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TRADITIONAL POTTERY KILNS FOR TERRACOTTA WARES

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Abstract

Pottery industry is one of the small-scale industries in India. Rural potters usually burn firewood in traditional pottery kilns. In order to produce high quality pottery products, a better burning process is needed and the better burning process is obtained by an ergonomically designed structure kiln. The purpose of the project is to build a more efficient pottery kiln that will be able to achieve uniform temperatures inside the kiln and decrease fuel consumption through better heat distribution. The traditional kilns are bonfire kilns, which involve open firing in a shallow pit. These kilns suffer higher fuel consumption, poor ware strength and extensive breakage. Smokes produced during firing can cause serious health problems for pottery workers and their families. There is a lack of thermally stable and well designed bonfire kilns. Accounting the demerits of traditional one is led to development of energy efficient pottery kiln by changing different parameter of the kiln like change in firewall height, Chimney height and roof geometry, well insulated boundary, substantial improvement in the performance of the kiln will help to increase in production and less hazardous to human health. This modification suggests a new design for a pottery kiln that is more efficient.

Key words: **kiln, firewood, bonfire kilns, fuel consumption, Chimney, roof geometry, insulated boundary.**

1. Introduction :

The growth of rural industrial sector is the key to the development of our rural masses and for this, technical inputs are essential for reducing costs, increasing productivity, and raising the quality of output. One of the rural industrial sectors in our nation is the pottery industry, and many rural families rely on the sale of pottery as a source of income. For several generations. Potters are still using traditional processes for producing pottery. As a result, this pottery is unable to compete with potteries available in the market. Due to the traditional method, the manufacturing cost of pottery is also high. Kindling and controlling fire to bring the hardness, impervious to water etc. in the articles made from clay was at first an art practiced without understanding the benefit of any scientific principles. But from that primitive bonfire or pit kilns to the modern kilns, a long research and development has occurred, experimentation, trial and error and through studies have been performed at every stage.

The pottery industry uses a lot of energy, and the most of the traditional kilns used in rural areas to fire the pottery are relatively inefficient. The small-scale industry cannot afford the high efficiency pottery kilns utilised in the organised sector because to their high cost. The burning process in conventional kilns has to be optimised in order to raise product quality while lowering production costs. A kiln may be described as an enclosure to contain heat and potters use it to fire their pots. So far they have developed a countless number of different kiln type depending upon the demand, traditional, skills and materials.

2. Types of Kiln

2.1 Bonfire Kilns

These kilns are still widely used for firing traditional red clay products and dates back more than 10000 years. There are many local variations of open firing, but the essential procedure involves surrounding the pottery with easily available fuels like straw, grass and cow dung etc. Generally, a shallow pit is dug into ground 14-20 inches deep. Twings, branches or needs are placed in the pit lining, along it's side and bottom. The pots are then placed over this lining. Pots are piled very closely. A layer of broken fragments of fired pottery is placed over the green pots and finally covered by insulating materials like clay and ash etc. (Fig.10.1). fuel is sometime stacked in and around the pieces. In some cases when the pits are made quite deep, most or the fuel is placed at the bottom itself.

Advantages:

i) Fixed structure is not required

ii) Variety of fuel – straw, grass and cow dung etc. can be used which is readily available against no cost.

iii) In Sukuma kilns of Tanzania, the firing takes not more than one and temperature hardly goes up to 700°C. This is good for cooking pots because the clay does not start to sinter, and its open structure can more easily adjust to thermal shock.

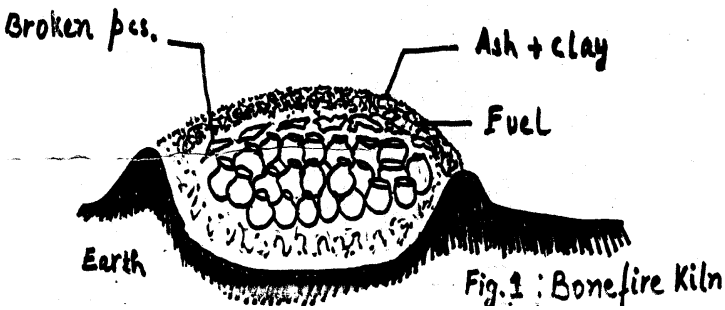

Fig.1 Bornfire Kiln

Limitations:

i) Limited to use in non-rainy season

ii) Temperature seldom exceeds 700°C, sufficient to make porous, low fired earthenware.

iii) Low retention of heat

iv) The wares are often subjected to the direct impingement of the flame and this discolour the pottery wares to black. Thus when black pottery is desired, shredded dung is added at the end of firing to built carbon in pores of the ware.

v) Improper circulation of heat giving rise to non-uniformity of temperature.

2.2 Pit Kilns With Wall

These kilns are still in use in Spain and Mexico. This is a kiln essentially with low circular wall with openings for fires. The circular wall is made of clay or mud which becomes in effect a rudimentary kiln (Fig.2). The upper part of the kiln is built for each firing which is a layer of clay and straw over the pots with small opening left for draft. Firing time is about two to four hours.

Advantages

i) better retention of heat due to circular wall then bonfire kilns.

ii) better system of feeding the wood, which would also allow air for better mixing and circulation of heat as comparison to the bonfire kilns.

iii) this introduction of air at the bottom of pit may yield a gain of 100°C in respect of peak temperature.

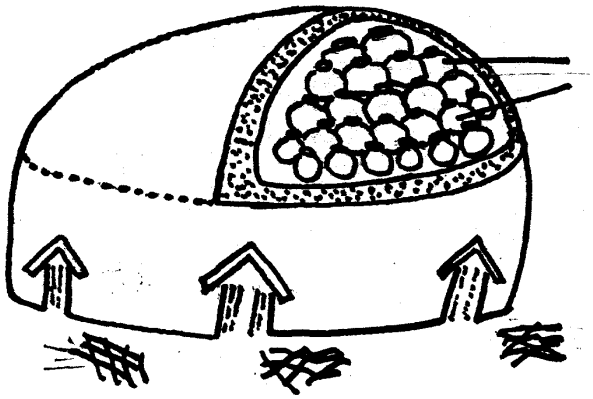

Fig 2. Primitive Kiln

Limitations

i) Same as in bonfire kilns.

2.3 Updraught Kilns

These kilns were firstly developed in Ancient Egypt and Mesopotamia and are still in operation at North Africa, India and Crete.

The form of the kiln is essentially a cylinder, opened at top with an entrance tunnel for the fire provided at bottom. The floor, on which the wares are placed, is made perforated to let the fire pass Fig.3 Open-top Up-draught kiln upward through the wares, escaping from the top. The top of the kiln is covered by broken pieces of wares or tiles. These kilns are 120 cm. to 200 cm. in diameter and the fire mouth is 40 cm. to 60 cm. (Fig. 3).

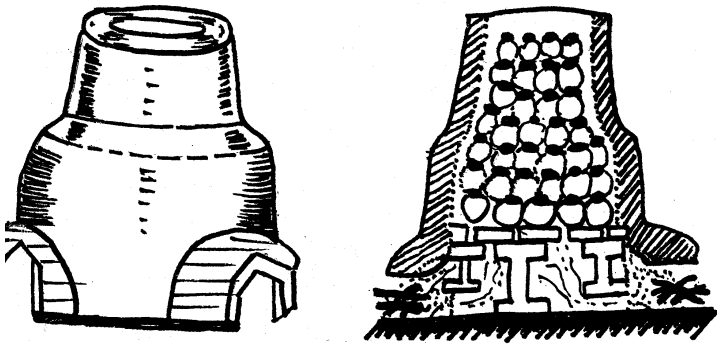

Fig 3. Updraught Kiln

Advantages

i) Better control of fire than pit furnaces.

ii) Better circulation of hot gases and flues, resulting more uniformity in temperature.

iii) Better retention of heat due to walls of higher height then pit furnaces.

iv) The top of kiln can even be covered during the firing to retain heat but allow the escape of sufficient hot gases to create a draft.

v) A temperature up to 900°C can be attained.

Limitations

i) Air entry in these kiln is from fuel feed opening and is not symmetrical, which results in insufficient mixing of air and fuel and also radiation loss from fuel feed opening is high.

ii) No control over fuel burning rate except varying the fuel feed, which is not a better way than to control on air flow.

iii) No arrangement of damper to control excess air or exhaust losses.

iv) skill is required in setting of wares, as more space is left in the area of cold spots so that more hot gases may pass while the spots tending to overheat should stacked more densely.

v) No arrangement of chimney to increase the firing temperature and to improve the direct for combustion efficiency and so to reduce firing time.

2.4 Permanent Updraught Kilns

The design of open to up draught kiln was improved by Greek and Roman people in respect of its permanent dome and the kiln was popularized person people migrating to India. The firing is introduced in to a small tunnel (fire mouth) leading into a chamber (Fig.4).

The wares are loaded from a gets and fired as in open top up draught kilns.

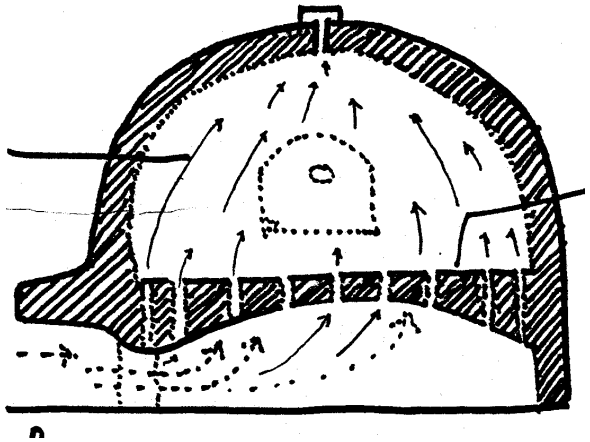

Fig. 4 Up-draught kiln

Advantages over open top up-draught kiln

i) The draught is controlled by opening and closing a hole which gives better uniformity of heat in the kilns.

ii) Better retention of heat.

2.5 European Up-Draught Kilns

The up-draught kilns originated in Germany and came over to Europe where it was further developed and developed to its perfection as bottle kilns. These kilns were widely used until the beginning of the century when they were replaced by down-draught kiln (Fig.5).

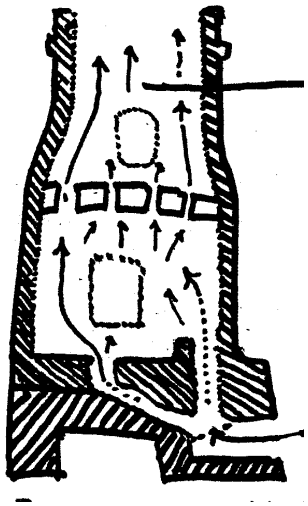

Fig. 5 Bottle kiln

Advantages over open – Top up-draught kilns

i) The wares are placed in saggars to protect it from combustion gases then saggers are loaded from a gate.

ii) Waste heat is partially utilized in a biscuit chamber over the main chamber.

iii) Provision of firing coal on cast iron grate which made it possible to speed up combustion of the fuel to increase firing temperatures and reduce the intake of excess air to increase fuel efficiency.

iv) Addition of chimney on top of chamber creates the extra draught needed to draw combustion air through the grates.

v) Damper is placed at the top to control the draught.

Limitations of up-draught kiln

i) Hot gases passes very fast through the wares so that the heat of gases has little time to be transferred to the wares.

ii) The bottom of the up-draught kiln tends to become hotter as the hot gases strike here first.

iii) Whenever the space left between the wares is no uniform due to faulty loading of wares, this tends to make hot zones.

iv) Up-draught of the gases creates the tendency of hot gases to pass from open spaces by faulty loading easily thereby giving non-uniformity of temperature.

2.6 Down Draught Kilns

These kilns were developed by European and the Khurja kilns are typical examples. In fact the draw-backs of the up draught kilns led to invention of down-draught kilns, where the hot gases are produced in a fire box and these hot gases circular from the fire box to the top of kiln chamber, and are then pulled down through the setting of wares and leave through flue hole in the floor to go to the chimney through flue channels (Fig. 6)

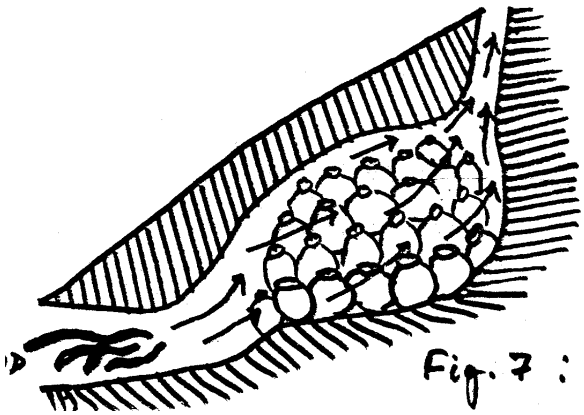

Fig. 6 Downdraught kiln

Advantages over up-draught kiln

i) As the hot gases first go to top and then down ward, the downward movement tends to avoid hot spots and seeks its passage through the cold spots where the downward pull is stronger, In this way the draught will reduce temperature difference by itself.

ii) Bag wall, which directs the hot gases upward also helps to minimize the difference of temperature at top and bottom by lowering the height of bag wall to lower down the temperature of top and vice-versa.

iii) The combustion gases spend a longer time inside the chamber, compared to up-draught kilns. Simply because they have longer path to go and thus more heat is transferred to the wares and consequently fuel is saved.

Disadvantages

i) Height of chimney is to be on higher side to create strong pull, which is required to create the draft for movement of gases downward and finally through chimney.

ii) Cost of construction is high.

iii) External bracing is required as in up-draught kilns.

2.7 Cross – Draught Kilns

The cross draught kilns were originated in far-east and as in case of up-draught kilns these kilns must have been developed from open bone fire kilns. In these type of cross-draught kilns, the heat goes from one side and out on the other side and passes through the pottery wares. These kilns are easier to construct than down-draught kilns but the temperature uniformity is limited. There are different kilns based on cross-draught system of flues and are mentioned as below :

2.7.1 Cave Kilns

These cave kilns were used in Japan & China from other country. These early cave kilns

of Japan may seem crude and rudim entry but beautiful high fired stone wares were produced. Potters found that higher temperatures could be reached by enclosing the fire, instead of building up a wall around the fire like bonfire & up-draught kilns, the potters hollowed out a cave into a bank of clay. The lower served as a fire box and the hot gases were carried through the ware across the cave chamber and out through the flue hole. Such kilns were capable of firing stone wares. The main chamber was about 4 to 5 feet across, three feet high and ten to twelve feet long. The cave was shaped at an angle of about 30 degree. The entrance of the kiln was just large enough for a man to crawl through and a flue hole and was at the back and loading to ground level above (Fig.7)

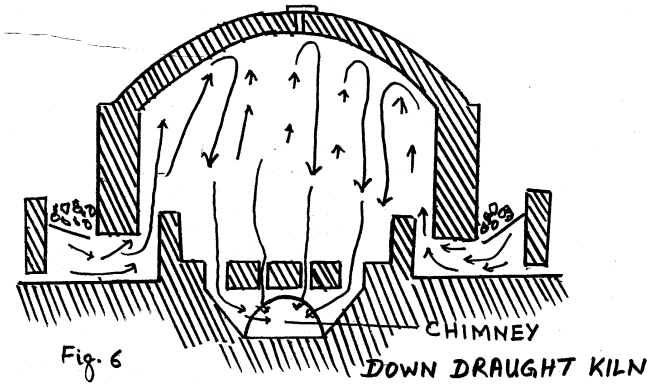

Fig.7 Cave Kiln

Advantages over Bone fire Kilns

i) Since the kiln was completely enclosed and backed up with earth, retention of heat is better.

ii) Heat was forced into a cross draught path, instead of sweeping directly upward.

iii) Having diminishing cross-section towards the flue it helped to promote uniformity of temperature and as the hot gases passed through the constricted rear of the kiln, increased velocity & the Heat transfer to the wares more.

Disadvantage / limitations

i) Compared to Down draught kilns the heat transfer from hot gases & flames to wares is low.

iii) Setting of wares is little difficult.

2.7.2 Tube Kilns

The cave kiln, supposedly, was made quite longer until it was developed in to the long slopping design about one thousand years ago in the far east. These tube kilns are 50 years old and are still in use. The kiln chamber is a long uninterrupted type with an exit on top. The tube is fire-box and the combustion gases go through the whole kiln to the top exist and transfer all of their heat to wares on the way when the lower section has reached maturing temperature, stocking in to next section of tube kiln begin through side holes just above the matured section (Fig. 8).

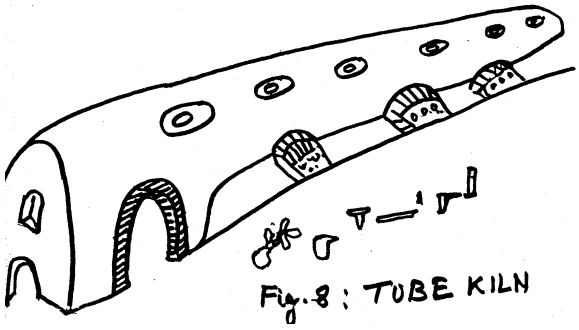

Fig.8 Tube Kiln

Advantages

i) The combustion air enters through the fire box and it is very hot when it reaches the firing zone. In this way firing slowly moves upward until the whole kilns is fired.

Limitations

i) Movement of hot gases and flames is cross-draft, which is not better than Down Draught movement of the same.

2.7.3 Chamber Kiln

In China, the tube kilns were further developed by breaking up the long tube into separate but connected chambers. The design makes use of down draft circulation with the exhaust heat through which the heat is passed from one chamber to the next chamber, which is a limitation in tube kilns.

When the whole chamber is loaded with wares, fire is ignited in the main fire mouth. This is a dome enclosure with a grate for holding the fuel and passage to admit fresh air. The fire is kept low at first to dry out the ware, then gradually the temperature is increased. The heat from the fire mouth warms the whole kiln and a strong draught develops in the ascending chambers. When maximum heat is reached in the fire mouth, the first chamber will have reached in the red heat stage or more throughout at the desired peak temperature. Fuel is then fed into the first chamber through the openings of fuel feed and wood burns rapidly because of air for combustion is pre-heated as it passes through the main fire-mouth when the temperature reaches in the second chamber. Preheated air reaches this chamber from the cooling first chamber (Fig. 9).

Advantages

i) Architecturally, the structure is self supporting, hence no external bracing is necessary.

ii) Dome, being of Catenary type, expanding domes rise without strain on any part of the kiln during heating.

iii) Firing is quite rapid, therefore, lack of insulation is not a great disadvantage.

iv) The blow holes at the top of each chamber may be opened during firing to permit moisture to escape and to allow some of the flame to escape, so as to create initial draught for better firing.

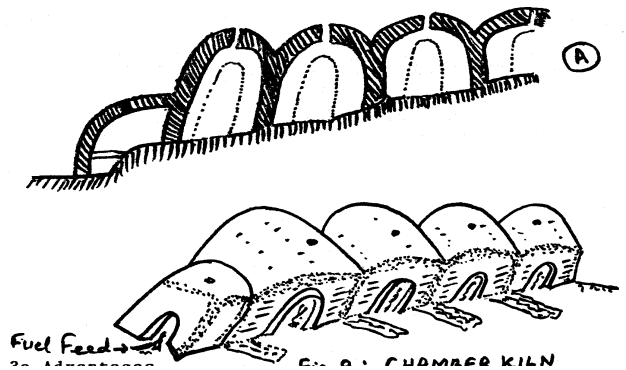

Fig.9 Chamber Kiln

Limitations

i) Tendency towards rapid cooling as all the air for combustion passes through the previous chamber tends to cool.

ii) Uniformity of temperature is not so good as compared to Down-draught kilns.

2.8 Wood burning Kiln

a. The traditional method is still used extensively, particularly by the rural potters all over the country where alternative sources of energy are not available. One of the virtues of this kiln can be erected and made ready for use in a day's time and at the same time can easily be reconstructed if it does not work satisfactorily.

b. However, disadvantages of a wood fired kiln are many and it has since turned out to be almost prohibitive in view of the scarcity and rising cost

of fire wood. In the meantime indiscriminate destruction of wood for burning purposes has created ecological imbalance in the country.

c. A wood fired kiln can not be recommended because:

- It takes more space, and wood is very difficult to collect, handle, dry and store;
- It takes more time to fire and attain the required temperature. Moreover, it does not give more than 850°C temperature which is not adequate for glaze firing;
- To operate, it is physically troublesome and tiring:
- Temperature in a wood fired kiln cannot be regulated
- It has become more uneconomic due to increase in the price of wood.

2.9 Gas Fired Kiln

a. Glazed pottery is possible only if the firing system can be fully controlled and regulated and the required temperature provided evenly at a minimum of 1100°C. In a traditional wood fired kiln, which cannot generate more than 850°C, the temperature cannot be regulated; therefore, it is neither adequate nor appropriate for glazes pottery.

b. A General survey has been conducted in some places where gas fired systems are in operation. It was found that nearly 2 tonnes of fired wood are required to generated 850°C as against a gas fired kiln costing little more for a single firing with a temperature ranging between 1050°C to 1150°C. As such gas fired kiln is more economical with desired results for glazed pottery compared to wood burning kiln. A gas fired kiln is also relatively more efficient and economic for biscuit firing.

c. The developed gas fired kiln (5'X4'X5') is supported by iron straps round the walls in 4 corners against any possible crack due to high pressure of gas inside. There is a chimney as an outlet of the heat as also an electric motor fitted for increasing the pressure of gas through air circulation, which provides substantial economy in gas consumption. Heat generated in a gas fired kiln is around 1100°C and is suitable for proper burning of different pottery articles both at biscuit and glaze stages although glaze fire needs relatively higher temperature.

2.10 Oil Fired Kiln

a. Oil fired kiln looks like the same as that of a gas fired kiln except that an oil fired kiln has an oil reservoir attached on the top along with an electric motor which is connected with two pipes leading to the back side of the kiln where they are joined with the kiln. Separated into two parts, they then pass along the two sides of the kiln. These pipes are fitted with two burners in the upper side and two burners in the lower side. These four burners exert heat from behind a refractory partition which, while keeping the fire from directly reaching the arranged materials, burn them properly. This type of kiln and can burn the pottery items up to a maximum of 1200°C temperature.

b. While the investment cost of an oil fired kiln is about the same as that of a gas fired kiln, the fuel cost in the case of the former higher compared to the latter with the efficiency remaining at about the same level.

2.10.1 Portable Oil Fired Kiln :

The Low-cost Portable Oil fire kiln is used for firing glazed and unglazed Terracotta Wares. Hitherto, the village potters fire their products in an open hearth, popularly known as "Clamp", utilizing organic matters like leaves, straws, grass, cow-dung, coconut fibre wood, other agricultural waste etc. as fuel. These are the oldest traditional kilns used for firing unglazed wares only but could not be used for firing Glazed Terracotta wares satisfactorily till now.

Keeping in view the production of Glazed terracotta wares. Which is not possible in the traditional kilns and without saggers even in other types of wood fired kilns. To overcome this scenario, this Low cost Portable oil fired kiln has been designed and developed.

Basically, if we summarized, there traditional kilns are not dependable due to several draw-backs such as :-

i) The kilns are open without any walls except few with walls of small height (`2') resulting problem in loading of wares and non-uniformity in temperature due

to movement of winds through kiln (through the cracks developed during firing in mud plaster).

ii) Plenty of heat energy is wasted, resulting lower thermal efficiency.

iii) Difficult to load the articles, being no regular platform as a result the articles are loaded generally in way which arrest the entry of adequate air-supply.

iv) Due to inadequate supply of air and irregular circulation of gases inside the kiln, the wares are generally produced non-uniform in colour and occasionally with black patches.

v) Without any controls devices in the traditional kilns, they are difficult to operate for controlled rise of temperature, resulting high rejection of goods.

vi) Finally, these kilns cannot be operated in rainy seasons.

Later on, these types of kiln were also gradually converted into pit-type kiln with low height wall at some places, (up-draft kilns). But all these development could not upgrade the technique of firing of Glazed Terracotta wares as well as improve the thermal performance of kilns.

The said kiln will create a new avenues for quality up-gradation and diversification of products like glazed terracotta wares for the rural potters, which will improve their economical status as well as fulfil the needs of common people as well as create job opportunities in the rural areas. The distinguished feature compared to prior art are furnished.

The Portable Oil Fired Kiln for firing Glazed and Unglazed Terracotta Wares can be used for biscuiting and glost firing together in one operation. The Portable Oil fired kiln for firing Glazed and Unglazed terracotta wares is portable and is readily available in modular, pre-fabricated parts. The use of ceramic fibre has made the portable oil fired kiln for firing glazed and unglazed terracotta wares of low mass and of low heat storage.

The Portable Oil Fired Kiln for firing glazed and unglazed terracotta wares is more eco-friendly and easy to operate than traditional kilns. The Portable Oil Fired Kiln for firing glazed and Unglazed terracotta wares is thermally efficient than traditional kilns and thus the peak temperature can be attained as high as 1150oC as compared to 750oC, generally attainable in traditional kilns. The fuel Combustion device (Burners) can be operated for providing Oxidizing as well as Reducing conditions during firing of glazes and unglazed terracotta wares.

3. Conclusion

The above study provides the different types of traditional kilns with their advantages and disadvantages. By minimising the limitations of kilns and by providing some modifications, they can be a fuel and money saver for traditional potters. These kilns suffer from higher fuel consumption, poor ware strength and extensive breakage. It is also not affordable for small potters. Smoke produced during firing can cause serious health problems for pottery workers and their families. There is a lack of thermally stable and well designed bonfire kilns. Accounting the demerits of traditional one has led to the development of an energy efficient pottery kiln by changing different parameters of the kiln like firewall height, chimney height and roof geometry, well insulated boundary, and substantial improvement in the performance of the kiln will help to increase production and be less hazardous to human health. With acquiring such a modification, the development of an energy efficient kiln is under progress.

4. References

[1]. Adegoke, O.S. et al (1987) “Summary of Raw Materials Occurrence” Guid to Non – Metallic Industrial Potentials of Nigeria Vol 1, P. 180-195

2] “Energy Efficiency in Ceramic Processing” Practical Worksheets for Industry, Produce by Tangram Technology Ltd.

[3] Status report on Ceramic Industry at Khurja, U.P (India) by T.P.Bhattacharya, CSIR-CGCRI, Kolkata, March 1982.

[4] Publication in the Book entitled “Practical Guide to Energy Conservation in Ceramic Industry” PCRA, New Delhi, (2012)

[5] J. Durakovic, S. Delalic,“Temperature Field Analysis of Tunnel Kiln for Brick Production”, RMZ-Materials and Geo Environment, Vol. 53, No. 3, 2006.

[6] Agberia J. T.1993. Design and Construction of a Gas-Fired Kiln for Ceramics Production. Nigerian Journal of Technical Education. Vol. 10 No 1&2. Planning Division, National Board for Technical Education, Kaduna.