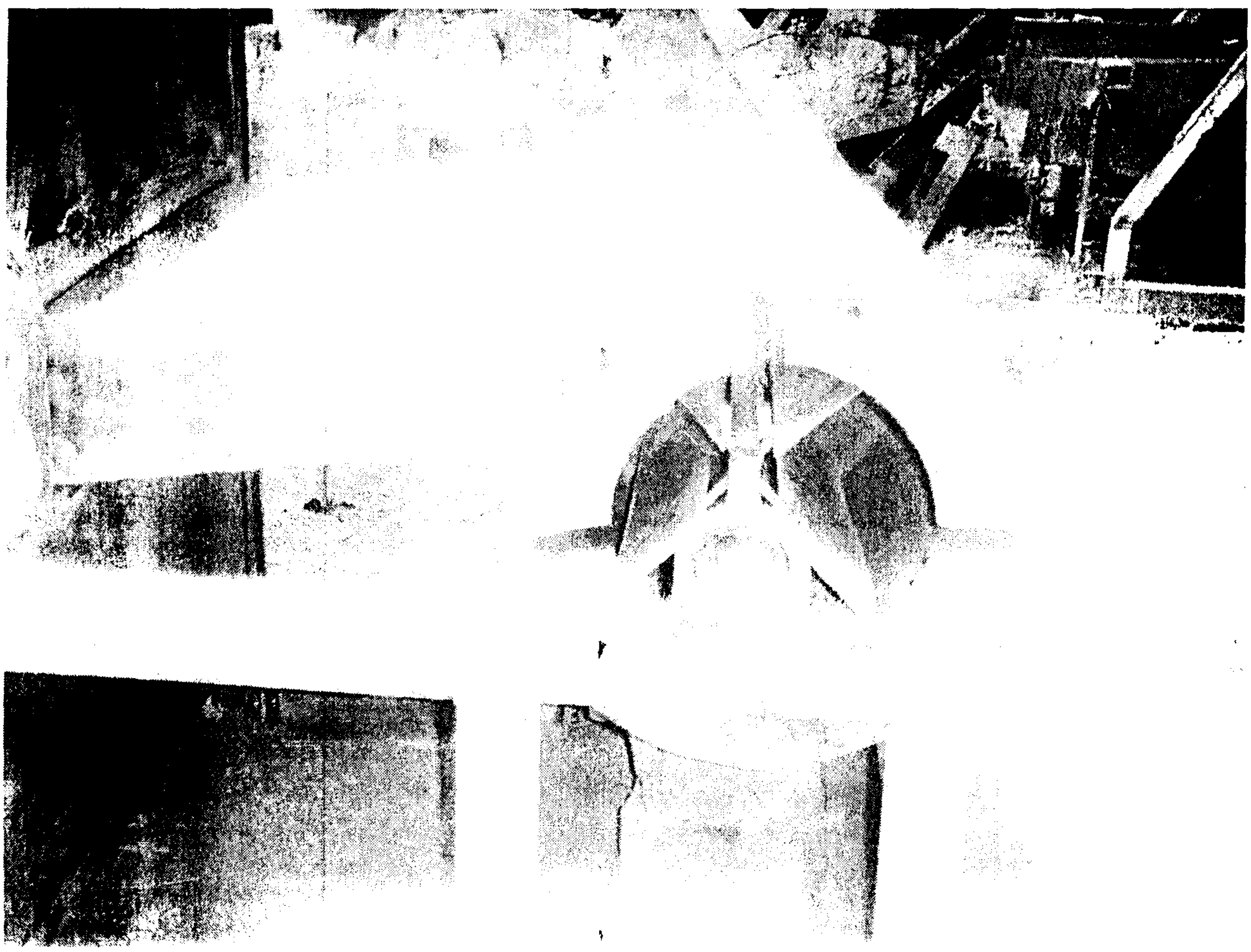

plate 3.3: The fan assembly

3.4.4 The Burner

The burner converts the gas coming out from the reactor to a bluish flame. It consists of series of holes, 3/8-in. in diameter, where combustible gas is allowed to pass through. The secondary holes located at the periphery of the burner are used to supply the air necessary for the combustion of gases. The burner is removable for easy lightening of the rice husk and set in place during the gasification process

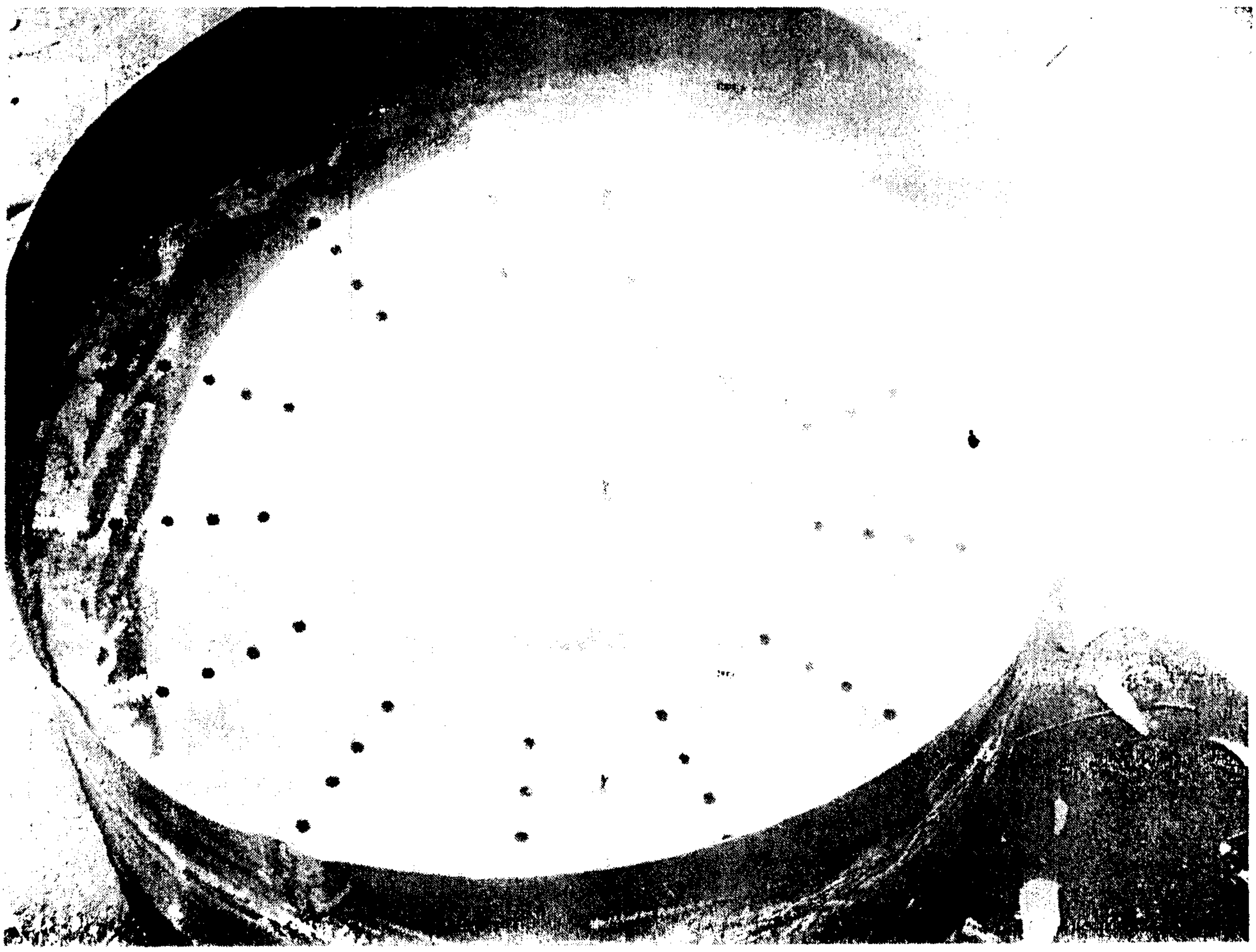

Plate 3.4: The burner showing heat outlet holes

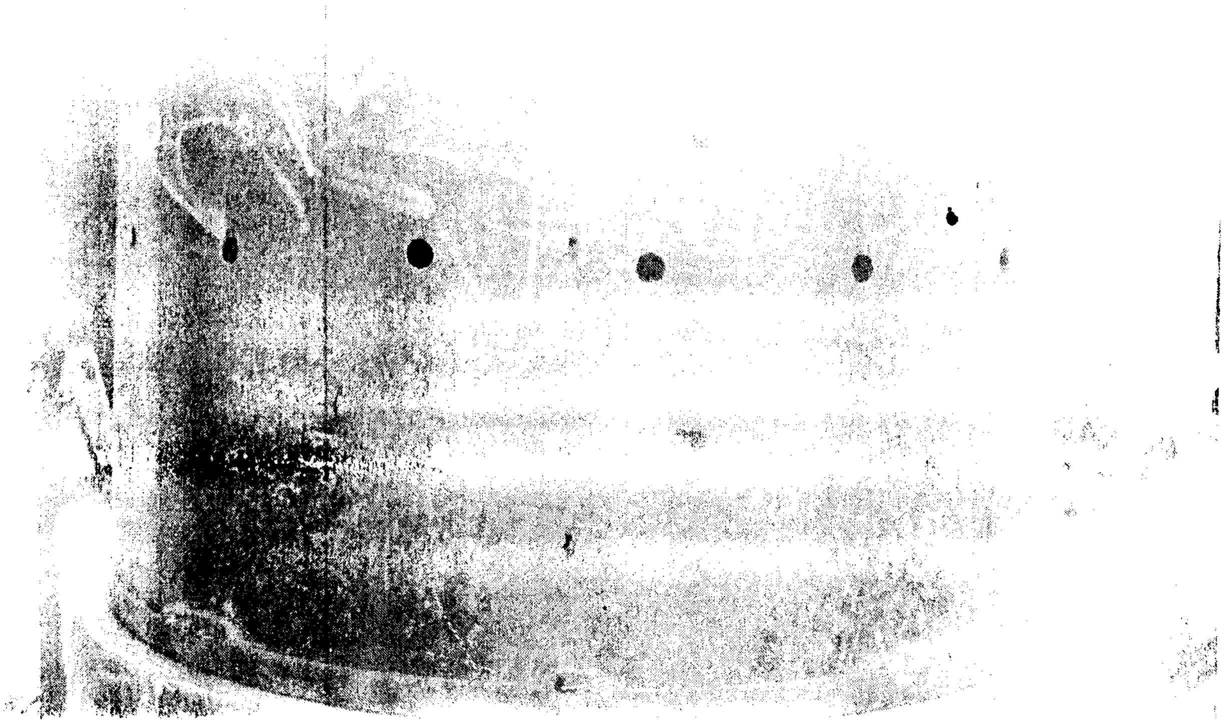

Plate .3.5: The burner showing secondary hole for oxygenation to aid burning

3.5 ASSUMPTIONS OF MACHINE DIMENTIONS

Outer Reactor

Diameter = 60cm,

Radius = 30cm

Height = 60cm

Inner Reactor

Diameter = 50cm,

Radius 25cm

Height = 70cm

Burner

Diameter = 53cm

Height = 10cm

The char chamber

Length = 70cm

Height = 70cm

3.5.1 Outer Reactor

Diameter 60cm

Radius 30cm

Height = 80cm

To get the folding length by using the formula πD

Where,

π = 3.142

D = 60cm

πD = 3.142 x 60 = 188.52 ≈ 190cm

To calculate for its volume, using the formula

Volume of cylinder V = $\pi r^2 h$

π = 3.142

r = 30cm

h = 60cm

$\pi r^2 h$ = 3.142 x $(30)^2$ x 60

V = 3.142 x 900 x 60

V = 169668cm

3.5.2 Inner Reactor

Diameter = 50cm

Radius = 25cm

Height = 70cm

To get the folding length by using the formular πD

Where,

π = 3.142

D = 50cm

πD = 3.142 x 50 = 170.6cm ≈ 171cm

To get the volume of the inner reactor which is the actual machine volume,

Using the formular volume = $\pi r^2 h$

π = 3.142

r = 25cm

h = 70cm

πr^2h = 3.142 x $(25)^2$ x 70

V = 3.142 x 625 x 70

Volume = 13746.25cm

Therefore actual volume of the machine = 13746.25cm

Inner Reactor Height = 70cm

Outer Reactor Height = 60cm

Difference = 70 – 60 = 10cm

The reason for this difference is to create space for the burner to seat very tight instead of being suspended on top

3.5.3 Burner

Diameter = 53cm

Radius = 26.5cm

Height = 10cm

Applying πD to get the burner folding length

π = 3.142

D = 53cm

πD = 3.142 x 53 = 166.526

πD = 3.142 x 50 = 170.6cm ≈ 170m

Calculating for the burner volume by applying the formular

volume = πr^2h

$V = \pi r^2 h$

$\pi = 3.142$

r = 26.5cm

h = 10cm

$v = 3.142 \times (265)^2 \times 10$

$= 3.142 \times 702.25 \times 10$

V = 22064.695cm

3.6 Fabrication Stages

All the components of the machines were made of mild steel and angle iron as shown in the figure below

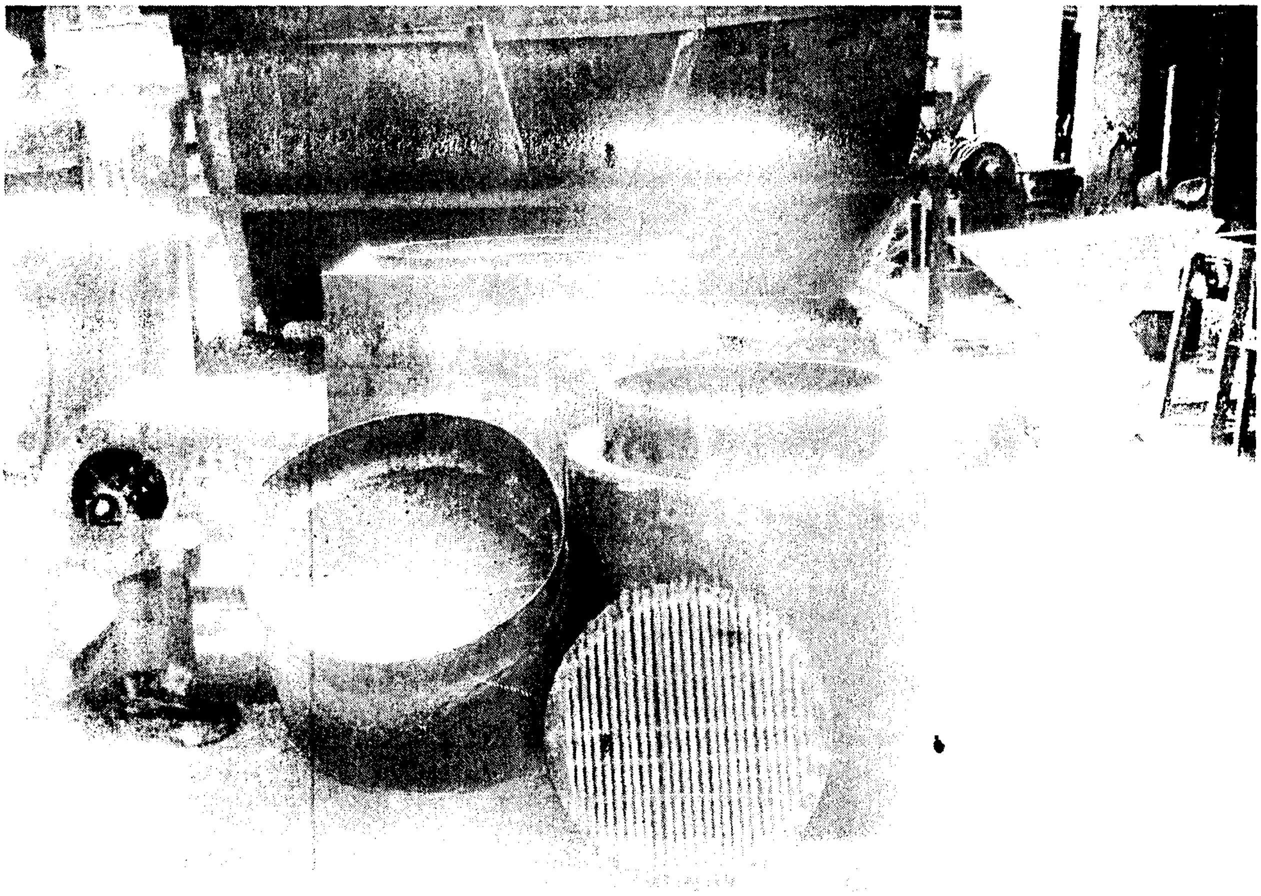

plate. 3.6: All components parts of the machine

The fabrication process involves the various stages which include:

1 Measuring and Marking Stage

2 Cutting Stage

3 Setting and Tacking Stage

4 Bending and Rolling stage

5 Welding Stage

6 Grinding Stage

7 Drilling Stage

8 Assembling Stage

9 Painting

3.6.1 Measuring and Marking Stage

This stage is the beginning of all the fabrication process after the purchase of materials, measuring is carried out with the use of engineering Measuring tape of about 16ft in length, each length of the machine components were measured with the tape and the required length were marked with the use of a marker and ruled with a ruler or try-square to join the marked points in case if there are more the one points in order to ensure straight cutting of the marked portion.

3.6.2 Cutting Stage

This stage involves the use bench vice, hack saw and cutting machine or cutter to cut the marked portion, the bench vice is used to hold the material which is to be cut (angle iron), the vice tightened very well and the required length is marked and ruled with a is small try square at angle 90 degree to make sure it is straight and then hack saw with a saw blade attached to it is use for cutting, the same thing is applicable to the cutting of mild steel metal plate. Beveling may be required of the angle iron which is also marked with the try square at both ends of the same side of the iron and cut off with hack saw.

3.6 3 Setting and Tacking Stage

This stage is where the cut iron is set with try square to ensure that the iron is at angle 90^0 before tacking is done, tacking is done first before permanent welding is done, this help to ensure that the iron is well set in position in order to avoid bending of the frame or iron

3.6.4 Bending and Rolling stage

The bending stage has to do with the use of bending machine and rolling machine. the bending may be done at any required angle like angle 45^0, 90^0, 120^0 etc while rolling is being made into drum form or shape or cylindrical form.

3.6.5 Welding Stage

This stage involves the permanent joining together of the tacked joints or parts of the machine. this is done with the use of an electric arc welding machine and mild steel electrode of about gauge 12.

3.6.6 Grinding Stage

The grinding stage involves the use of grinding machine with grinding disc fixed to it and the machine is connected to electricity as a source of power for the rotation of the grinding disc which is used to grind off welded joints or portion for smoothening purposes when the machine is switched on.

3.6.7 Drilling Stage

This stage involves the use of drilling machine and a drill bit fixed to it, the machine also makes use of electricity as a source power. Drilling is done when the point to be drilled is marked and centre punched before it can be drilled.

3.6.8 Assembling

Assembling has to do with coupling or putting together all the component parts of the fabricated machine together to form a complete machine.

3.6.9 Painting

Painting is done with the use of spraying machine, the paint to be used is first mixed with fuel which act as diluting agent that makes it easy for spraying, then the paint is poured in to the spraying compartment of the machine through which spraying is done with the aid air pressure produced from the spraying machine pump cylinder.

3.7 Mode of Operation

The rice husk is feed or loaded into the reactor through the funnel when the stopper is opened with the burner removed and the grate well positioned at the bottom of the inner reactor to hold or prevent the rice husk from falling into the char chamber or box. The burner is removed and the husk is lighted or set on fire with the aid of paper and the burner is replaced on top of the reactor, with the char chamber closed the fan is switched on to blow in air secondary air into the char chamber which is air tight and helps to direct the air to the reactor containing the rice husk.

The air provided by the fan and the atmospheric air that enters into the reactor through the secondary holes helps to burn the husk.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.10 Presentation of Results

4.1.1 Testing and Result

4.1.2 Testing

A test was carried out on the rice husk gasifier and it was found to be working effectively and the agricultural waste (Rice Husk) was able to produce required heat from it as it was observed and the quantity of heat generated was determined with the use of a thermometer at different time interval as shown in table 4.1

4.1.3 Presentation of Result

Time/minute	Temperature/ ^{O}C
5	160
10	200
15	270
20	390
25	500

Ambient temperature $37^{O}C$

Burning moisture content of rice husk 14% dry base

Inside wall temperature of the reactor from the first temperature reading

Heat input = Q = M.C.DT

Q = Heat generated

M = Hourly expenditure of husk = 10.5kg.

C = Specific heat capacity of rice husk = 26.23kj/kg (Emmanuel 1993)

DT = Inside wall temperature t minus ambient temperature (T_2-T_1)

Ambient temperature T_1 = 37^0C

Substituting these values gives

Q = 10.5 x 26.23 x T_2 - T_1

10.5 x 26.23 x 123

Q = 33876.045J

4.2 Discussion of Result

The temperature of the surrounding environment was determined with the thermometer and was observed to be 37^0C (Ambient Temperature). The gasifier was ignited with a piece of paper and allowed for about 3 minute for the fire to transfer from the paper to the rice husk before the fan is switched on and the gasifier was allowed to work for about 5minute before the temperature of the gasifier was determined with the thermometer and was observed to be 160^0C, on further gasification the temperature increases to 200^0C and it was observed to be constant. On further loading of the gasifier with the rice husk the temperature increases further to 270^0C. The temperature was discovered to be increasing as the gasifier is been loaded at 5minute interval and the temperature was also read at the same time.

This experiment was repeated for several times and at each time the temperature was determined as shown in the table 4.2 above.

4.3 Cost Analysis

In any engineering design, the economic benefit has to be put into consideration through the selection of materials which are very cheap and at the same time meet the specific purpose for which the machine was designed. The essence of costing the design and fabrication is better appreciated when considerations are given to the fact that a product is incomplete unless the cost of designing and fabricating the product are evaluated. The cost of designing and fabricating the rice husk gasifier is classified as follows:

i. Material cost

ii. Labour cost

iii. Overhead cost

iv. Total cost

4.3.1 Material Cost

This is the cost of all the materials used in the fabrication of rice husk gasifier. For simplicity and clarity, table 4.2 gives the summary of the cost of materials used in the fabrication.

Table 4.2 **Summary of Material Cost**

S/No	Materials	Specification	Number Required	Unit Cost	Amount
1	Mild steel metal plate	Guage 16	4	4200	16800
2	Angle iron	1inch	2	1000	2000
3	Iron rod	10mm	2	1000	2000
4	Shaft	32mm	1	1000	1000
5	Bearing	3.65B	2	400	800
6	Bolt and Nuts	13size	10	15	300

		17size	12		
7	Pulley	2hp	2	400	800
8	Belt		1	150	150
9	Angle iron	2inch	2	3000	3,000
10	Binding wire and hinges	1inch	1roll 2 hinges	100 50	150
11	Spraying			3000	3,000
12	Auto card drawing			4000	4,000
13	Purchase transportation			500	500
					Total 34500

4.3.2 Labour Cost

Taking a direct labour cost of 25% of the material cost (Olareaju, 2005)

Labour cost $= \frac{25}{100}$ x material cost = 0.25 x 34500 = 8625

4.3.3 Overhead Cost

This includes all other expenses incurred apart from material and labour cost. Taking an overhead cost of 20% of the material cost (Olareaju, 2005)

Overhead cost $\frac{20}{100}$ x material cost = 0.20 x 34500 = 6900

4.3.4 Total cost

The total cost of fabricating the rice husk gasifier is the sum of all the material cost, labour cost and overhead cost.

Total cost = Material Cost + Labour Cost + Overhead Cost

Total Cost = 34500 + 8625 + 6900 = 50025

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This project work focused on the design and fabrication of a motorized rice husk gasifier that is cheap, easily affordable to the rural processing farmers, easy to maintain and less laborious to use. This gasifier will go a long way to make rice processing very attractive to rural processors, reduces deforestation as it uses agricultural waste also reduces environmental pollution from rice husk that are dumped on road sides and also saves cost of purchase of firewood, gas, electricity that are other alternative heat source for rice parboiling. All the components parts of the gasifier were fabricated from mild steel. the fan is powered with a diesel engine which makes it easy for rural farmers to be able to operate the machine. This machine will help to harness energy that are left in what we call agricultural waste which are not really waste just because of lack of equipment and machines needed to harness the resources in agricultural waste are not available. This machine can also be use to burn agricultural waste like sawdust, ground nut shells, rice straws e.t.c.

5.2 Recommendation

The loading mechanism of the gasifier should be improved upon as to have constant an continuous loading of the raw material (rice husk) with the use of a machine so as to make the gasifier more efficient and to save the operator from loading it manually.

More spaces should be created around the burner and the gaifier for proper oxygenation to aid fast burning of the rice husk since oxygen supports burning.

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APPENDICES

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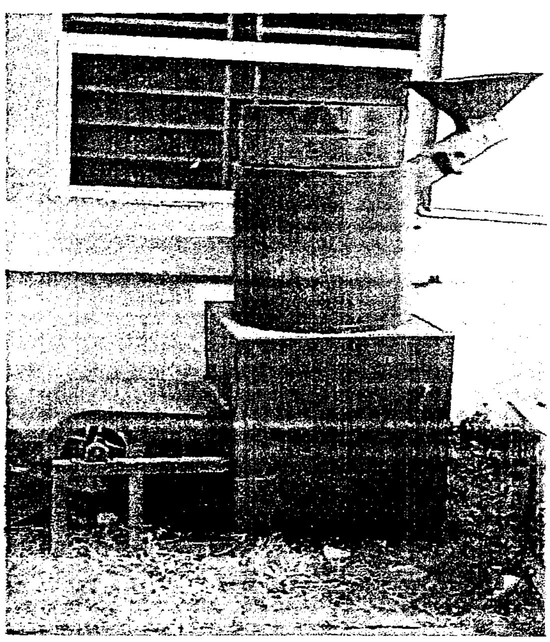


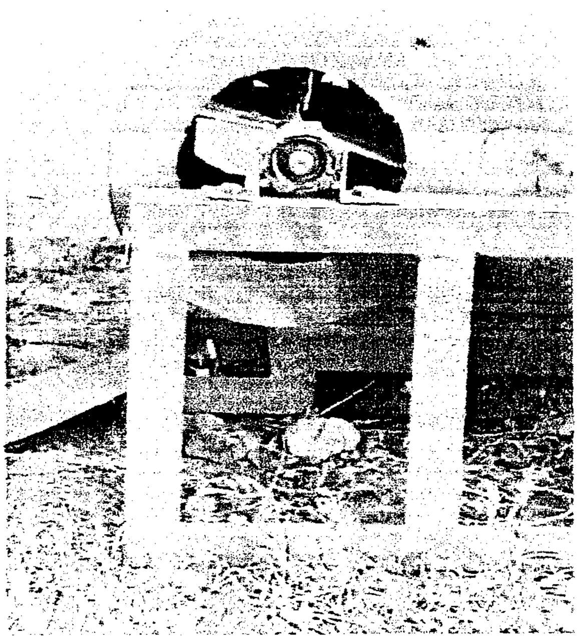

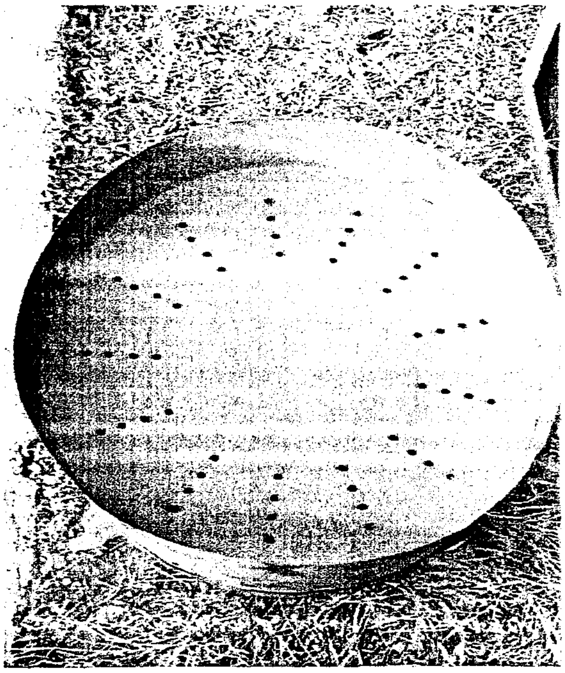

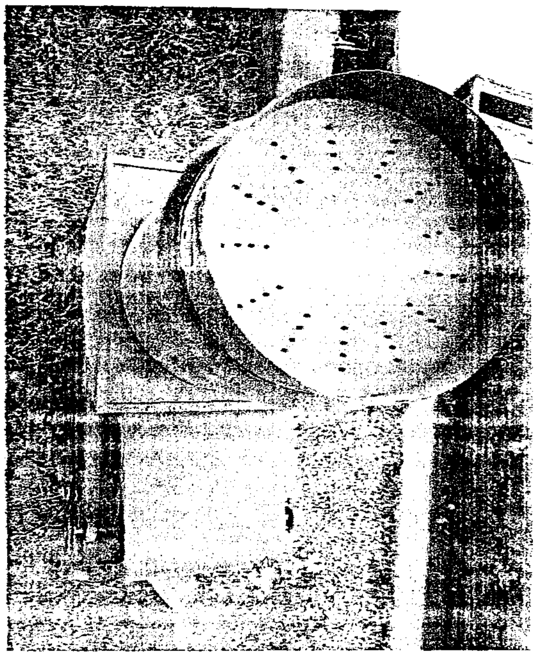

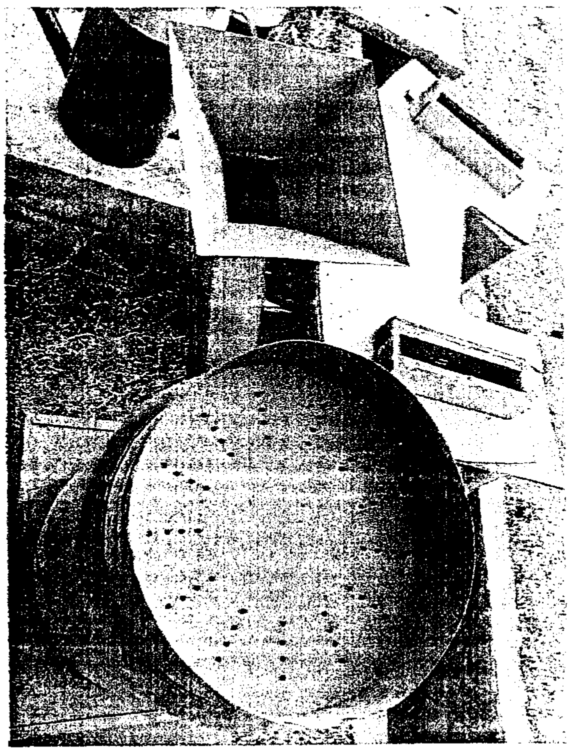

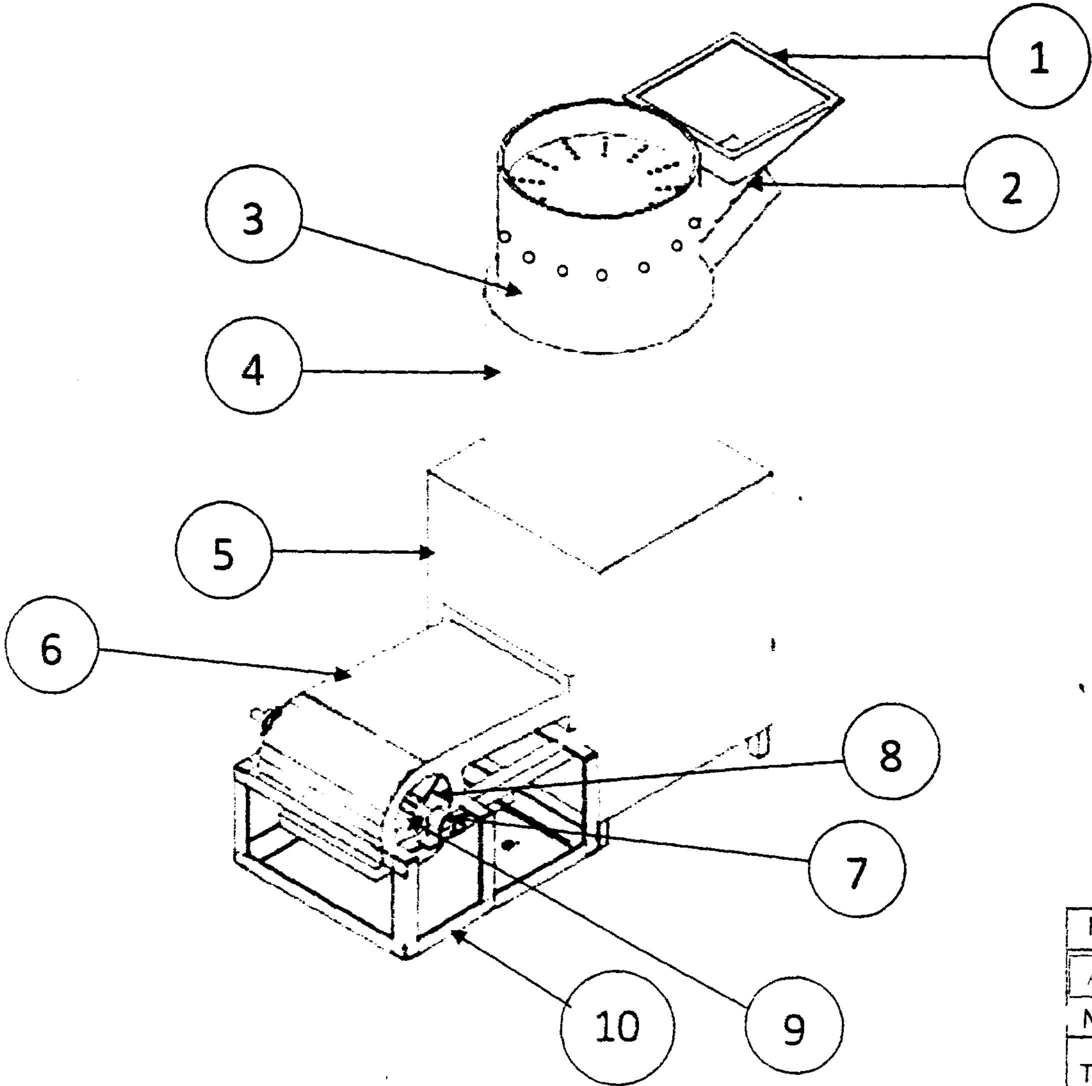

1) Hopper
2) Flow channel (husk)
3) Burner
4) Reactor/Gasifier
5) Char chamber
6) Fan assembly
7) Bearing
8) Shaft
9) Fan blade
10) Machine frame

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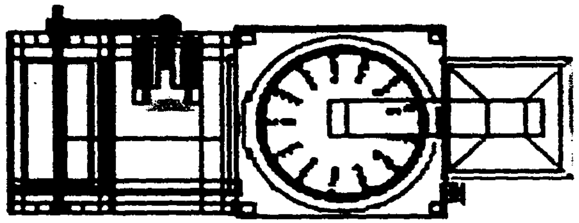

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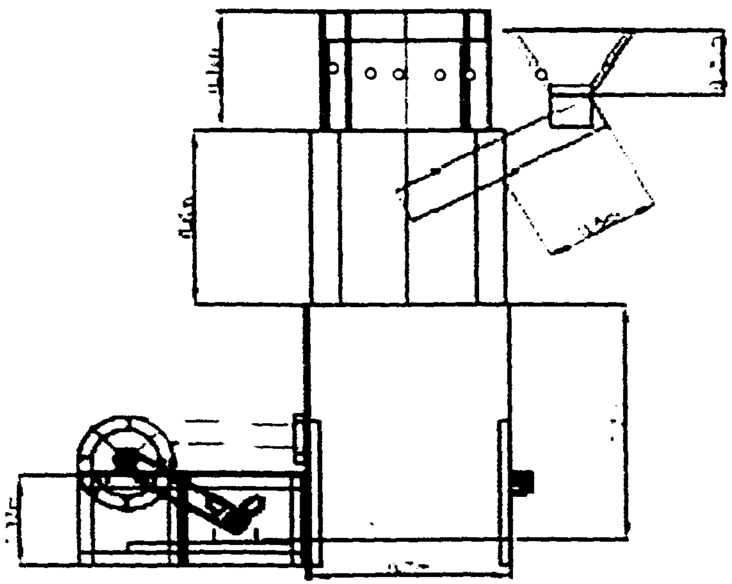

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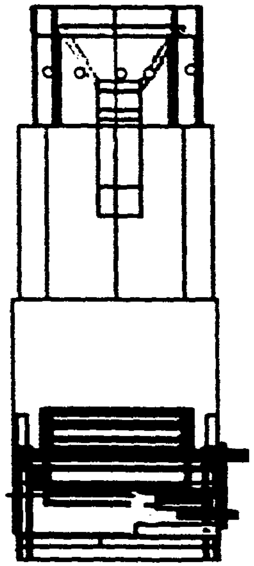

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