



# Wall Building

## Technical Brief

Building Advisory Service and Information Network

### Firing of clay bricks and tiles

#### Introduction

This technical brief is the last of four and deals with firing of clay brick and tiles. The other briefs are concerned with "Preparation of clay for brickmaking", "Moulding" and "Drying of clay bricks and tiles". Fired bricks for house construction is the preferred building material in most developing countries. However, quite a number of brickworks have ceased production because of fuel shortage and/or rising fuel prices: In industrialised countries strict pollution restrictions are nowadays applied on emissions from brick kilns. If such restrictions would fully be applied in developing countries, quite a number of brickworks would have to be shut down considering their present emissions.

In many developing countries clay bricks are still fired in clamps. Nearly five times as much wood is often required to operate a wood-fired clamp compared with any other industrial kiln. Some minor modifications in the construction of the clamp and an appropriate burning process can help to achieve a considerable saving of precious firewood. Changing to oil-fired kilns or other fuel sources is mostly out of question for the small-scale, artisanal brick producer, because of the necessary high investment for adequate furnaces and equipment.

Emphasis is laid in this technical brief on showing:

- how fuel saving can be achieved,
- how the quality of burnt bricks and tiles can be improved,
- how wastage of fired clay products can be reduced, and
- how kiln waste heat can be utilised by using intermittent operated kilns.

#### Firing in the brickmaking process

Firing of clay bricks and tiles is the last stage in the production process of burnt

clay bricks and tiles and has to be professionally managed. During this process the brickmaker is confronted with fundamental problems, such as how to reduce the high rate of breakage, and how to fire with a minimum of energy input and at the same time achieving the highest possible out-put of first-grade products. Kiln personnel has normally to work in shifts, exposed to heat, smoke and dust. Because of these constraints a brickworks manager is always confronted with the search for and training of suitable personnel for this production process. In addition he has to find ways to ease the work at the kilns. Rising fuel prices cause tremendous problems, especially for small-scale brick and tile producers in developing countries. As a result many brick producers are beginning to pay attention to the use of agricultural wastes in brickmaking, although they have little or no experience in the utilisation of waste for firing. This equally applies to the use of fossil fuels.

#### Brick kilns

There are a large number of different types of kilns which can be classified e.g. according to the type of firing systems or structural forms. These kilns are divided in periodic or intermittent and continuous operated kilns. According to the direction of heat/smoke flow kilns are furthermore sub-divided into three classes:

- up-draught firing;
- down-draught firing;
- horizontal-draught firing (Table 1).

Note: This technical brief will not cover the different kiln designs (see "References")

Figures on energy consumption, output and grade of quality can vary very much depending on the nature of clay, firing temperature and size of the kiln as is shown in Table 2.

<b>Periodic or intermittent kiln (up-draught, no chimney)</b>	<ul style="list-style-type: none"> <li>• Clamp</li> <li>• Vertical shaft brick kiln (VSBK)</li> </ul>
<b>Periodic or intermittent kiln (down-draught, operated with chimney)</b>	<ul style="list-style-type: none"> <li>• Scotch kiln</li> <li>• Round kiln</li> <li>• Annular kiln</li> <li>• Zig-zag kiln (archless)</li> </ul>
<b>Continuous kiln (horizontal draught, operated with chimney)</b>	<ul style="list-style-type: none"> <li>• Bull's trench kiln (archless)</li> <li>• Hoffmann kiln</li> <li>• Tunnel kiln</li> </ul>

Table 1: Types of brick kilns according to the flow direction of waste gases

Kiln type	Rate of energy in %	Rate of 1st grade quality in %	Output, bricks in thousands
Clamp	100	30 - 60	3 - 50
Clamp, improved	80	50 - 80	5 - 200
Scotch	70	60 - 90	5 - 100
Bull's trench	50	60 - 90	100 - 2.000
Hoffmann	40	70 - 90	80 - 500
Tunnel	20	90 - 98	70 - 500
VSBK	20	90 - 95	4 - 6 in one shaft

Table 2: Different types of kilns, their energy consumption, rate of product quality and production output.



Fig. 1: Sealing of the clamp's top against heat loss; leaving smoke outlets

## Firing processes and terms

The behaviour of dried clay bricks and tiles during the firing process depends on the composition of the clay, the grain size distribution of the raw product, the rate of shrinkage, the firing temperature and the maturing time. In order to produce a mechanically strong and durable building component the "green" product is being fired in three stages: pre-heating (or water smoking), firing, and cooling.

### First stage:

#### Pre-heating or water-smoking

Drying of green products is a purely physical process. Firing of the product changes the mineral association of the clay through chemical and physical reactions. At first, the residual mixing or pore water, still inherent in the brick or tile has to be removed prior to the full heat exposure, transforming clay into a ceramic body. Evaporation takes place above 100° C and ends when the clay body reaches approximately 150° C. For pre-

heating plenty of air movement through the kiln is required to prevent body defects which occur during water smoking and can cause discoloration of the bricks and tiles. The more residual water remains in the dried brick or tile, the longer water-smoking will last, and the more energy is needed. Therefore only well dried green products should be stacked into the kiln.

If no more water can be detected, the rise of temperature continues steadily up to around 400° C, at which moment the chemically combined water of crystallisation is released. From this moment onwards the process enters into the stage of "firing". It should be noted that some clays which have heated too rapidly may later sustain heating damage.

#### Practical hints:

1. A loose setting of bricks and tiles in the kiln is essential to allow free access of hot air and fast escape of water vapour.

2. Presence of water vapour can be tested by holding a cold piece of metal or glass into the escaping smoke. Vapour will condense on it as droplets.
3. Heating rate is reduced by increasing the air volume, thus reducing condensation of vapour on the bricks.

### Second stage: Firing

During the firing stage clay particles are irreversibly transformed into solid bodies by silicate bonding (= sintering or vitrification). This transformation takes place in the temperature range up to 900° C. It is a complex and sensitive process which is accompanied by shrinkage of the clay body. Firing is only successful during this stage if two factors are observed:

- Constant increase of temperature.
- Holding the top temperature for several hours, if not for a full day, particularly in clamp kilns with poor heat distribution. The time of holding an evenly high temperature is known as "soaking" or





Fig. 3: Combined firing system: Firewood is fed on the bottom. Coffee husks are fed from above. Fire holes are covered with pieces of sheet-metal



Fig. 2: Bricks stacked with a finger's width between them

"maturing", which is essential to bind the clay body into a strong unit.

Correct firing needs permanent control and supervision of the whole process. Unless this stage is well completed, the next stage, "cooling" of a large mass of thousands of bricks should not be started.

#### Practical hints:

1. Back flow of smoke and heat, which occurs mainly in clamps, can only be remedied by setting the stacked bricks one finger wide apart, and/or by enlarging smoke flues, and/or by opening flue dampers, and/or by sealing the clamp walls against false air leakage.
2. The rising of firing temperature can be checked by inserting  $\frac{3}{4}$  inch diam. steel pipes into the kiln walls at different heights or through vertical flues situated in the kiln ceiling. Colour gradation varies from dark red (approximately at  $450^{\circ}\text{C}$ ) to red (at  $800^{\circ}\text{C}$ ), light red (at  $950^{\circ}\text{C}$ ), yellowish-white (at  $1050^{\circ}\text{C}$ ).

3. A temperature below  $400^{\circ}\text{C}$  can be estimated by inserting a wooden peg. The quicker that catches fire, the higher the temperature.
4. The heating rate should be slow in simple brick kilns because of lack of temperature control and difficulties in precise fuel feeding.
5. In chimney operated kilns the firing speed can be checked with a draught gage: An open-ended glass U-tube, filled with water can measure the draught or suction at any point of the kiln by inserting one end of it into an opening in the kiln flue. The difference in the water level indicates whether the flue(s) should be opened or closed.

The end of firing (stop of fuel feed) can be determined by checking the allowed rate of shrinkage. In brick kilns with vaults: Measure the gap between vault and upper layer of bricks.

In clamp kilns: The incline of the kiln's top gives an indication of the process of sintering (vitrification).





Fig. 4: Clamp dug into sloping ground

### Third stage: cooling

The glassy material which formed while the top temperature was maintained for several hours is very sensitive to cooling down. There was a slow, continuous rise in temperature at the beginning of the firing. Likewise there should now be a continuous fall of the temperature in the kiln. This stage of firing must be controlled as well. During cooling down clay products should contract at a steady rate. Too rapid cooling will result in cracked bricks, especially if the brick clay is sandy. The cooling "speed" has therefore to be determined by the characteristics of the clay. Bricks are normally discharged from the kiln when they have reached outside air temperature.

### Practical hints:

1. Too rapid cooling can be stopped by insulating the clamp with an additional layer of mud.
2. Ensure that clamp and/or kiln walls and ceilings are airtight.
3. Cooling speed is increased by partly opening the firing hole(s), flue(s) or damper(s).

### How to improve the efficiency of clamps

As mentioned before, energy consumption in field clamps is high compared

with any other type of kiln. Another disadvantage of clamp firing is the resulting low rate of first grade bricks which is mainly due to very poor kiln insulation, dense stacking of green bricks and the uncontrolled influx of cold air into the firing holes which are open during the firing process.

Good insulation of the clamp walls and the ceiling, and a better loose brick stacking will ensure a thorough burning of all bricks, including those placed on the outer stacks and edges of the clamp. Thus energy consumption in clamps could be reduced by 20 to 40 %. The rate of first grade bricks can rise up to 80 %. Energy efficiency of clamps can be improved by:

1. "Jacketing" the outer clamp walls with broken bricks and "puddling" with a thick layer of mud.
2. Constructing a "permanent" firing tunnel with burnt bricks and mud mortar.
3. Covering the ceiling of the kiln with two layers of broken bricks and sealing these with two layers of mud (Fig. 1).
4. Stacking bricks with a finger's width between them (Fig. 2) to allow vapour

to escape and kiln heat to reach up the approximately 30 courses.

5. Covering the fire holes with pieces of sheet-metal (Fig. 3)

### How to utilise waste heat from clamps dug into a slope

A sloping terrain is ideal for firing bricks in clamps dug into a slope (Fig. 4). Three kiln walls are set against natural ground and are thus "protected" against heat loss. Only the front wall with the firing holes needs to be sealed. The kiln top can be covered with soil and mud prior to the beginning of the cooling process. Such a well enclosed mass of fired bricks contains an enormous amount of heat. This could be utilised for pre-heating green bricks in a second kiln.

Waste heat normally escapes through the walls and top of a clamp. In clamps built into a sloping site it could be collected in a flue at the rear end of the "bottom" kiln and led into the firing holes of another kiln put up into the slope above the first clamp (Fig. 5 and 6).



Fig. 5: Bottom and top kiln

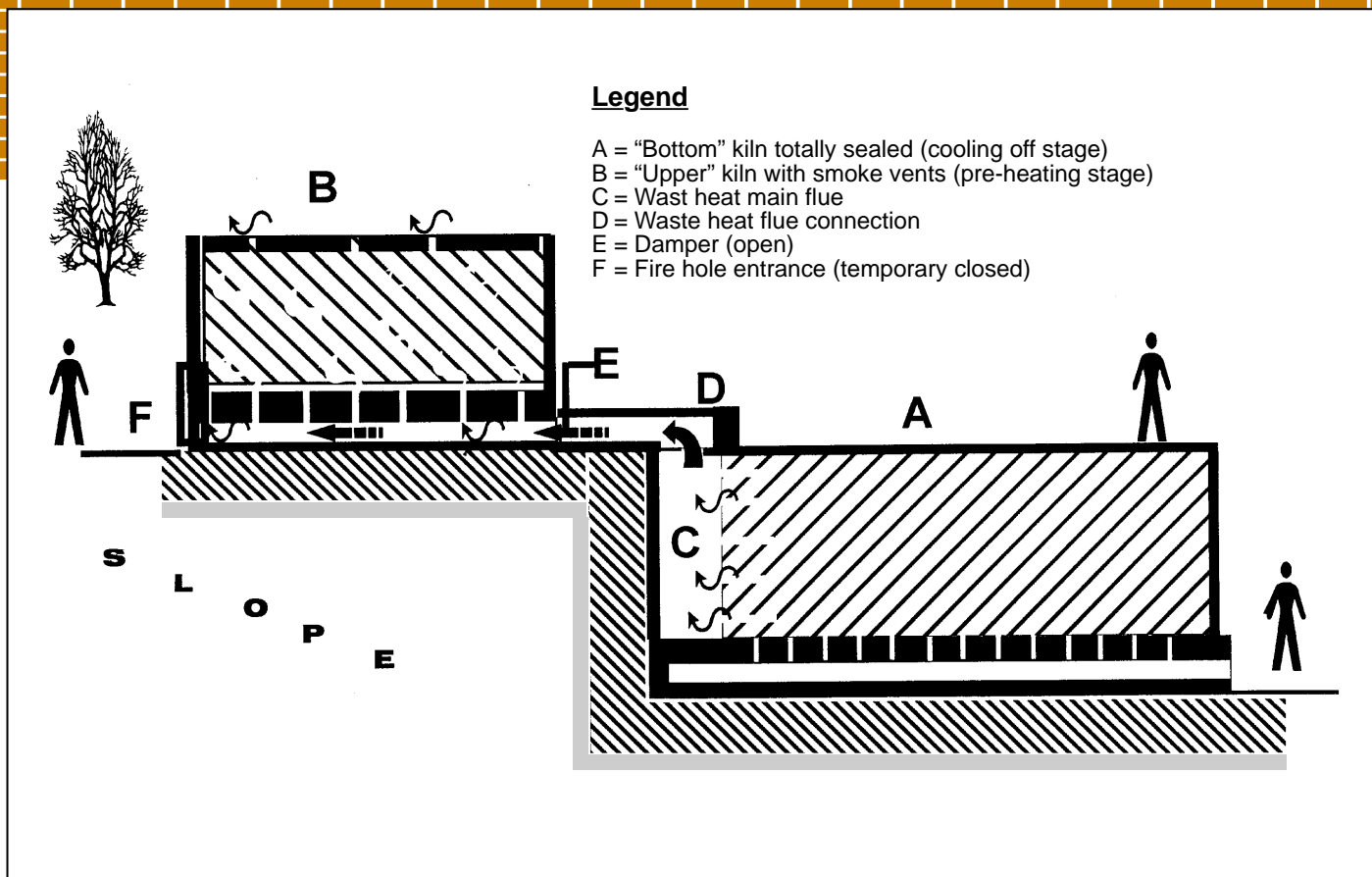


Fig. 6: Clamps at different levels; pre-heating kiln B with waste heat from kiln A.

Waste heat can also be utilised if individual kilns are grouped around a single chimney. Hot flue gases can be conducted from one kiln to pre-heat the next one. Firing takes place in one kiln and at the same time green bricks in the next kiln are pre-heated, and so on.

### How to utilise agricultural wastes for firing

Agricultural wastes, such as coffee husk, rice husk, saw dust, etc. can be blended with the clay raw material in the preparation process. These substances then burn completely within the clay body during the firing process.

Another possibility is to throw husks, coconut shells and/or maize cobs into the firing holes as additional fuel to the firewood, which has to be burned first. Only when the ignition heat is sufficient will the husks blaze up and immediately release additional amounts of heat. Once the backflow of heat has begun, charging is stopped and the next fire hole is fed. The permanent clamp kiln shown in Fig. 3 is fuelled with coffee husks from bins set into the outer kiln walls above some firing holes. The husks descend into the fire hole through a gear-controlled rotary

feed mechanism. Firewood can thus be saved considerably this way. Another feeding method is blowing coffee or rice husks into the fire holes by means of an electric blower.

### The Vertical shaft brick kiln (VSBK)

An economical up-draught brick kiln for small-scale brickmaking has been developed in China using coal fines as fuel. The vertical shaft brick kiln is a very useful alternative to small- and medium-scale brick producers who plan to operate their kilns continuously. The VSBK, however, needs particularly well trained personnel to run it. It also requires green bricks for the charges of high quality. The kiln's extremely energy-efficient firing process combined with a minimum of air pollution is its biggest advantage in comparison with other kiln types. It also ensures a quick payback within a few years of the invested capital to the brick producer, after firing has commenced.

### Possible causes and remedies of faults in fired bricks and tiles

Because the burning process of bricks and tiles takes place inside the kiln and is

not "visible" from the outside, it is difficult to monitor this process throughout. It is also difficult to "read" and interpret the firing results, if the burnt product appears different from what is actually expected. To minimise any faults a constant quality control during the firing process is indispensable. Table 3 lists possible faults, their causes and remedies.

### Considerations of economics and flexibility

Large kilns are generally more economical in the use of fuel compared to smaller kilns. If a number of kilns are "interconnected", it is easier to utilise waste heat in the drying process or for pre-heating. Small-scale brickmakers could form a co-operative and thus use a larger kiln on co-operative basis. They would have lower firing costs, higher output with a better quality. A combination of traditional brickmaking techniques, such as hand-moulding, with chimney-operated brick kilns which can utilise waste heat is absolutely feasible. But expert advice on the correct steps to be taken in the firing process of clay bricks and tiles is advisable and also available.

Fault	Cause or source	Remedy
Defects of sizes and shape	Raw material; clay preparation; moulding; drying	Analyse raw material; control the processing
Spalling or chipping; multiple surface cracks	Heating sensitivity; vapour stress; too close brick stacking; too short drying time	Reduce temperature; loosen stacked bricks; reduce residual water content
Sumping; standing marks	Raw material; temperature too high; too many layers stacked on each other	Analyse raw material; reduce temperature and/or soaking; reduce layers of stacked bricks
Large cracks	Too rapid increase of temperature above 600° C	Slow down firing speed; check extruder's end screw
Fine cracks	Too rapid cooling; sensitive clay; influx of cold air into fire holes	Reduce cooling speed; analyse clay; stop influx of cold air
Underfiring	Temperature too low; soaking or maturing ignored; false air inleakage	Increase temperature; ensure time for soaking; improve sealing
Efflorescence	Pre-heating stage; condensation of water vapour on cold brick	Reduce pre-heating speed; loosen stacked bricks
Efflorescence after delivery at building site	Soluble salts inherent in clay; insufficient soaking time	Can disappear with rain, otherwise contact laboratory
Lime blowing after kiln discharge	Absorption of moisture	Change to other clay deposit for different raw material

Table 3: Possible faults in burnt bricks and tiles, their causes and remedies

## Conclusion

Where professional skills and technical infrastructure are insufficient, and where the market fluctuates, a production at small scale level is preferred. Brick and tile producers who continue to use only firewood for the firing process will one day have to stop pro-

duction either due to increasing costs of firewood, to ever scarcer access to this type of fuel and also due to imposed environmental restrictions.

An attempt should be made to use alternative fuels and other kiln types. In this brickworks managers can seek external expert assistance; they can collaborate much closer with other local brick and

tile producers; they can contact ceramic professionals in their country for planning an economical and commercially viable production process, and for training the necessary personnel; they should regularly consult with local fuel suppliers; and they should really check with government offices on environmental issues.

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Text, tables, drawing and photographs by and further information from:

Gerhard Merschmeyer  
Energy Saving Brickmaking Consulting/Planning/Training  
Theodor-Fontane-Str.13  
D-26160 Bad Zwischenahn / Germany

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**gate**

German Appropriate Technology Exchange  
Dag-Hammarskjöld-Weg 1 - 5  
Postfach 51 80  
D-65726 Eschborn Germany  
Phone + 49 - 6169 - 79-3095  
Fax + 49 - 6196 - 79-7352  
e-mail: gate-basin@gtz.de  
(2000)

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