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A SIMPLE CHARCOAL KILN

FOR HARDWOODS OR OTHER DENSE BIOMASS

(QUICK, EFFICIENT, ECONOMIC WITH LOW ENVIRONMENTAL IMPACT)

By

Hassan Gomaa and Mohmed Fathi *

ABSTRACT:

Charcoal is a carbonaceous solid with a fixed carbon content of 70% or more. It is usually manufactured from hardwoods or other dense biomass by pyrolysis. Worldwide charcoal production is estimated to lie in the range of 26 to 100 million tons per year, and is growing at an estimated rate of about 3% per year. In the USA and Europe charcoal is used as a barbecue fuel, but elsewhere it is employed as a reductant for metal ores (e.g. the manufacture of ferrosilicon in Norway and iron in Brazil) and other industrial purposes.

In the developed countries efficient processes are employed for charcoal production in large kilns or retorts. Meanwhile in the developing world inefficient processes are widely used for charcoal production. Because of pollution associated with the inefficient conversion of biomass to charcoal, this charcoal fuel cycle is among the most greenhouse-gas intensive energy source employed by mankind.

Such inefficient process is traditionally used in Egypt. The typical capacity of the Egyptian traditional charcoal process is about 1-2 ton of charcoal/cycle (the cycle duration of 3 - 5 weeks). These small capacity processes are widely spread in the rural area. Due to the high pollution to the neighborhood caused by charcoal manufacturers, the concerned environmental authorities have stopped them, however, charcoal manufacturers and their labors are suffering, beside that the charcoal production is nearly stopped.

The paper presents the results of testing A SIMPLE CHARCOAL KILN for hardwoods or other dense biomass. This kiln has been developed, constructed and tested as a pilot plant by the NREA Biomass R&D department aiming to substitute the closed traditional charcoal kilns for solving the a/m problem. The main features of the kiln are:

Simple: without mechanical or electrical components.

Quick: the cycle duration of 3 - 5 hours + 10- 12 hours cooling time.

Efficient: high charcoal yield.

Economic: suitable capital cost and low running cost.

Has low environmental impact: all wood gases released during carbonization are controlled and burned as a fuel for the process to reduce emissions

* **Eng. Hassan A. Gomaa** Biomass General Manager / Renewable Energy Authority (NREA)

Eng Mohamed Fathi Biomass R&D department / Renewable Energy Authority (NREA)

INTRODUCTION:

Charcoal is a carbonaceous solid with a fixed carbon content of 70% or more. It is usually manufactured from hardwoods or other dense biomass by pyrolysis. Worldwide charcoal production is estimated to lie in the range of 26 to 100 million tons per year, and is growing at an estimated rate of about 3% per year. Charcoal is used as a fuel for heating and barbecue. It is also employed as a reductant for metal ores (e.g. the manufacture of ferrosilicon in Norway and iron in Brazil) and other industrial purposes. During the world war charcoal were also gasified to generate gas in order to be used as a fuel in motor cars and trucks.

In the developed countries, efficient processes are employed for charcoal production in big industrial kilns, retorts and portable steel kilns. Meanwhile in the developing world inefficient processes are widely used for charcoal production. Since pollution is associated with the inefficient conversion of biomass to charcoal, this charcoal fuel cycle is among the most greenhouse-gas intensive energy source employed by mankind.

Traditionally, in Egypt such inefficient process is widely spread in the rural areas. Due to the air high pollution caused by the charcoal process the neighborhood has complained to the concerned environmental authorities. Therefore, the environmental authorities have stopped the charcoal manufacturing, however, this causes generates severe problem to the charcoal manufacturers and their labors, beside the stoppage of charcoal production.

THE EGYPTIAN TRADITIONAL CHARCOAL PRODUCTION PROCESS:

In Egypt there is a strong tradition of charcoal manufacturing form old fruit trees and other trees grown through the cultivated areas. The Egyptian charcoal production is estimated to lie in the range of 200 to 500 thousand tons per year. Charcoal is used as a barbecue fuel and for other industrial purposes.

The charcoal process used traditionally in Egypt has a typical batch capacity of 3-7 ton charcoal/cycle (cycle duration: 2-3 weeks). The main feature and the design of this process are shown in fig. No. (1,2)

These small capacity processes are widely spread in the rural areas. Due to the high pollution to the neighborhood caused by Charcoal manufacturers, the concerned environmental authorities have been stopped them, at the mean time the Charcoal manufacturers and their labors are suffering, in addition to this, the charcoal production is nearly stopped.

For solving the a/m problem, there has been a crucial necessity for developing a new charcoal production process to substitute the closed traditional ones. So NREA have developed a new charcoal production process.

THE CARBONIZATION PROCESS:

Less attention is usually given to the understanding of the carbonization process, which sometimes results in lower charcoal yields. It can be as follows:

Combustion:

In fact, the main chemical process in wood burning is the consumption of carbon by combustion following the dehumidification and devolatilisation steps, providing Carbon dioxide if oxygen exists in sufficient amounts: $C + O_2 \longrightarrow CO_2$.

Incomplete combustion:

If wood is heated under lack of oxygen conditions the chemical process is then the incomplete combustion with carbon monoxide formation: $C + ½ O2 \longrightarrow CO$.

Carbonization through incomplete combustion:

Normally charcoal is manufactured in kilns, the necessary heat for wood decomposition is obtained form partial wood burning at the initial stages. The carbonization occurs following the initial stage of wood burning by ensuring restricted amount of air having access to all parts of the woodpile. The incomplete combustion is the basis of this carbonization process through which charcoal is obtained from wood within four consecutive phases as follows:

1. *Drying (Up to 170 oC):*

Wood loses only water and its external form does not significantly change.

2. *Initial decomposition (170-270 oC):*

At about 170 oC, the decomposition of wood starts leading to the initial phase of carbonization; the organic acids and tars are evolved together with water vapor. Also gasses like CO and CO2 are gradually evolve

3. *Exothermic decomposition (270-350 oC):*

The wood decomposition proceeds with evolution of gases and organic liquids at higher rate accompanied with heat.

4. *Final decomposition (Above 350 oC):*

The wood decomposition takes place in a smoother manner. During this phase the relative amount of CO and CO2 to H2 and light hydrocarbons goes down as the temperature increases. The process should cease at temperatures between 450 and 550 oC because above these temperatures the charcoal yield decreases and then the charcoal itself starts to be consumed.

The percentage of the yield of combustible gases depends on the operating carbonization temperature. Analysis of the evolved gases have shown the following composition; (CO:25%; CO2: 15%; O2: 5%; CH4: 4.5%; H2: 2%; C2H6: 1%; + N2: 47.5%) which has a heating value of 2000 Kcal/ Nm3.

Since The CO content is about 25 % (by volume) in the evolved gases, the evolved gases can easily said to be a pollutant (the maximum permitted level of CO in the atmosphere is 20 PPM).

Carbonization through pyrolysis:

Also, charcoal can be manufactured through a pyrolysis process by heating wood under the absence of oxygen in kilns having a closed chamber. The necessary heat for wood decomposition is obtained form partial wood burning or other sources of heat energy. The devolatilisation occurs following to the initial stage of wood dehumidification by ensuring absence of air in the closed chamber having access to control and collect all evolved gases and vapors or organic liquids and tars. Water vapor also appears in the flue gases and its amount depends on the initial moisture content of wood. The combustible gases such as hydrogen, methane, ethane and other light hydrocarbons are formed through relatively slow pyrolysis of wood as well as by cracking of tars and heavy hydrocarbons.

THE MAIN IDEA OF THE SIMPLE CHARCOAL KILN:

Is to produce charcoal through pyrolysis in a **Simple, Quick, Efficient**, and **Economic** kiln. It also must be **Has lower environmental impact** through burning of all gases and vapor evolved during carbonization as a fuel for the process to reduce emissions and its greenhouse effect. It also and can be constructed in a **Suitable sizes by local materials**. The main features of this idea are shown in fig. No. (3)

THE REALIZATION OF THE PILOT SIMPLE CHARCOAL KILN:

The first trials have begun during determination the VS % of deferent kind of plant residues (50-100 gm. of wood capacity), fig (4-a). The second trial was a very very small kiln constructed from empty paint cans (2-3 kg.), fig (4-b, 5-a). The third trial was a very small kiln constructed from empty barrels (20-30 kg) fig (4-c). These three trials were successful where, most of the evolved gases and vapors are completely combusted as a fuel to complete the process with a cycle duration about (3-4 hrs). Due to this success the pilot simple charcoal kiln is constructed (100-250 kg) fig (4-d).

DESCRIPTION OF THE PILOT SIMPLE CHARCOAL KILN AND ITS OPERATION:

The pilot simple kiln is a double wall chamber made of steel sheets as shown in fig. (4-d) and its capacity is about 1 m^3 of wood. The outer wall has a thermal insulation. The kiln has a stake equipped with a butterfly valve to control the outlet of the evolved gases as well as the air entry during the beginning of the process. The kiln has 2 doors; the inner one is tightly closed after the wood is pilled up inside the chamber to prevent the gases and vapors to be evolved directly to the atmosphere or the air to enter inside. Thus eliminating its incidence as pollutant and also recover its energetic potential. After closing the outer door the starting stove is ignited to begin the carbonization process phases fig (5-b). The central pipe in the chamber bottom takes out the evolved gases and vapors directly over the stove to be burnt as a fuel for completing the carbonization process fig (5-c). The process should be ceased at temperatures between 450 and 550 ^oC because, above these temperatures the charcoal yield decreases and then the charcoal itself starts to be consumed. When the carbonization process is completed the gases and vapors stop evolving and the fire is put off. The process duration is about 4-5 hours. After 4-6 hours, as a time for cooling to be take place, the doors are opened for taking out the charcoal and recharging the kiln with wood for the another cycle.

THE PILOT SIMPLE CHARCOAL KILN PRIMARLY PERFORMANCE:

The pilot simple charcoal kiln has been manufactured 2 weeks before. Only two charges of wood were carbonized in it when this paper prepared. The first charge was incomplete one (25%), this only for checking the kiln. Another complete charge (114 kg of broken white wood has 11.5% RH) was carbonized, the yield charcoal was 34 kg has 00% RH & 00% VS. The fig(6) shows the graph of the temperature in the kiln inner chamber against time as two important process parameters.

From the graph and the observations it can be stated that:

- The initial stage covered 6 hrs, and the stove consumed 15 kg of wood. With time and through practices this period can be reduced to 3-4 hrs, and also the consumed wood for starting the kiln can be reduced to 10 kg.
- The wood decomposition period reaches 2 hrs.(time of combustible gases and vapors evolution)
- The heat energy content of evolved gases and vapors is more than enough for the process completion.
- A heavy smoke of incomplete combusted products during about 1 hr, is associated due to, the air entry area is not enough to permit the needed quantity of air for complete combustion of the evolved gases and vapors.
- To solve the a/m problem there are two solutions:
  - Adapting the air entry.
  - Extracting part of the combustible evolved gases and vapors from the inner chamber to be stored or used directly as a source of energy.

- The two solutions will be executed and evaluated.
- The charcoal yield was: 33.5 % (dry bases), 29.8 % (wet bases)
  30.7 % , 27.4% respectively (considering the stove wood charges).

THE CONCLUSION:

This first test on the pilot kiln is a successful step towards new kilns has t**he following main advantages:**

- Quick: Cycle duration is about 4-6 hours + 5-6 hours for cooling.
- Simple has no mechanical or electrical components and the design is flexible can be locally manufactured in mass production in suitable sizes by local materials.
- Saving time and requires minimum control and/or observation of kiln working conditions.
- Efficient has a high charcoal yield with minimum partial wood burning at the initial stages.
- Economic: suitable capitals cost and low running cost so it is a more simple and economic alternative to a traditional carbonization process.
- Has low environmental impact: The gases and vapors evolved as a by-product during this process did not send to the atmosphere as dangerous pollutant but it used as an energy source for the process. No Tars, organic liquids and other condense yield because they are kept at high temperature to the burning area before condensation.
- Recover significant part of energy, if the gas excess than that needed to the process, is stored in a cylindrical gasholder with a floating top. From this reservoir the gas is to be used in several applications which do not require the use of premium fuels such as ceramic kilns; limestone kiln heating of green- houses and its burning in small internal combustion engines.
- It is comparatively very small in size:

RECOMMENDATIONS:

The improved kiln described and tested in this study needs additional efforts and support to be manufactured in mass production and to be introduced to the market. NERA appreciates future co-operation with the interesting firms for realizing this aim.

ACKNOWLEDGMENTS:

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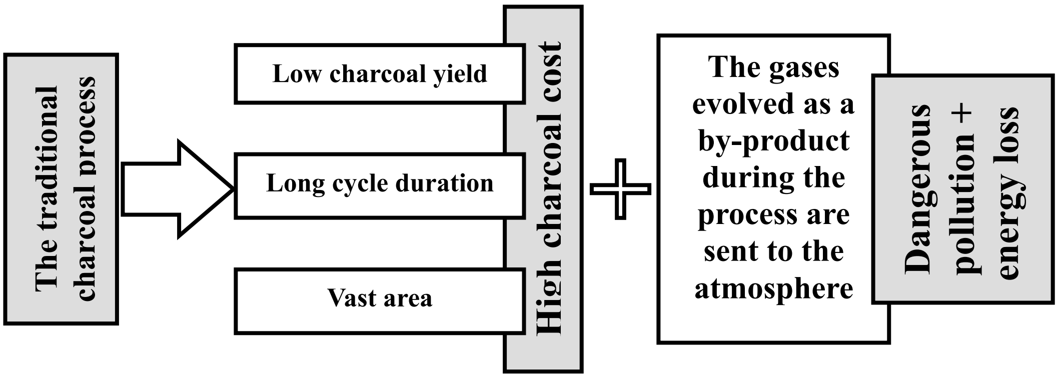

Fig (1) The traditional charcoal process main feature

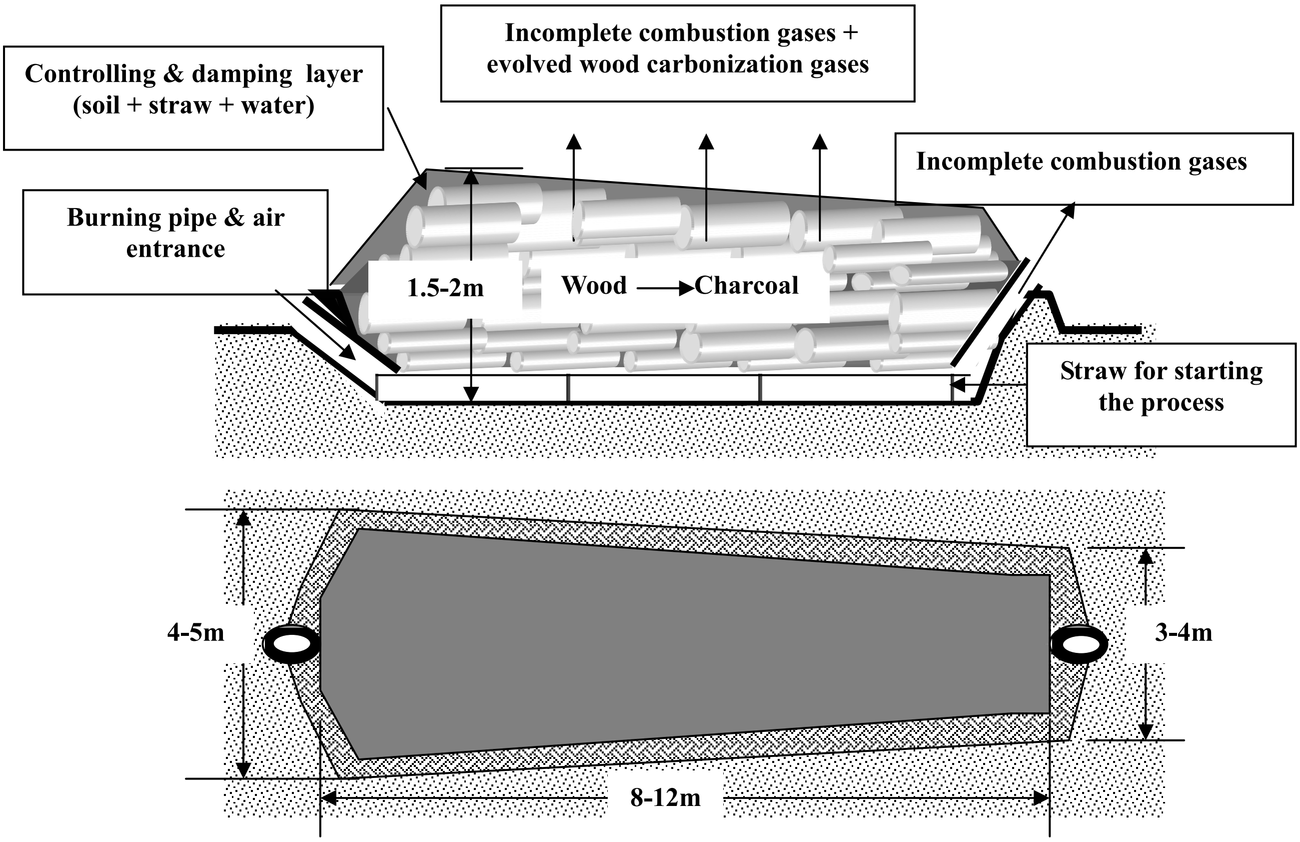

Fig (2) The traditional charcoal process design

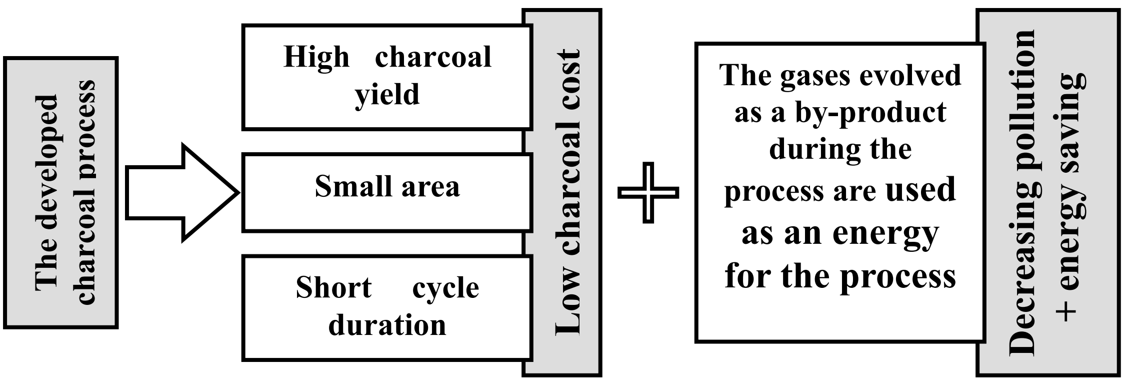

Fig (3) The developed charcoal process main feature

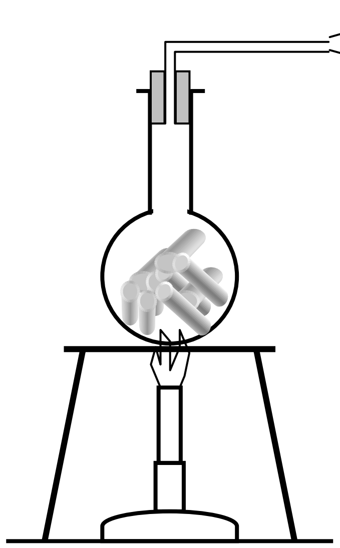

Fig (4-a) VS determination

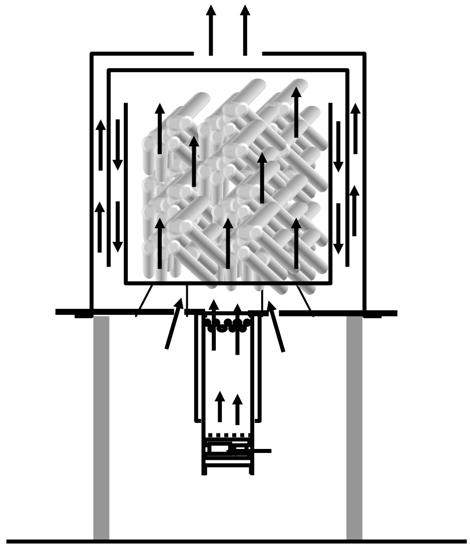

Fig (4-b,c) A vv small kiln from paint cans or barrels

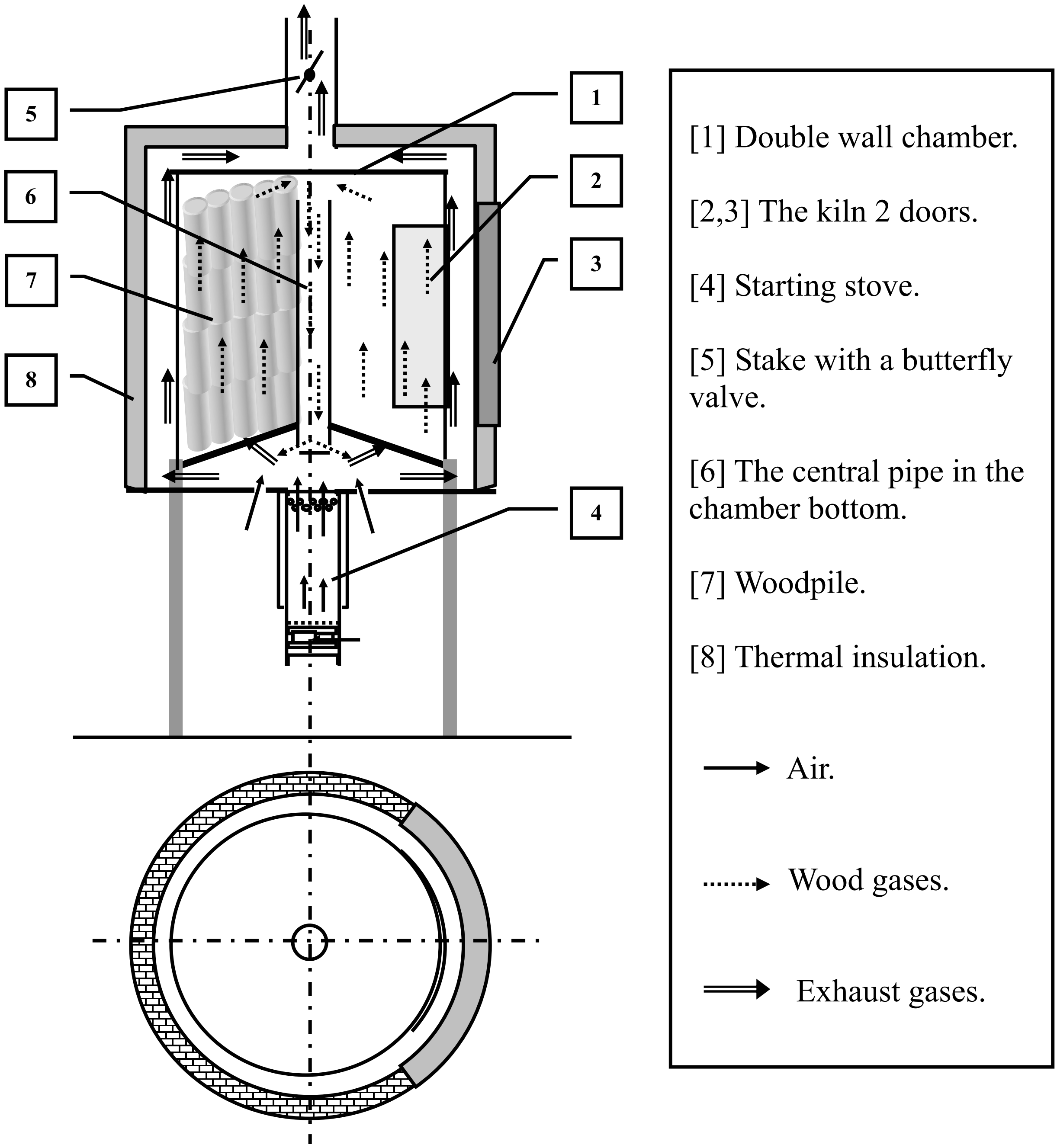

Fig (4-c,d) THE PILOT SIMPLE KILN DESIGN

Fig (5-a) The Flame of Combusting Gases and Vapors after removing the outer pant can in the second trials

Fig (5-b) The Starting Stove of the Pilot Kiln under the Air Entrance

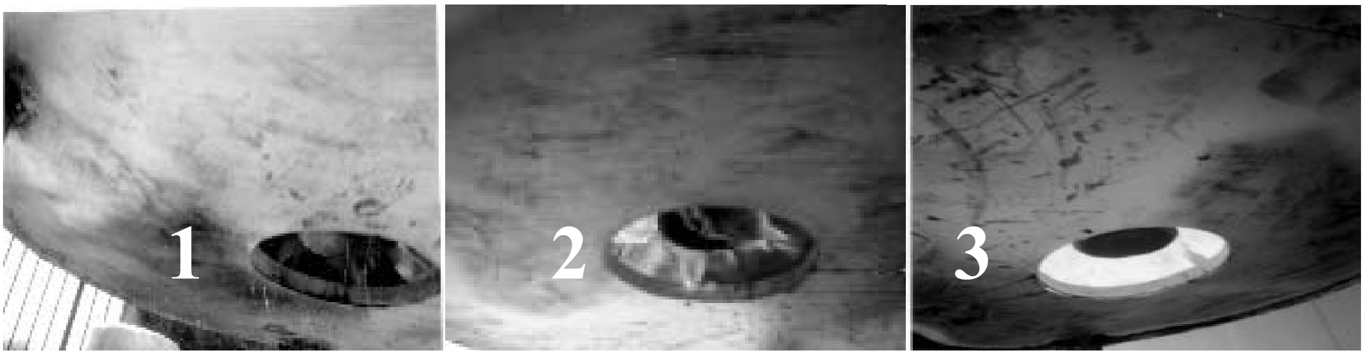

Fig (5-c) The Flame of Combusting Gases and Vapors as it appears from The Pilot Kiln Air Entrance over the starting stove.