Fixed Chimney Bull’s Trench Kiln (FCBTK) technology is the most widely used brick firing technology in South Asian countries. It is a continuous, moving fire kiln in which the fire is always burning and moving forward in the direction of air flow due to the draught provided by a chimney. The bricks are being warmed, fired and cooled simultaneously in different parts of the kiln.

It is a modified version of Bull’s trench kiln introduced by a British engineer W. Bull in 18761. Initially it had movable metal chimneys which were placed on the brick setting and were moved as the firing progressed. This technology was modified to more efficient and less polluting fixed chimney Bull’s Trench Kilns and there was a large scale shift to fixed chimney Bull’s trench kilns (FCBTKs) due to a regulatory ban on use of moving chimney kilns during 1990’s in India, followed by similar regulations in Bangladesh and Nepal.

### Enterprises Using This Technology

<table>
<thead>
<tr>
<th>Kiln</th>
<th>Nature of enterprise</th>
<th>Level of mechanization</th>
<th>Brick produced</th>
<th>Production capacity</th>
<th>Operational season</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCBTK</td>
<td>CONTINUOUS MOVING FIRE</td>
<td>INDUSTRIAL</td>
<td>MANUAL</td>
<td>SOLID</td>
<td>MEDIUM Between 1-10 million bricks</td>
</tr>
</tbody>
</table>

### Number of Operational Enterprises and Total Production

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of enterprises</th>
<th>Total production billion bricks/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>India*</td>
<td>35,000</td>
<td>185</td>
</tr>
<tr>
<td>Pakistan*</td>
<td>11,500</td>
<td>56</td>
</tr>
<tr>
<td>Bangladesh*</td>
<td>4,500</td>
<td>17.4</td>
</tr>
<tr>
<td>Nepal*</td>
<td>450</td>
<td>2.3</td>
</tr>
<tr>
<td>Total</td>
<td>51,450</td>
<td>260.7</td>
</tr>
</tbody>
</table>

*Numbers are estimates only

**PER ANNUM CONTRIBUTION TO TOTAL BRICK PRODUCTION IN INDIA, PAKISTAN, BANGLADESH AND NEPAL**

79% Approximately 260 BILLION BRICKS
FACTSHEETS ABOUT BRICK KILNS IN SOUTH AND SOUTH-EAST ASIA

1 FIXED CHIMNEY BULL’S TRENCH KILN (FCBTK)

DESCRIPTION AND WORKING

1. In FCBTK, the fire moves in a closed circular or oval circuit (central perimeter 180-220 m) through the bricks stacked in the annular space between the outer and the inner wall of the kiln.

2. The kiln does not have a permanent roof and bricks stacked in the kiln are covered with a layer of ash & brick dust, which acts as a temporary roof and inhibits the heat loss as well as seals the kiln from leakages.

3. It operates under the natural draught provided by the chimney (20 – 38 m high) located at the center of the kiln.

4. There are 3 distinct zones in an operating FCBTK:
   4.1. Brick firing zone where the fuel is fed and combustion is happening.
   4.2. Brick preheating zone (in front of the firing zone) where green bricks are stacked and being preheated by the flue gases and
   4.3. Brick cooling zone (behind the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

5. Air Inlet: Air enters into the kiln from back end of the cooling zone which is kept open to allow air entrance.
   5.2. Seal to guide flue gas: Front end of the preheating zone is sealed to guide the flue gas to chimney through the flue gas duct system.

6. Solid fuels like coal, firewood, agriculture residue etc are fed from the feed holes provided at the top of the kiln by the two firemen standing on the top of the kiln. Fuel is fed at an interval of every 15-20 minutes and each fuel feeding lasts for 5-10 minutes.

7. The fire travels a distance of 6-10 m in 24 hours and fires 20,000 to 50,000 bricks. Daily, fired bricks are unloaded from the front of the brick cooling zone (7.1) and an equivalent batch of green bricks is loaded ahead of the brick preheating zone (7.2).
FIXED CHIMNEY BULL’S TRENCH KILN (FCBTK)

AIR EMISSIONS AND IMPACTS

MEASURED EMISSION FACTORS

<table>
<thead>
<tr>
<th>g/kg of fired bricks</th>
<th>CO2</th>
<th>Black Carbon</th>
<th>PM</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>131</td>
<td>0.13</td>
<td>1.38</td>
<td>2.0</td>
</tr>
<tr>
<td>Range</td>
<td>94.7-163.8</td>
<td>0.07-0.28</td>
<td>0.26-2.63</td>
<td>1.09-3.36</td>
</tr>
</tbody>
</table>

MEASURED PM EMISSIONS

Average: 570 mg/Nm3
(Range: 150 - 1250 mg/Nm3)

Emissions standards for brick kilns in South and South-East Asia

- Nepal: 700 for forced draught kilns
- Bangladesh: 1000
- Pakistan: Emission standards not notified
- India: 1000 for small kilns
- Nepal: 700 for natural draught kilns
- Bangladesh: 1000
- Nepal: 600 for forced draught kilns
- Nepal: 700 for natural draught kilns

SPECIFIC ENERGY CONSUMPTION

Energy consumed for firing 1 kg of fired brick
Average: 1.30 MJ/kg of fired bricks
(Range: 1.1 - 1.46 MJ/kg of fired brick)

MECHANISMS OF HEAT LOSS

- Losses from the kiln surface
- Heat loss through the chimney
- Heat loss through the flue gas

PRODUCT QUALITY

- 70% of bricks meet the quality standards
- 30% of bricks are inferior in quality

INFERIOR BRICK

- Under-fired and over-burnt
- Poor insulating properties

GOOD BRICK

- Well-fired and well-burnt
- Good insulating properties

COMMENTS ON EMISSIONS

- Poor fuel feeding practices and incomplete combustion in an FCBTK result in high emissions of PM and gaseous pollutants leading to poor air quality around FCBTK clusters.
- A significant part of the PM emissions consist of smaller particles (PM<sub>2.5</sub> and black carbon) which has adverse effects on human health and local vegetation.

MAIN CAUSES FOR HEAT LOSS

- Incomplete combustion of coal and heat losses from the kiln surface are the two main sources of heat loss in an FCBTK.

CAPITAL COST BREAKDOWN

- Construction Material: 84%
- Labour: 15%
- Equipment: 1%

Exposure to Respirable Suspended Particulate Matter

- Flue gases exhausted from the chimney, ash covering and unpaved surfaces around an FCBTK result in very high concentration of dust in the surrounding environment and the workers are exposed to high concentration of respirable suspended particulate matter (RSPM).

Risk of accidents

- As FCBTKs do not have a permanent roof, there is always a danger of caving-in of the brick setting or falling off the kiln structure and this poses serious risks of accidents.

Exposure to Thermal Stress

- Workers such as fireman, while working on the kiln top are exposed directly to radiation from the kiln roof and flames.

Compliance with ILO standards and remarks on migratory labour and conditions of labour

- Practices followed at FCBTK enterprises do not comply with the International Labour Standards.
- Majority of the workers of FCBTK are seasonal migrants and they along with their families work on the kilns. They live in temporary housing with poor access to basic amenities like safe drinking water, electricity, education, health and sanitation.
Facts about FCBTK, the most commonly used kiln.

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>FCBTK</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR EMISSION (g/kg FIRED BRICK)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td>131</td>
<td>Incomplete combustion in FCBTK results in high value of emissions. The average value of PM emissions lie within the notified limit, however, some of the kilns emit higher PM.</td>
</tr>
<tr>
<td>Black Carbon</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>1.18</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>FUEL &amp; ENERGY (SEC (MJ/kg fired brick))</td>
<td>1.30</td>
<td>Incomplete combustion and heat losses result in increase in the fuel consumption in FCBTK.</td>
</tr>
<tr>
<td>FINANCIAL PERFORMANCE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital Cost (USD)</td>
<td>50,000-80,000</td>
<td>Low capital investment and high return is one of the main reasons for popularity of FCBTK technology among brick makers.</td>
</tr>
<tr>
<td>Production Capacity</td>
<td>3-8 million bricks/year</td>
<td></td>
</tr>
<tr>
<td>Simple Payback</td>
<td>0.4 – 1.1 years</td>
<td></td>
</tr>
<tr>
<td>PRODUCT QUALITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Types of product</td>
<td>All types of product</td>
<td>Non-uniform temperature distribution across the kiln cross-section results in variation in product quality.</td>
</tr>
<tr>
<td>Good Quality Product</td>
<td>60 %</td>
<td></td>
</tr>
<tr>
<td>OHS Exposure to dust</td>
<td></td>
<td>FCBTK has poor OHS conditions and it is a major shortcoming of this technology.</td>
</tr>
<tr>
<td>OHS Exposure to Thermal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of accidents</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FOR MORE INFORMATION: www.gkspl.in/whats_new.html  www.accobrick.in

REFERENCES
3 Pritpal Singh. Presentation at the seminar on cleaner brick production held at Patna on 06th December 2012 organised by Bihar Pollution Control Board and Development Alternatives.
10 Ibid.

I. International Labour Standards are instruments drawn up by ILO in the form of conventions (the basic principles to be implemented) and recommendations (more detailed guidelines). Details on the standards for OHS can be found at http://www.ilo.org/public/2002standards/subjects-covered-by-international-labour-standards/occupational-safety-and-health/lang--en/index.htm. A list of all such Instruments on OHS with their status is available at HYPERLINK "http://www.ilo.org/dyn/normlex/en/"
INTRODUCTION AND HISTORY1, 2
Natural Draught Zigzag Firing kiln is a continuous, cross draught, moving fire kiln in which the air flows in a zigzag path due to the draught provided by a chimney. It has many similarities with FCBTK technology; the main difference being the zigzag air flow path.

Zigzag firing concept was first used in Buhrer kiln (Patented in 1868). The concept was later used in Habla kilns. In India, Central Building Research Institute (CBRI) first introduced the zigzag firing technology based on induced draught (with the help of a fan) during early 1970’s.

As per available information, Natural Draught Zigzag firing technology was first used in India in 1997 by Priya Bricks in Kolkata by modifying an existing FCBTK. The technology was adopted by Prayag Clay Products at Varanasi and, through them, has been propagated to more than 50 kilns by the end of 2013. It is now gaining popularity as an alternate to FCBTK technology.

ABOUT THE KILN
Kiln Nature of enterprise Level of mechanization Brick produced Production capacity Operational season
CONTINUOUS MOVING FIRE INDUSTRIAL MANUAL SOLID MEDIUM Between 1-10 million bricks DRY SEASON

ENTERPRISES USING THIS TECHNOLOGY
Country Number of enterprises Total production billion bricks/year
India3 ~50 ~0.25

% CONTRIBUTION TO THE TOTAL BRICK PRODUCTION IN INDIA
~1%

Out of the total annual production of 250 billion bricks in India, only around 250 million bricks are produced by Natural Draught Zigzag firing technology.

GEOGRAPHICAL DISTRIBUTION

NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION*
Country Number of enterprises Total production billion bricks/year
India3 ~50 ~0.25

*Numbers are estimates only.

~1%

Out of the total annual production of 250 billion bricks in India, only around 250 million bricks are produced by Natural Draught Zigzag firing technology.
FACTSHEETS ABOUT BRICK KILNS IN SOUTH AND SOUTH-EAST ASIA

**Natural Draught Zigzag Firing Technology (Zigzag ND)**

**Description and Working**

1. Natural Draught Zigzag firing kiln is a moving fire kiln in which the fire moves in a closed rectangular circuit (central perimeter 140-180 m) through the bricks stacked in the annular space between the outer and the inner wall of the kiln.

2. It operates under the natural draught provided by the chimney (30 - 40 m high) located at the center of the kiln.

3. The bricks are stacked in such a manner to form distinct chambers (~2 m long) and guide the air flow in a zigzag path. Zigzag flow increases the air flow path length and turbulence in the air, thereby resulting in improved combustion & heat transfer rate and uniform temperature across the kiln cross section.

4. The kiln does not have a permanent roof and bricks stacked in the kiln are covered with a layer of ash & brick dust, which acts as a temporary roof and inhibits the heat loss as well as seals the kiln from leakages.

5. There are 3 distinct zones in an operating zigzag kiln:
   - **Firing zone**
     - 5.1 Brick firing zone where the fuel is fed and combustion is happening.
     - 5.2 Brick preheating zone (in front of the firing zone) where green bricks are stacked and being preheated by the flue gases.
     - 5.3 Brick cooling zone (behind the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

6. **Air Inlet:** Air enters into the kiln from back end of the cooling zone which is kept open to allow air entrance.
   - 6.1 Air Inlet: Air enters into the kiln from back end of the cooling zone which is kept open to allow air entrance.
   - 6.2 Seal to guide flue gas: Front end of the preheating zone is sealed by a plastic sheet to guide the flue gas to chimney through the flue gas duct system.

7. **Firing zone**
   - 7.1 Firing zone extends to 6 chambers (~12 m) and solid fuels like coal, firewood, agriculture residue etc are fed through the feed holes provided at the top of the kiln continuously by a single fireman standing on the top of the kiln.

8. **Fire travel**
   - 8.1 The fire travels a distance of 6-7 m in 24 hours and fires 20,000 to 50,000 bricks. Daily, fired bricks are unloaded from the front of the brick cooling zone (8.1) and an equivalent batch of unfired bricks is loaded ahead of the brick preheating zone (8.2).
FACTSHEETS ABOUT BRICK KILNS IN SOUTH AND SOUTH-EAST ASIA

NATURAL DRAUGHT ZIGZAG FIRING TECHNOLOGY (ZIGZAG ND)

AIR EMISSIONS AND IMPACTS

FUELS AND ENERGY

FINANCIAL PERFORMANCE

PRODUCT QUALITY

OCCUPATIONAL HEALTH AND SAFETY

MEASURED EMISSION FACTORS

<table>
<thead>
<tr>
<th>g/kg of fired bricks</th>
<th>CO2</th>
<th>Black Carbon</th>
<th>PM</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>0.01</td>
<td>0.22</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>0.005-0.07</td>
<td>0.04-0.47</td>
<td>0.21-0.57</td>
<td></td>
</tr>
</tbody>
</table>

MEASURED PM EMISSIONS

Average: 144 mg/Nm³
(31– 263 mg/Nm³)

EMISSION STANDARDS

Notified for PM only

Country | PM (mg/Nm³) |
---------|-------------|
India   | 1000 for small kilns < 15000 bricks per day
        | 750 for large kilns > 15000 bricks per day

COMMENTS ON EMISSIONS

Improved combustion in a natural draught zigzag kiln results in significantly low emissions of PM and CO. Also the long path traversed by flue gases due to zigzag flow helps in settling of the particulate matter in the kiln.

SPECIAL ENERGY CONSUMPTION

Energy consumed for firing 1 kg of fired brick
Average: 1.066 MJ/kg of fired bricks
(Range: 1.02 - 1.21 MJ/kg of fired brick)

Capital cost breakdown

| Construction Material | 84% |
| Labour               | 19% |
| Equipment            | 1%  |

Capital cost of kiln technology
For annual production capacity of 3 – 8 million bricks, excluding land and working capital cost
50,000 to 80,000 USD

Product Quality
As per the local market perception
GOOD – 85%
INFERIOR – 10%
LOSSES & BREAKAGES – 5%

Better heat distribution in the kiln results in uniform temperature across the kiln cross section in the firing zone. This results in uniform quality of bricks across the kiln cross-section.

Types of product that can be fired in the kiln
Solid bricks ✔
Hollow/ Perforated bricks ✔
Roof tiles ✔
Floor tiles ✔

Usually only solid bricks and to some extent hollow bricks are fired in natural draught zigzag kiln, however, other products can also be fired in combination with the solid bricks.

COMMONLY USED FUELS

Coal
Most commonly used

Biomass
Eg. sawdust, firewood, biomass briquettes

Industrial waste/by-products
Eg. pet-coke, used rubber tyres

SPECIFIC ENERGY CONSUMPTION

Energy consumed for firing 1 kg of fired brick
Average: 1.06 MJ/kg of fired bricks
(Range: 1.02 - 1.21 MJ/kg of fired brick)

Note: Measured at firing temperature of 900-1100°C

PROFILS OF EXPOSURE

Exposure to Respirable Suspended Particulate Matter
Ash covering, brick dust and unpaved surfaces around natural draught zigzag kiln result in high concentration of dust in the surrounding environment and the workers are exposed to high concentration of respirable suspended particulate matter (RSPM).

This results in high incidence of respiratory tract infections and cardiovascular diseases among workers.

Exposure to Thermal Stress
Workers such as fireman, while working on the kiln top are exposed directly to radiation from the kiln roof and flames.

This results in eye & skin diseases and dehydration among workers.

Risk of accidents
As this kiln do not have a permanent roof, there is always a danger of caving-in of the brick setting or falling off the kiln structure and this poses serious risks of accidents.

High risk of injuries

Compliance with ILO standards and remarks on migratory labour and conditions of labour
Practices followed at natural draught zigzag kiln enterprises do not comply with the International Labour Standards on occupational health and safety drawn up by ILO. 8

Majority of the workers of natural draught zigzag kiln are seasonal migrants and they along with their families work on the kilns. They live in temporary housing with poor access to basic amenities like safe drinking water, electricity, education, health and sanitation.

Construction Material 84%
Labour 15%
Equipment 1%

Capital cost breakdown
Capital cost of kiln technology
For annual production capacity of 3 – 8 million bricks, excluding land and working capital cost
50,000 to 80,000 USD

Production capacity
20,000 to 50,000 bricks per day

Number of Operators required
30-40

Payback Period
Simple Payback 0.3 – 0.9 years
Discounted Payback (@ 6.5%) 0.3 – 1 years

Types of product that can be fired in the kiln
Solid bricks ✔
Hollow/ Perforated bricks ✔
Roof tiles ✔
Floor tiles ✔

Usually only solid bricks and to some extent hollow bricks are fired in natural draught zigzag kiln, however, other products can also be fired in combination with the solid bricks.

Inferior ~ 10%
Losses & Breakages ~ 5%
GOOD ~ 85%

As per the local market perception

Notes

1. Measured at firing temperature of 900-1100°C

2. Exposure to Respirable Suspended Particulate Matter

3. Exposure to Thermal Stress

4. Risk of accidents

5. High risk of injuries

6. Notified for PM only

7. Compliance with ILO standards and remarks on migratory labour and conditions of labour

8. As this kiln do not have a permanent roof, there is always a danger of caving-in of the brick setting or falling off the kiln structure and this poses serious risks of accidents.

9. The causes of heat loss

Heat losses from the kiln surfaces are the main source of heat loss in a natural draught zigzag kiln.

Better heat distribution in the kiln results in uniform temperature across the kiln cross section in the firing zone. This results in uniform quality of bricks across the kiln cross-section.

Types of product that can be fired in the kiln
Solid bricks
Hollow/ Perforated bricks
Roof tiles
Floor tiles

Usually only solid bricks and to some extent hollow bricks are fired in natural draught zigzag kiln, however, other products can also be fired in combination with the solid bricks.

Notes

1. Measured at firing temperature of 900-1100°C

2. Exposure to Respirable Suspended Particulate Matter

3. Exposure to Thermal Stress

4. Risk of accidents

5. High risk of injuries

6. Notified for PM only

7. Compliance with ILO standards and remarks on migratory labour and conditions of labour

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Notes

1. Measured at firing temperature of 900-1100°C

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3. Exposure to Thermal Stress

4. Risk of accidents

5. High risk of injuries

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Roof tiles
Floor tiles

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Notes

1. Measured at firing temperature of 900-1100°C

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3. Exposure to Thermal Stress

4. Risk of accidents

5. High risk of injuries

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9. The causes of heat loss

Heat losses from the kiln surfaces are the main source of heat loss in a natural draught zigzag kiln.

Better heat distribution in the kiln results in uniform temperature across the kiln cross section in the firing zone. This results in uniform quality of bricks across the kiln cross-section.
Performance of natural draught zigzag kiln is compared with the most commonly used continuous kiln technology in the region which is FCBTK.

### REFERENCES
6. Note on ‘Occupational health and safety study (OHS) of brick industry in the Kathmandu valley’ by Department of Environmental Sciences and Engineering (DESE), Kathmandu University, Nepal
7. Ibid.

### ACKNOWLEDGEMENTS
The project team would like to acknowledge the financial support received from the Swiss Agency for Development and Cooperation for preparation of the fact-sheets. A large part of the information on natural draught zigzag kiln has been sourced from Prayag Clay Products Pvt. Ltd. (www.pcppl.in). This is gratefully acknowledged.

Note: In the initial stage of this initiative of developing fact-sheets on brick kiln technologies, fact-sheets are developed for South and South-East Asia and Latin America regions. Fact-sheets on brick kiln technologies of other regions will be developed over time.

Disclaimer: The country borders indicated on the map do not necessarily reflect the FFDAs official position. The red dotted line represents the Line of Actual Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

Acknowledgements to the International Labour Standards and OHS in the construction sector.

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Web: www.gkspl.in

FOR MORE INFORMATION:
www.gkspl.in/letsint_new.html
www.wcdelhi.in
HIGH/INDUCED DRAUGHT ZIGZAG FIRING TECHNOLOGY (ZIGZAG HD)

INTRODUCTION AND HISTORY

High/Induced Draught Zigzag Firing kiln is a continuous, cross draught, moving fire kiln in which the air flows in a zigzag path. The draught required for the air flow is provided by a fan.

Zigzag firing concept was first used in Buhrer kiln (Patented in 1868) which was similar to a Hoffmann kiln in construction. This concept was later used in Habla kilns, which were widely used in Germany between the first and Second World Wars. They were also very popular in Australia.

In India, high draught zigzag firing technology was first introduced by Central Building Research Institute (CBRI) during early 1970’s which, later on, was replicated in Bangladesh and Nepal. In the last forty years, many modifications have happened to the original design and several different variations of high draught zigzag kilns can be found in the field.

GEOPGRAPHICAL DISTRIBUTION

INDBIA
PAKISTAN
BHUTAN
BURMA
NEPAL
BANGLADESH

NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION* IN INDIA, BANGLADESH AND NEPAL

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of enterprises</th>
<th>Total production billion bricks/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>~2000</td>
<td>~10</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>~150</td>
<td>~0.75</td>
</tr>
<tr>
<td>Nepal</td>
<td>~150</td>
<td>~0.60</td>
</tr>
</tbody>
</table>

*Numbers are estimates only

% CONTRIBUTION TO THE TOTAL BRICK PRODUCTION IN INDIA, BANGLADESH AND NEPAL

-4% Out of the total annual production of around 270 billion bricks in India, Bangladesh and Nepal, only around 11 billion bricks are produced by high draught zigzag firing technology.
FACTSHEETS ABOUT BRICK KILNS IN SOUTH AND SOUTH-EAST ASIA

The chimney is usually of lower height (15 - 30 m) and the kiln operates under the draught provided by a fan which draws the flue gases from the kiln and discharges it through the chimney. In the original design chimney was located on one side of the kiln and was connected with the kiln through an underground tunnel. However, in the modified designs (especially in eastern India), chimney is located at the center of the kiln.

The bricks are stacked in such a manner to form distinct chambers (~2.5 m long) and guide the air flow in a zigzag path. Zigzag flow increases the air flow path length and turbulence in the air, thereby resulting in improved combustion & heat transfer rate and uniform temperature across the kiln cross section.

There are 3 distinct zones in an operating high draft kiln:
5.1 Brick firing zone where the fuel is fed and combustion is happening,
5.2 Brick preheating zone (in front of the firing zone) where green bricks are stacked and being preheated by the flue gases and
5.3 Brick cooling zone (behind the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

Firing zone extends to 3 chambers (~7.5 m) and solid fuels like coal, firewood, agriculture residue etc are fed through the feed holes provided at the top of the kiln continuously by a single fireman standing on the top of the kiln.

The fire travels a distance of 2 chambers (~5 m) in 24 hours and fires 15,000 to 40,000 bricks. Daily, fired bricks are unloaded from the front of the brick cooling zone (8.1) and an equivalent batch of green bricks is loaded ahead of the brick preheating zone (8.2).

The kiln does not have a permanent roof and bricks stacked in the kiln are covered with a layer of ash & brick dust, which acts as a temporary roof and inhibits the heat loss as well as seals the kiln from leakages. The double layered outer wall with clay filled in between also reduces the heat loss.

Cooling zone
Firing zone
Preheating zone
Fuel feed holes
**High/Induced Draught Zigzag Firing Technology (ZIGZAG HD)**

### Air Emissions and Impacts

**Measured Emission Factors**

<table>
<thead>
<tr>
<th>g/kg of fired bricks</th>
<th>CO2</th>
<th>Black Carbon</th>
<th>PM</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>1.62</td>
<td>0.24</td>
<td>0.02</td>
<td>0.005</td>
</tr>
<tr>
<td>I05</td>
<td>1.62</td>
<td>0.24</td>
<td>0.02</td>
<td>0.005</td>
</tr>
<tr>
<td>Range</td>
<td>100.2-117.1</td>
<td>0.0-0.05</td>
<td>0.09-0.47</td>
<td>0.85-2.37</td>
</tr>
</tbody>
</table>

**Emission Standards**

Notified for PM only

<table>
<thead>
<tr>
<th>Country</th>
<th>PM (mg/Nm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>1000</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>1000</td>
</tr>
<tr>
<td>Nepal</td>
<td>600</td>
</tr>
</tbody>
</table>

**Comments on Emissions**

Improved combustion in a high draught zigzag kiln results in significantly low emissions of PM and CO. Also the long path traversed by flue gases due to zigzag flow helps in settling of the particulate matter in the kiln.

### Fuels and Energy

**Commonly Used Fuels**

- **Coal**: Most commonly used
- **Biomass**: Eg. sawdust, firewood, biomass briquettes
- **Industrial waste/by-products**: Eg. pet-coke, used rubber tyres

**Specific Energy Consumption**

Average: 1.03 MJ/kg of fired brick

(Range: 0.95 - 1.11 MJ/kg of fired brick)

**Energy Consumed for Firing 1 kg of Fired Brick**

Average: 1.03 MJ/kg of fired brick

(Range: 0.95 - 1.11 MJ/kg of fired brick)

**Capital Cost Breakdown**

- **Construction Material**: 75%
- **Labour**: 15%
- **Equipment**: 12%

**Product Quality**

- **As per the local market perception**: 50,000 to 80,000 USD

**Better heat distribution in the kiln results in uniform temperature across the kiln cross-section in the firing zone. This results in uniform quality of bricks across the kiln cross-section.**

**Types of Product that can be fired in the Kiln**

- Solid bricks
- Hollow/Perforated bricks
- Roof tiles
- Floor tiles

**Usually only solid bricks and to some extent hollow bricks are fired in high draught zigzag kiln, however, other products can also be fired in combination with the solid bricks.**

### Financial Performance

**Capital Cost of Kiln Technology**

For annual production capacity of 2.5 - 6 million bricks, excluding land and working capital cost

**50,000 to 80,000 USD**

### Product Quality

**Product Quality**

- **As per the local market perception**

**Good - 80%**

**Inferior - 15%**

**Losses & Breakages - 5%**

**Capital cost breakdown**

- **Construction Material**: 75%
- **Labour**: 15%
- **Equipment**: 12%

### Occupational Health and Safety

**Exposure to Respirable Suspended Particulate Matter**: Ash covering, brick dust and unpaved surfaces around high draught zigzag kiln result in high concentration of dust in the surrounding environment and the workers are exposed to high concentration of respirable suspended particulate matter (RSPM).

This results in high incidence of respiratory tract infections and cardiovascular diseases among workers.

**Exposure to Thermal Stress**: Workers such as fireman, while working on the kiln top are exposed directly to radiation from the kiln roof and flames.

This results in eye & skin diseases and dehydration among workers.

**Risk of Accidents**: As this kiln does not have a permanent roof, there is always a danger of caving-in of the brick setting or falling off the kiln structure and this poses serious risks of accidents.

**High risk of injuries**

**Compliance with ILO standards and remarks**

Practices followed at high draught zigzag kiln enterprises do not comply with the International Labour Standards on occupational health and safety drawn up by ILO.

Majority of the workers of high draught zigzag kiln are seasonal migrants and they along with their families work on the kilns. They live in temporary housing with poor access to basic amenities like safe drinking water, electricity, education, health and sanitation.

**Inferior Brick**

Under-fired and over-burnt

**Good Brick**

Not under-fired and over-burnt
3 HIGH/INDUCED DRAUGHT ZIGZAG FIRING TECHNOLOGY (ZIGZAG HD)

CONCLUSION

Performance of high draught zigzag kiln is compared with the most commonly used continuous kiln technology in the region which is FCBTK.

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>HIGH DRAUGHT ZIGZAG</th>
<th>FCBTK</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR EMISSION (g/kg FIRED BRICK)</td>
<td></td>
<td></td>
<td>High draught zigzag kiln emits ~80% lower PM and ~85% lower Black Carbon as compared to FCBTKs. This is mainly because of better combustion of fuel and settling of particulates in the kiln itself due to zigzag flow: Emission of CO2 and CO from zigzag kiln is lower because of less consumption of fuel and improved combustion.</td>
</tr>
<tr>
<td>CO</td>
<td>105</td>
<td>131</td>
<td></td>
</tr>
<tr>
<td>Black Carbon</td>
<td>0.02</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>0.24</td>
<td>1.18</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>1.62</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>FUEL &amp; ENERGY</td>
<td></td>
<td></td>
<td>High draught zigzag kiln consumes ~20% less fuel as compared to FCBTK because of better combustion and heat recovery.</td>
</tr>
<tr>
<td>SEC (MJ/kg fired brick)</td>
<td>1.03</td>
<td>1.30</td>
<td></td>
</tr>
<tr>
<td>FINANCIAL PERFORMANCE</td>
<td></td>
<td></td>
<td>Capital cost of setting up a high draught zigzag kiln is slightly higher than that of an FCBTK for same production capacity. This is because of cost incurred for fan. However, due to less fuel consumption and better product quality, payback period for high draught zigzag kiln is equivalent to FCBTK.</td>
</tr>
<tr>
<td>Capital Cost (USD)</td>
<td>50,000-80,000</td>
<td>50,000-80,000</td>
<td></td>
</tr>
<tr>
<td>Production Capacity</td>
<td>2.5-6 million bricks/year</td>
<td>3-8 million bricks/year</td>
<td>The range of products of high draught zigzag kiln is the same as that of FCBTK. But due to improved combustion and uniform temperature attained throughout the kiln cross-section in high draught zigzag kiln, product quality is improved.</td>
</tr>
<tr>
<td>Simple Payback</td>
<td>0.4 – 11 years</td>
<td>0.4 – 11 years</td>
<td>The simple payback for high draught zigzag kiln is equivalent to FCBTK.</td>
</tr>
<tr>
<td>PRODUCT QUALITY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Types of product</td>
<td>All kind of products</td>
<td>All kind of products</td>
<td>The range of products of high draught zigzag kiln is the same as that of FCBTK. But due to improved combustion and uniform temperature attained throughout the kiln cross-section in high draught zigzag kiln, product quality is improved.</td>
</tr>
<tr>
<td>Good Quality Product</td>
<td>80 %</td>
<td>60 %</td>
<td></td>
</tr>
<tr>
<td>OHS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure to dust</td>
<td></td>
<td></td>
<td>On OHS, high draught zigzag kiln offers no improvement over FCBTK. Both kilns have poor OHS conditions, which is a major shortcoming of these technologies.</td>
</tr>
<tr>
<td>Exposure to Thermal stress</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of accidents</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

REFERENCES

3 Presentation by Punjab State Council for Science and Technology, India on the findings of the study on ‘Revision of Comprehensive Industry Document for Brick Kilns’.
4 Ibid. 2
8 Report on 'Occupational health and safety (OHS) of brick industry in the Kathmandu valley’ by Department of Environmental Sciences and Engineering (DESE), Kathmandu University, Nepal
9 Ibid.
10 International Labour Standards are instruments drawn up by ILO in the form of conventions (the basic principles to be implemented) and recommendations (more detailed guidelines). Details on the standards for OHS can be found at http://www.ilo.org/global/standards/subjects-covered-by-international-labour-standards/occupational-safety-and-health/lang--en/index.htm. A list of all such instruments on OHS with their status is available at http://www.ilo.org/dyn/normlex/en/f?p=100:103:0::NO:::OCCUPUNIVERSAL:1

FOR MORE INFORMATION:

www.gkspl.in/whats_new.html, www.ecobrick.in

ACKNOWLEDGEMENTS

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Design & Illustration
Shoili Kanungo

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INTRODUCTION AND HISTORY

Vertical shaft brick kiln (VSBK) is a continuous, updraft, moving ware kiln in which the fire remains stationary while there is counter current heat exchange between air (moving upward) and bricks (moving downward).

The VSBK technology has evolved from the traditional up-draught kilns in rural China during late 1950s; however, the widespread dissemination of the technology took place after the economic reforms. At its peak during the mid 1990s, thousands of VSBKs were reported to be operating in China. Since 1990, under different technology transfer projects the technology has been transferred to several developing countries including India, Nepal and Vietnam. Whereas the dissemination of VSBK technology in India and Nepal has been relatively slow, the experience in Vietnam has been very positive. Vietnamese brick makers have been able to innovate and have added new features to the technology, and in the process have transformed a rural technology into an industrial technology.

ABOVE THE KILN

ENTERPRISES USING THIS TECHNOLOGY

<table>
<thead>
<tr>
<th>Kiln</th>
<th>Nature of enterprise</th>
<th>Level of mechanization</th>
<th>Brick produced</th>
<th>Production capacity</th>
<th>Operational season</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTINUOUS MOVING WARE</td>
<td>INDUSTRIAL</td>
<td>SEMI MECHANIZED</td>
<td>SOLID</td>
<td>SMALL &amp; MEDIUM Between 0.5-10 million bricks</td>
<td>PERENNIAL</td>
</tr>
</tbody>
</table>

GEOGRAPHICAL DISTRIBUTION

NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION IN INDIA, NEPAL AND VIETNAM

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of enterprises</th>
<th>Total production billion bricks/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>India¹</td>
<td>~110</td>
<td>~0.3</td>
</tr>
<tr>
<td>Nepal²</td>
<td>~25</td>
<td>~0.1</td>
</tr>
<tr>
<td>Vietnam³</td>
<td>~600</td>
<td>~1.8</td>
</tr>
</tbody>
</table>

¹Numbers are estimates only

% CONTRIBUTION TO THE TOTAL BRICK PRODUCTION IN INDIA, NEPAL AND VIETNAM

Out of the total annual production of around 280 billion bricks in India, Nepal and Vietnam only around 2.2 billion bricks are produced by VSBK technology.
Vertical shaft brick kiln is a continuous, moving ware kiln in which bricks are fired in a vertical shaft of rectangular/square cross-section. The height of the shaft is around 6 – 10 m and the cross-section of the shaft can range from 1.0 x 1.5 m to 1.75 x 3.75 m. Mostly, the kiln consists of two or more shafts. The shafts are enveloped by an outer wall made up of bricks and the gap between the shaft and outer kiln wall is filled with insulating materials like clay, fly ash and rice husk. Some of the modern kilns in Vietnam are also using glass wool for insulation.

Generally each shaft is connected with two chimneys (2.1), located at diagonally opposite corners of the shaft. The working platform (the top of the shaft) is usually shaded by a roof (2.2). Green bricks and fuel, which are loaded in the shaft from the top, are lifted to the working platform using conveyors or lifts (2.3). However, in some of the traditional kilns manual transportation of bricks is also practiced.

Air for combustion enters the shaft from the bottom (5.1). It gets preheated by the hot fired bricks in the lower section of the shaft (brick cooling zone) before reaching the combustion zone. After combustion, the hot flue gases preheat the green bricks in the preheating zone before exiting the kiln through the chimneys (5.2). The kiln works as a very efficient counter current heat exchanger where the heat transfer takes place between the air moving up (continuous flow) and the bricks moving down (intermittent movement) in the shaft.

The brick setting in the shaft is supported on removable bars (6.1) provided at the bottom of the shaft. Brick unloading is carried out in batches from the bottom with the help of a trolley (6.2). Generally, every 2-3 hours, one batch is unloaded at the bottom and a batch of green bricks is loaded at the top. At any given time, there are typically 8 to 12 batches in the kiln.

Green bricks loaded from the top gradually move down the shaft. The peak firing temperature is at the middle of the shaft, where combustion of fuel is taking place. Fired bricks after cooling are unloaded at the bottom. There are 3 distinct zones in an operating VSBK:

1. **Brick preheating zone:** It is in the upper section of the shaft where the green bricks get preheated by the hot flue gases on their way to the chimney.
2. **Brick firing zone:** It is located in the middle of the shaft where fuel combustion is taking place.
3. **Brick cooling zone:** It is in the lower section of the shaft where the hot fired bricks are cooled down by the cold ambient air entering into the shaft.
FACTSHEETS ABOUT BRICK KILNS IN SOUTH AND SOUTH-EAST ASIA

VERTICAL SHAFT BRICK KILN TECHNOLOGY (VSBK)

MEASURED EMISSION FACTORS

EMISSION STANDARDS

COMMONLY USED FUELS

SPECIFIC ENERGY CONSUMPTION

MEASURED PM EMISSIONS

PRODUCT QUALITY

OCCUPATIONAL HEALTH AND SAFETY

AIR EMISSIONS AND IMPACTS

FUELS AND ENERGY

FINANCIAL PERFORMANCE

CHEMICALS AND WATER

COMMENTS ON EMISSIONS

MAIN CAUSES FOR HEAT LOSS

CAPTIVE BRICK PRODUCER

Production
capacity
8000 to 12,000 bricks per day

Brick size
230 mm x 115 mm x 75 mm

Number of Operators required
10

Payback Period
Simple Payback 0.9 – 1.8 years
Discounted Payback (6.5%) 1.3 – 2.0 years

Payback Period: 0.9 – 1.8 years

Type of Product that can be fired in the VSBK

Solid bricks
Hollow/Perforated bricks
Roof tiles
Floor tiles

GOOD BRICK

UNDER-FIRED BRICK

UNDER-FIRED AND OVER-BURNT

LOW RISK OF INJURIES

Risk of accidents

With properly constructed VSBKs having mechanised brick lifting and brick-unloading processes, the exposure of workers to accidents is low. However, with VSBKs which are not properly constructed and involve manual lifting and unloading of bricks, the risk of injuries could be high.

Compliance with ILO standards and remarks on migratory labour and conditions of labour

Practices followed at vertical shaft brick kiln enterprises do not always comply with the International Labour Standards on occupational health and safety drawn up by ILO.

The working conditions in the Vietnamese kilns which involve local labour are better compared to VSBKs in India and Nepal, which employ migrant labour.

Exposure to Respirable Suspended Particulate Matter

The VSBK has a permanent kiln structure and with introduction of the chimneys in the kiln (the initial VSBKs of China did not have chimneys), the air pollutants concentration in the surrounding environment is quite low and the exposure of workers to air pollution is less. However, the workers loading bricks in the kiln shaft are exposed to air pollutants.

The workers loading bricks can develop respiratory tract infections.

Exposure to Thermal Stress

Because of shading and insulation of the kiln, workers working on the kiln are protected from the direct exposure to Sun and exposure to heat from the kiln is also very low.

This reduces the thermal stress and consequent risk of eye & skin diseases and dehydration among workers.

Note: Measured at firing temperature of 900-1050°C

Because of proper combustion of fuel, efficient heat transfer and minimal heat losses, VSBK is one of the most energy efficient brick kiln technologies.

A very efficient counter flow heat transfer arrangement between air and bricks, uniform fuel distribution and sufficient insulation around the kiln attribute to the efficiency of a VSBK.

The main sources of heat loss in a VSBK are the flue gases and fired bricks coming out of the kiln.

MEASURED EMISSION FACTORS

<table>
<thead>
<tr>
<th>g/kg of fired bricks</th>
<th>CO2</th>
<th>Black Carbon</th>
<th>PM</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>70.5</td>
<td>0.001</td>
<td>0.15</td>
<td>1.84</td>
</tr>
<tr>
<td>Range</td>
<td>62.2-78.7</td>
<td>0-0.002</td>
<td>0.12-0.19</td>
<td>0.85-2.83</td>
</tr>
</tbody>
</table>

EMISSION STANDARDS

Notified for PM only

<table>
<thead>
<tr>
<th>Country</th>
<th>PM (mg/Nm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>250</td>
</tr>
<tr>
<td>Nepal</td>
<td>600</td>
</tr>
<tr>
<td>Vietnam</td>
<td>No emission standard has been notified for brick kilns</td>
</tr>
</tbody>
</table>

COMMONLY USED FUELS

Coal

Most commonly used

SPECIFIC ENERGY CONSUMPTION

Energy consumed for firing 1 kg of fired brick

Average: 0.8 MJ/kg of fired brick

(Range: 0.54 – 1.1 MJ/kg of fired brick)

MEASURED PM EMISSIONS

Average: 107 mg/Nm³

(Range: 101 - 114 mg/Nm³)

PRODUCT QUALITY

As per the local market perception

GOOD - 90%

LOSSES / BREAKAGES - 10%

Capital cost breakdown

Construction Material 65 %
Labour 15 %
Equipment 20 %

Capital cost of kiln technology

For a two-shaft VSBK with annual production capacity of 1.5 - 3 million bricks and excluding land and working capital cost

60,000 to 80,000 USD

FINANCIAL PERFORMANCE

Construction Material 65 %
Labour 15 %
Equipment 20 %

Capital cost of kiln technology

For a two-shaft VSBK with annual production capacity of 1.5 - 3 million bricks and excluding land and working capital cost

60,000 to 80,000 USD

Production capacity: 8000 to 12,000 bricks per day

Brick size: 230 mm x 115 mm x 75 mm

Number of Operators required: 10

Payback Period: Simple Payback 0.9 – 1.8 years

Discounted Payback (6.5%) 1.3 – 2.0 years

Type of product that can be fired in the VSBK

Solid bricks
Hollow/Perforated bricks
Roof tiles
Floor tiles

VSBK is well suited for firing solid bricks. It can also be used to fire bricks with perforations, but is not suitable for firing hollow bricks or thinner products like tiles.

Good brick

Under-fired and over-burnt
### CONCLUSION

Performance of vertical shaft brick kiln is compared with the most commonly used continuous kiln technology in the region which is FCBTK.

### PARAMETERS

<table>
<thead>
<tr>
<th>Parameters</th>
<th>VSBK</th>
<th>FCBTK</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AIR EMISSION (g/kg FIRED BRICK)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td>70.5</td>
<td>131</td>
<td>Vertical shaft brick kiln emits ~85% lower PM and negligible amount of Black Carbon as compared to FCBTKs. This is mainly because of better combustion of fuel and use of internal fuel. Emission of CO2 from VSBK is lower because of less consumption of fuel.</td>
</tr>
<tr>
<td>Black Carbon</td>
<td>0.001</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>0.15</td>
<td>1.18</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>1.84</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td><strong>FUEL &amp; ENERGY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SEC (MJ/kg fired brick)</td>
<td>0.8</td>
<td>1.30</td>
<td>VSBK consumes ~35% less fuel as compared to FCBTK because of better combustion &amp; heat recovery and low heat losses.</td>
</tr>
<tr>
<td><strong>FINANCIAL PERFORMANCE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital Cost (USD)</td>
<td>60,000-80,000</td>
<td>50,000-80,000</td>
<td>Capital cost of setting up of a VSBK is around 1.5-2 times more as compared to FCBTK for the same production capacity. This is mainly because of the cost of equipments and construction of the kiln.</td>
</tr>
<tr>
<td>Production Capacity</td>
<td>1.5-3 million bricks/year</td>
<td>3-8 million bricks/year</td>
<td></td>
</tr>
<tr>
<td>Simple Payback</td>
<td>0.9 – 1.8 years</td>
<td>0.4 – 1.1 years</td>
<td></td>
</tr>
<tr>
<td><strong>PRODUCT QUALITY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Types of product</td>
<td>Solid &amp; Perforated bricks</td>
<td>All kind of products</td>
<td>VSBK is suited for firing only solid and perforated bricks; however, all types of product can be fired in a FCBTK. The quality of bricks fired in VSBKs are better as compared to those from FCBTKs.</td>
</tr>
<tr>
<td>Good Quality Product</td>
<td>90 %</td>
<td>60 %</td>
<td></td>
</tr>
<tr>
<td><strong>OHS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure to dust</td>
<td></td>
<td></td>
<td>Vertical shaft brick kiln enterprise offers better OHS conditions as compared to a FCBTK enterprise.</td>
</tr>
<tr>
<td>Exposure to Thermal stress</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of accidents</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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REFERENCES
1 Brick by Brick: The Herculean Task of Cleaning up the Asian Brick Industry written by Urs Heierly and Sameer Maithel available at www.gkspl.in/Brick_by_brick.pdf.
2 Presentation by Punjab State Council for Science and Technology, India on the findings of the study on “Revision of Comprehensive Industry Document for Brick Kiln”.
6 Ibid 1.
7 Ibid 6.
8 Ibid 7.
9 Ibid 10.
Hoffman kiln technology is a continuous, moving fire kiln in which the fire is always burning and moving forward through the bricks stacked in the circular, elliptical or rectangular shaped closed circuit with arched roof. The fire movement is caused by the draught provided by a chimney or a fan. Hoffman kiln was developed and patented by Friedrich Hoffman in Germany in the year 1858. These kilns were once widely used in Europe for bricks, ceramics and lime production. Hoffman kiln technology was introduced in India in the Malabar coastal region (south-west coast) by the German missionaries in 19th century and is still prevalent in the same region. The original design of Hoffman kiln had a circular circuit built around a central chimney. However, this design has been modified with time and now Hoffman kilns with elliptical or rectangular shape are more in practice.

### About the Kiln

<table>
<thead>
<tr>
<th>Kiln Nature</th>
<th>Nature of enterprise</th>
<th>Level of mechanization</th>
<th>Brick produced</th>
<th>Production capacity</th>
<th>Operational season</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTINUOUS MOVING FIRE</td>
<td>INDUSTRIAL</td>
<td>SEMI MECHANIZED</td>
<td>SOLID &amp; HOLLOW</td>
<td>MEDIUM Between 1-10 million bricks</td>
<td>PERENNIAL</td>
</tr>
</tbody>
</table>

### Enterprises Using This Technology

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of enterprises</th>
<th>Total production billion bricks/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>India1</td>
<td>~500</td>
<td>~2</td>
</tr>
</tbody>
</table>

*1Numbers are estimates only

### Geographical Distribution

![Map showing geographical distribution of Hoffman kilns in South and South-East Asia]

### INTRODUCTION AND HISTORY

Hoffman kiln technology was developed and patented by Friedrich Hoffman in Germany in the year 1858. These kilns were once widely used in Europe for bricks, ceramics and lime production. Hoffman kiln technology was introduced in India in the Malabar coastal region (south-west coast) by the German missionaries in 19th century and is still prevalent in the same region. The original design of Hoffman kiln had a circular circuit built around a central chimney. However, this design has been modified with time and now Hoffman kilns with elliptical or rectangular shape are more in practice.

### NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of enterprises</th>
<th>Total production billion bricks/year</th>
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<tr>
<td>India1</td>
<td>~500</td>
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*1Numbers are estimates only

### % CONTRIBUTION TO THE TOTAL BRICK PRODUCTION IN INDIA

-1% Out of the total annual production of around 250 billion bricks in India, only around 2 billion bricks are produced by Hoffman kiln technology.
In a Hoffman kiln, the fire moves through the bricks stacked in an elliptical or rectangular shaped annular circuit (central perimeter 80 – 90 m) which is covered with an arched roof (1.1). The kiln structure is usually covered with a shade (1.2) to protect it from rains.

The fire movement is caused by the draught provided by a chimney (2.1) (25 – 35 m high) which is located on one side of the kiln. Sometimes a fan is also used to augment the draught. The chimney is connected to the central flue duct (2.2) of the kiln through an underground duct (2.3).

There are 3 distinct zones in an operating Hoffman kiln:
1. Brick firing zone where the fuel is fed and combustion is happening,
2. Brick preheating zone (in front of the firing zone) where green bricks are stacked and being preheated by the flue gases and
3. Brick cooling zone (behind the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

Air Inlet: Air enters into the kiln from the back end of the cooling zone which is kept open to allow air entrance.

Seal to guide flue gas: The front end of the preheating zone is sealed to guide the flue gas to the chimney through the flue gas duct system.

The kiln is connected to the central flue duct through openings provided in the inner wall of the kiln. Openings just before the seal are kept open to allow entrance of flue gases from the kiln to the central flue duct.

Feed holes are provided in the kiln roof for feeding of fuels. Solid fuels (mainly firewood or coal) are fed from the feed holes by a single firer standing on the roof of the kiln. Fuel is fed at an interval of every 15-20 minutes and each fuel feeding lasts for 5-10 minutes.

The fire travels a distance of around 10 m in 24 hours and fires 10,000 to 20,000 bricks. Daily, fired bricks are unloaded from the back end of the brick cooling zone (6.1) and an equivalent batch of green bricks is loaded ahead of the brick preheating zone (6.2).
**FACTSHEETS ABOUT BRICK KILNS IN SOUTH AND SOUTH-EAST ASIA**

**HOFFMAN KILN TECHNOLOGY**

**AIR EMISSIONS AND IMPACTS**

**COMMONLY USED FUELS**
- Biomass (mainly firewood)
- Coal

**SPECIFIC ENERGY CONSUMPTION**
Energy consumed for firing 1 kg of fired brick:
- Average: 1.36 MJ/kg of fired bricks
- Range: 1.21 - 1.52 MJ/kg of fired brick

**PRODUCT QUALITY**

- **Product Quality**
  - As per the local market perception
  - **GOOD ~ 85%**
  - **INFERIOR ~ 10%**
  - **LOSSES & BREAKAGES ~ 5%**

**Capital cost of kiln technology**
For annual production capacity of 3 - 6 million bricks, excluding land and working capital cost
- **100,000 to 150,000 USD**

**Capital cost breakdown**
- **Construction Material**: 82%
- **Labour**: 15%
- **Equipment**: 3%

**MEASURED PM EMISSIONS**
Average: 260 mg/Nm²
(Range: 200-315 mg/Nm²)

**EMISSION STANDARDS**
Notified for PM only

**COMMENTS ON EMISSIONS**
Better combustion in well operated Hoffman kilns results in low particulate matter emissions.

**MAIN CAUSES FOR HEAT LOSS**
The main sources of heat loss in a Hoffman kiln are the heat losses in the flue gases, fired bricks and high thermal mass of the kiln structure.

**CO2**
- Black Carbon
- PM
- CO

**MEASURED PM EMISSIONS**
Average: 260 mg/Nm²
(Range: 200-315 mg/Nm²)

**PRODUCT QUALITY**

**Exposure to Respirable Suspended Particulate Matter**
The concentration of air pollutants in the surrounding environment of a Hoffman kiln is quite low. However, the workers unloading the bricks are exposed to high concentration of dust because of ash of burned fuel.

**Exposure to Thermal Stress**
The workers unloading the bricks have the risk of developing respiratory tract infections and cardiovascular diseases.

**Risk of accidents**
In a properly constructed Hoffman kiln, the risk of accidents is low.

**Low risk of injuries to workers.**

**Compliance with ILO standards and remarks on migratory labour and conditions of labour**
Practices followed at Hoffman kiln enterprises do not always comply with the International Labour Standards on occupational health and safety drawn up by ILO.

**FUELS AND ENERGY**

**COMMONLY USED FUELS**
- Biomass (mainly firewood)
- Coal

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Energy consumed for firing 1 kg of fired brick:
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**FINANCIAL PERFORMANCE**

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For annual production capacity of 3 - 6 million bricks, excluding land and working capital cost
- **100,000 to 150,000 USD**

**Capital cost breakdown**
- **Construction Material**: 82%
- **Labour**: 15%
- **Equipment**: 3%

**Production**
- **capacity**: 10,000 to 20,000 bricks per day

**Brick size**
- **230 mm x 115 mm x 75 mm**

**Number of Operators required**
- **15-20**

**Payback Period**
- **Simple Payback**: 0.8 - 11 years
- **Discounted Payback @ 6.5%**: 0.9 - 12 years

**INFERIOR BRICK**
under-fired and over-burnt

**GOOD BRICK**

**OCCUPATIONAL HEALTH AND SAFETY**

**Exposure to Respirable Suspended Particulate Matter**
The concentration of air pollutants in the surrounding environment of a Hoffman kiln is quite low. However, the workers unloading the bricks are exposed to high concentration of dust because of ash of burned fuel.

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Practices followed at Hoffman kiln enterprises do not always comply with the International Labour Standards on occupational health and safety drawn up by ILO.
Hoffman Kiln Technology

**CONCLUSION**

Performance of Hoffman kiln is compared with the most commonly used continuous kiln technology in the region which is FCBTK.

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>HOFFMAN KILN</th>
<th>FCBTK</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR EMISSION (g/kg fired brick)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂</td>
<td>NA</td>
<td>131</td>
<td>NA</td>
</tr>
<tr>
<td>Black Carbon</td>
<td>NA</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>NA</td>
<td>1.18</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>NA</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>FUEL &amp; ENERGY (MJ/kg fired brick)</td>
<td>1.36</td>
<td>1.30</td>
<td>The working principles of Hoffman kiln and FCBTK are similar and hence fuel consumption is comparable. In a FCBTK, heat loss from the kiln surfaces is prominent while in case of a Hoffman kiln, heat loss due to the thermal mass of the kiln structure is prominent.</td>
</tr>
<tr>
<td>FINANCIAL PERFORMANCE</td>
<td></td>
<td></td>
<td>Hoffman kiln has a permanent roof and shade, hence the capital cost of setting up a Hoffman kiln is almost twice as much as FCBTK of similar annual production capacity. Hoffman kilns are usually used for the production of value added products like good quality solid bricks, hollow bricks, roofing tiles, etc. and the payback period of Hoffman kiln is comparable to FCBTK.</td>
</tr>
<tr>
<td>Capital Cost (USD)</td>
<td>100,000-150,000</td>
<td>50,000-80,000</td>
<td></td>
</tr>
<tr>
<td>Production Capacity</td>
<td>3-6 million bricks/year</td>
<td>3-8 million bricks/year</td>
<td></td>
</tr>
<tr>
<td>Simple Payback</td>
<td>0.8 - 11 years</td>
<td>0.4 - 11 years</td>
<td></td>
</tr>
<tr>
<td>PRODUCT QUALITY</td>
<td></td>
<td></td>
<td>Both the kiln technologies are suitable for firing all types of product. However, the quality of bricks fired in a Hoffman kiln is better as compared to those from FCBTKs. Also while a Hoffman kiln can be used exclusively for production of roofing tiles and hollow bricks, in an FCBTK such exclusive production is not possible.</td>
</tr>
<tr>
<td>Types of product</td>
<td>All types of products</td>
<td>All types of products</td>
<td></td>
</tr>
<tr>
<td>Good Quality Product</td>
<td>85%</td>
<td>60%</td>
<td></td>
</tr>
<tr>
<td>OHS</td>
<td></td>
<td></td>
<td>Hoffman kiln enterprise offers better OHS conditions as compared to a FCBTK enterprise.</td>
</tr>
<tr>
<td>Exposure to dust</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure to Thermal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of accidents</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ACKNOWLEDGEMENT**

The project team would like to acknowledge the financial support received from the Swiss Agency for Development and Cooperation for preparation of the fact-sheets.

**Note:** In the initial stage of this initiative of developing fact-sheets on brick kiln technologies, fact-sheets are developed for South and South-East Asia and Latin America regions. Fact-sheets on brick kiln technologies of other regions will be developed over time.

**Disclaimer:** The country borders indicated on the map do not necessarily reflect the FDFA’s official position. The red dotted line represents approximately the Line of actual Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

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**Design & Illustration**
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Web: www.gkspl.in

**REFERENCES**

3. Presentation by Punjab State Council for Science and Technology, India on the findings of the study on ‘Revision of Comprehensive Industry Document for Brick Kilns’.

4. Ibid.
5. Ibid.
6. Report on ‘Occupational health and safety study (OHSS) of brick industry in the Kathmandu valley’ by Department of Environmental Sciences and Engineering (DESE), Kathmandu University, Nepal
7. Ibid.
Hybrid Hoffman Kiln (HHK) technology was developed and is widely used in China. The HHK combines use of green bricks produced by mixing powdered fuel with clay, and utilisation of waste heat by transferring the heat to an adjacent tunnel dryer to dry green bricks. These features lead to lower energy consumption and reduction of air pollution.

In South Asia, the HHK technology was first introduced in Bangladesh in 2006 under an UNDP-GEF supported project and since then it is being promoted with support from various development projects. As of June 2011, there were 8 HHKs operating in Bangladesh and another 8 were in pipeline.

### ABOUT THE KILN ENTERPRISES USING THIS TECHNOLOGY

<table>
<thead>
<tr>
<th>Kiln Nature of enterprise</th>
<th>Level of mechanization</th>
<th>Brick produced</th>
<th>Production capacity</th>
<th>Operational season</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTINUOUS MOVING FIRE</td>
<td>INDUSTRIAL</td>
<td>SEMI MECHANIZED</td>
<td>SOLID &amp; HOLLOW</td>
<td>LARGE &gt; 10 million bricks</td>
</tr>
</tbody>
</table>

### GEOGRAPHICAL DISTRIBUTION

Out of the total annual production of around 19 billion bricks in Bangladesh, around 0.12 billion bricks are being produced by hybrid Hoffman kiln technology.
In construction, a hybrid Hoffman kiln has a lot of similarities with a Hoffman kiln. The hybrid Hoffman kiln consists of a rectangular shaped annular circuit (1.1) with arched roof (1.2). The kiln structure is usually covered with a shade (1.3) to protect it from rains. The fire moves through the bricks stacked in the annular space. The fire movement is caused by a blower which forces the air required for combustion from behind.

Green bricks are produced by mixing powdered fuel with clay. Around 80% of the fuel required for firing bricks is mixed with clay as internal fuel. Green bricks pass through drying tunnels (2.1) on trolleys for drying. There are around 8 drying tunnels. Heat contained in the hot flue gases from the kiln is utilized in the drying tunnels. The temperature in the drying tunnel is maintained at around 120°C and the drying time is around 24 hours.

The dried green bricks are stacked in the kiln such as to form distinct chambers. Each chamber contains 8,000 – 9,000 bricks and is ~5 m in length.

Three distinct zones appear in an operating HHK:

4.1 Brick firing zone where the fuel is fed and combustion is happening,
4.2 Brick preheating zone (in front of the firing zone) where green bricks are stacked and being preheated by the hot flue gases and
4.3 Brick cooling zone (behind the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

Fuel (granulated coal) is fed into the firing zone of the kiln through feed holes provided in the kiln roof. The temperature in the firing zone is 950 – 1050°C.

The fire travels at a fast rate of ~1.25 m/hour and in the process fires around 50,000 bricks daily. Daily, fired bricks are unloaded from the back end of the brick cooling zone (6.1) and an equivalent batch of green bricks is loaded ahead of the brick preheating zone (6.2).

Hybrid Hoffman kiln does not have a tall chimney. Hot flue gases from the central flue duct (7.1) of the kiln are first diverted to the drying tunnels through duct (7.2) and then are released in the atmosphere through a rectangular opening (7.3) of 5-6 m height.

The dried green bricks are stacked in the kiln such as to form distinct chambers. Each chamber contains 8,000 – 9,000 bricks and is ~5 m in length.

Three distinct zones appear in an operating HHK:

4.1 Brick firing zone where the fuel is fed and combustion is happening,
4.2 Brick preheating zone (in front of the firing zone) where green bricks are stacked and being preheated by the hot flue gases and
4.3 Brick cooling zone (behind the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.
HYBRID HOFFMAN KILN TECHNOLOGY

AIR EMISSIONS AND IMPACTS

MEASURED EMISSION FACTORS

<table>
<thead>
<tr>
<th>g/kg of fired bricks</th>
<th>CO₂</th>
<th>Black Carbon</th>
<th>PM¹</th>
<th>CO²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>100</td>
<td>NA</td>
<td>0.29</td>
<td>NA</td>
</tr>
</tbody>
</table>

Emission factor values are available for CO₂ and PM emissions only.

MEASURED PM EMISSIONS⁴
Average: 20.3 mg/Nm³
(Range: 15.8 – 26.9 mg/Nm³)

EMISSION STANDARDS
Notified for PM only

Country | PM (mg/Nm³)
---|---
Bangladesh | No emission standard has been notified for HHK technology.

COMMENTS ON EMISSIONS
Because of use of internal fuel, particles generated during combustion are reduced significantly. Also a part of the particulate matter gets deposited on green bricks in the drying tunnel; this further reduces the particulate emission.

SPECIFIC ENERGY CONSUMPTION⁷
Energy consumed for firing 1 kg of fired brick
Average: 1.2 MJ/kg of fired bricks
(Range: As the SEC is measured for only one kiln, range of SEC values is not available.)

SPECIMEN ENERGY CONSUMPTION²
Energy consumed for firing 1 kg of fired brick
Average: 1.2 MJ/kg of fired bricks
(Range: As the SEC is measured for only one kiln, range of SEC values is not available.)

COMMONLY USED FUELS
Coal
Most commonly used

PRODUCT QUALITY

Capital cost of kiln technology⁵
For annual production capacity of around 15 – 18 million bricks, excluding cost of land and buildings.
600,000 - 650,000 USD

Capital cost breakdown

<table>
<thead>
<tr>
<th>Construction Material</th>
<th>NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labour</td>
<td>NA</td>
</tr>
<tr>
<td>Equipment</td>
<td>NA</td>
</tr>
</tbody>
</table>

Types of product that can be fired in the kiln

- Solid bricks
- Hollow/Perforated bricks
- Roof tiles
- Floor tiles

Better heat distribution and lower heat losses from kiln walls and roof result in uniform temperature across the kiln cross section in the firing zone thereby resulting in higher percentage of good quality bricks.

Exposure to Respirable Suspended Particulate Matter⁸
The concentration of air pollutants in the surrounding environment of a hybrid Hoffman kiln is quite low. However, firemen feeding the pulversised coal and workers unloading the bricks are exposed to moderate dust concentration.

Workers unloading the bricks have a risk of consequent diseases and dehydration.

Exposure to Thermal Stress¹⁰
Workers unloading the bricks from the kiln are exposed to high temperature due to radiation from hot kiln structure.

Workers unloading the bricks have a risk of developing respiratory tract infections and cardiovascular diseases.

Risk of accidents
In a properly constructed hybrid Hoffman kiln, the risk of accidents is low.

Low risk of injuries to workers.

COMPLIANCE WITH ILO STANDARDS AND REMARKS ON MIGRATORY LABOUR AND CONDITIIONS OF LABOUR
Practices followed at Hoffman kiln enterprises do not always comply with the International Labour Standards on occupational health and safety drawn up by ILO.¹¹

Note: Measured at firing temperature of 950-1050°C

Because of good waste heat recovery features, HHK is an efficient kiln technology.

MAIN CAUSES FOR HEAT LOSS
Heat losses in the kiln structure and heat contained in the fired bricks are the main cause of heat losses in HHK.

FUELS AND ENERGY

COAL
Most commonly used

FINANCIAL PERFORMANCE

Capital cost of kiln technology⁶
For annual production capacity of around 15 – 18 million bricks, excluding cost of land and buildings.
600,000 - 650,000 USD

Capital cost breakdown

<table>
<thead>
<tr>
<th>Production capacity</th>
<th>50,000 bricks per day</th>
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</thead>
<tbody>
<tr>
<td>Brick size</td>
<td>250 mm x 120 mm x 60 mm &amp; 240 mm x 115 mm x 53 mm</td>
</tr>
<tr>
<td>Number of Operators required</td>
<td>30-40</td>
</tr>
<tr>
<td>Payback Period</td>
<td>Simple Payback 11 – 1.4 years</td>
</tr>
<tr>
<td></td>
<td>Discounted Payback (@ 6.5%) 1.2 - 1.5 years</td>
</tr>
</tbody>
</table>

COMMENTS ON EMISSIONS
Because of use of internal fuel, particles generated during combustion are reduced significantly. Also a part of the particulate matter gets deposited on green bricks in the drying tunnel; this further reduces the particulate emission.

MAIN CAUSES FOR HEAT LOSS
Heat losses in the kiln structure and heat contained in the fired bricks are the main cause of heat losses in HHK.

OCCUPATIONAL HEALTH AND SAFETY

Exposure to Respirable Suspended Particulate Matter⁸
The concentration of air pollutants in the surrounding environment of a hybrid Hoffman kiln is quite low. However, firemen feeding the pulversised coal and workers unloading the bricks are exposed to moderate dust concentration.

Firemen and workers unloading the bricks have moderate risk of developing respiratory tract infections and cardio vascular diseases.

Workers unloading the bricks have a risk of consequent diseases and dehydration.

Compliance with ILO standards and remarks on migratory labour and conditions of labour Practices followed at Hoffman kiln enterprises do not always comply with the International Labour Standards on occupational health and safety drawn up by ILO.¹¹

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FUELS AND ENERGY

COAL
Most commonly used

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Heat losses in the kiln structure and heat contained in the fired bricks are the main cause of heat losses in HHK.
## HYBRID HOFFMAN KILN TECHNOLOGY

### CONCLUSION

Performance of hybrid Hoffman kiln is compared with the most commonly used continuous kiln technology in the region which is FCBTK.

<table>
<thead>
<tr>
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<th>HYBRID HOFFMAN KILN</th>
<th>FCBTK</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR EMISSION</td>
<td>CO₂</td>
<td>100</td>
<td>131</td>
</tr>
<tr>
<td></td>
<td>Black Carbon</td>
<td>NA</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>PM</td>
<td>0.29</td>
<td>1.18</td>
</tr>
<tr>
<td></td>
<td>CO</td>
<td>NA</td>
<td>2.0</td>
</tr>
<tr>
<td>FUEL &amp; ENERGY</td>
<td>SEC (MJ/kg fired brick)</td>
<td>1.20</td>
<td>1.30</td>
</tr>
<tr>
<td>FINANCIAL PERFORMANCE</td>
<td>Capital Cost (USD)</td>
<td>600,000 - 650,000</td>
<td>50,000-80,000</td>
</tr>
<tr>
<td></td>
<td>Production Capacity</td>
<td>15 – 18 million bricks/year</td>
<td>3-8 million bricks/year</td>
</tr>
<tr>
<td></td>
<td>Simple Payback</td>
<td>1.1 - 1.4 years</td>
<td>0.4 - 1.1 years</td>
</tr>
<tr>
<td>PRODUCT QUALITY</td>
<td>Types of product</td>
<td>All types of products</td>
<td>All types of products</td>
</tr>
<tr>
<td></td>
<td>Good Quality Product</td>
<td>90 %</td>
<td>60 %</td>
</tr>
<tr>
<td>OHS</td>
<td>Exposure to dust</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Exposure to Thermal</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Risk of accidents</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### REFERENCES

3. Ibid. 1
4. Ibid. 1
6. Ibid.
7. Ibid. 1
8. Ibid. 1
9. Report on ‘Occupational health and safety study (OHS) of brick industry in the Kathmandu valley’ by Department of Environmental Sciences and Engineering (DESE), Kathmandu University, Nepal
10. Ibid.
11. International Labour Standards are instruments drawn up by ILO in the form of conventions (the basic principles to be implemented) and recommendations (more detailed guidelines). Details on the standards for OHS can be found at http://www.ilo.org/global/standards/subjects-covered-by-internationallabourstandards/occupational-safety-and-health/lang--en/index.htm. A list of all such instruments on OHS with their status is available at http://www.ilo.org/child/whitelists/Tlmp/N09JX%5B%5B22012%20IQ%5D%5DOccupational_safety_and_h_ealth/
TUNNEL KILN TECHNOLOGY

INTRODUCTION AND HISTORY

Tunnel kiln is a continuous moving ware kiln in which the clay products to be fired are passed on cars through a long horizontal tunnel. The firing of products occurs at the central part of the tunnel. The tunnel kiln is considered to be the most advanced brick making technology. The main advantages of tunnel kiln technology lie its ability to fire a wide variety of clay products, better control over the firing process and high quality of the products.

The tunnel kiln technology was developed around mid 19th century in Germany. However, the application of the technology for brick firing took place in the 20th century. After the Second World War, the technology was widely adopted and led to the transformation of the European brick industry from several thousand small and scattered brick making units into a few hundred large scale and highly mechanised tunnel kiln units.

In Asia, China and Vietnam started adopting the technology during the 1970’s and now have several hundred tunnel kilns in operation. In India, there are very few (~5) tunnel brick kiln units.

GEOGRAPHICAL DISTRIBUTION

NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of enterprises</th>
<th>Total production billion bricks/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vietnam</td>
<td>-700</td>
<td>-10.5</td>
</tr>
<tr>
<td>India</td>
<td>-5</td>
<td>-0.08</td>
</tr>
</tbody>
</table>

*Numbers are estimates only

% CONTRIBUTION TO THE TOTAL BRICK PRODUCTION IN INDIA AND VIETNAM

~4%

Out of the total annual production of around 280 billion bricks in India and Vietnam only around 10.6 billion bricks are produced by tunnel kiln technology.
### Tunnel Kiln Technology

#### Description and Working

1. In a tunnel kiln, a continuous moving ware kiln, the clay products/bricks to be fired are passed on cars (1.1) through a long horizontal tunnel (1.2). The firing of bricks occurs at the central part of the tunnel. The length of tunnel can vary from 60 m to 150 m.

2. Generally, green bricks are produced by mixing powdered fuel with clay. Green bricks are then moved in the tunnel or chamber dryers on cars for drying. Heat from the hot flue gases coming out of the kiln is utilized for the drying of bricks.

3. The cars loaded with dried green bricks are pushed in the kiln. The cars are moved inside the kiln intermittently at fixed time intervals. The duration of the firing cycle can range from 30 to 72 hours.

4. Three distinct zones appear in an operating tunnel kiln:
   - **4.1** Brick firing zone where the fuel is fed and combustion is happening.
   - **4.2** Brick preheating zone (before the firing zone) where the green bricks are being pre-heated by the hot flue gases coming from the firing zone and
   - **4.3** Brick cooling zone (ahead of the firing zone) where fired bricks are cooled by the cold air flowing into the kiln.

5. Fuel (granulated/pulverised coal) is fed into the firing zone of the kiln through feed holes provided in the kiln roof. The firing zone usually extends up to 8 cars. The temperature in the firing zone is maintained at 900 - 1050°C.

6. There is counter current heat transfer between the bricks and the air. Cold air enters the kiln from the car exit end (6.1) and gets heated while cooling the fired bricks. After combustion, the hot flue gases travel towards the car entrance end losing a part of the heat to the green bricks entering the kiln.

7. Hot air/gases are extracted from the tunnel kiln at several points along the length of the kiln and are supplied to the drying tunnel/chamber. In some of the kilns, there is also provision of a hot air generator to supplement the requirement of hot air for drying.

8. The flue gases from the drying tunnel are released in the atmosphere through a chimney.
**TUNNEL KILN TECHNOLOGY**

**COMMONLY USED FUELS**
- Coal
- Petcoke

**SPECIFIC ENERGY CONSUMPTION**
Energy consumed for firing 1 kg of fired brick
- Average: 1.4 MJ/kg of fired brick
- Range: 1.34 - 1.47 MJ/kg of fired brick

**MEASURED EMISSION FACTORS**
- g/kg of fired bricks
  - CO2
  - Black Carbon
  - PM
  - CO

<table>
<thead>
<tr>
<th></th>
<th>CO2</th>
<th>Black Carbon</th>
<th>PM</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>166.3</td>
<td>negligible</td>
<td>0.24</td>
<td>3.31</td>
</tr>
<tr>
<td>Range</td>
<td>NA</td>
<td>NA</td>
<td>0.175 - 0.31</td>
<td>2.45 - 4.18</td>
</tr>
</tbody>
</table>

**MEASURED PM EMISSIONS**
Average: 41 mg/Nm$^3$
(Range: 21 - 53 mg/Nm$^3$)

**EMISSION STANDARDS**
- Notified for PM only

<table>
<thead>
<tr>
<th>Country</th>
<th>PM (mg/Nm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>No emission standard has been notified for tunnel brick kilns</td>
</tr>
<tr>
<td>Vietnam</td>
<td>No emission standard has been notified for tunnel brick kilns</td>
</tr>
</tbody>
</table>

**COMMENTS ON EMISSIONS**
Better fuel combustion results in lower emissions from a tunnel kiln.

**MAIN CAUSES FOR HEAT LOSS**
Heat contained in the kiln cars and fired bricks at the kiln exit and in hot flue gases are the main sources of heat loss in tunnel kilns.

**AIR EMISSIONS AND IMPACTS**

**FUELS AND ENERGY**

**FINANCIAL PERFORMANCE**

**PRODUCT QUALITY**
- Product Quality
  - As per the local market perception
  - GOOD - 95%
  - LOSSES & BREAKAGES - 2%
  - INFERN - 3%

**OCCUPATIONAL HEALTH AND SAFETY**

**Exposure to Respirable Suspended Particulate Matter**
- The concentration of air pollutants in the surrounding environment of a tunnel kiln is low

**Exposure to Thermal Stress**
- The workers have low risk of developing respiratory tract infections and cardiovascular diseases.

**Risk of accidents**
In a well operated tunnel kiln, the risk of accidents is low.

**Compliance with ILO standards and remarks on migratory labour and conditions of labour**
- Practices followed at tunnel kiln enterprises do not always comply with the International Labour Standards on occupational health and safety drawn up by ILO.
- Because of mechanisation of the processes, the working conditions of workers in tunnel kiln enterprises are relatively better.
Performance of tunnel kiln is compared with the most commonly used continuous kiln technology in the region which is FCBTK.

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>TUNNEL</th>
<th>FCBTK</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AIR EMISSION</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(g/kg FIRED BRICK)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td>166.3</td>
<td>131</td>
<td>Tunnel kiln emits ~80% lower PM and negligible BC as compared to FCBTK. This is mainly because of better combustion and use of internal fuel. The emission of CO is higher in case of tunnel kiln, probably due to incomplete combustion of internal fuel.</td>
</tr>
<tr>
<td>Black Carbon</td>
<td>0.00</td>
<td>0.13</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>0.24</td>
<td>1.18</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>3.31</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td><strong>FUEL &amp; ENERGY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(MJ/kg fired brick)</td>
<td>1.4</td>
<td>1.30</td>
<td>Tunnel kiln consumes marginally higher energy as compared to FCBTK. It is to be noted that the SEC in tunnel kilns also includes the energy utilised for the drying of bricks in the tunnel dryer.</td>
</tr>
<tr>
<td><strong>FINANCIAL PERFORMANCE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital Cost (USD)</td>
<td>-1,000,000</td>
<td>50,000-80,000</td>
<td>The capital cost of tunnel kiln is substantially higher as compared to FCBTK mainly because of mechanisation of brick production processes and considerably larger production.</td>
</tr>
<tr>
<td>Production Capacity</td>
<td>-15 million bricks/year</td>
<td>3-8 million bricks/year</td>
<td></td>
</tr>
<tr>
<td>Simple Payback</td>
<td>-2 years</td>
<td>0.4 - 1.1 years</td>
<td></td>
</tr>
<tr>
<td><strong>PRODUCT QUALITY</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Types of product</td>
<td>All types of products</td>
<td>All types of products</td>
<td>Both the kiln technologies are suitable for firing all types of product. However, the quality of bricks fired in tunnel kilns is better as compared to those from FCBTKs. Also while a tunnel kiln can be used exclusively for production of hollow bricks, in a FCBTK such exclusive production is not possible.</td>
</tr>
<tr>
<td>Good Quality Product</td>
<td>95 %</td>
<td>60 %</td>
<td></td>
</tr>
<tr>
<td><strong>OHS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exposure to dust</td>
<td></td>
<td></td>
<td>Tunnel kiln enterprise offers better OHS conditions as compared to a FCBTK enterprise.</td>
</tr>
<tr>
<td>Exposure to Thermal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of accidents</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**REFERENCES**
1. ‘Brick by Brick: The Herculean Task of Cleaning up the Asian Brick Industry’ written by Urs Heierly and Sameer Maithel available at www.gkspl.in/brick_by_brick.pdf.
3. Based on interaction with tunnel kiln owners and professionals working in brick sector
6. Ibid 2.
7. Ibid 5.
10. International Labour Standards are instruments drawn up by ILO in the form of conventions (the basic principles to be implemented) and recommendations (more detailed guidelines). Details on the standards for OHS can be found at http://www.ilo.org/global/standards/subjects-covered-by-international-labour-standards/occupational-safety-and-health/lang--en/index.htm. A list of all such instruments on OHS with their status is available at http://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12030:0::NO::#Occupational_safety_and_health
The clamp is the most basic type of kiln since no permanent kiln structure is built. It consists essentially of a pile of green bricks interspersed with combustible material. The green bricks are generally piled up on a thin bed of fuel (usually in case of coal fired clamps). Where spreading of fuel in thin bed is not possible (usually in the case of firewood fired clamps), tunnels are made through the base of the pile in order to feed the fuel. In an improved version of clamp, the outer walls are plastered (scoved) with mud to reduce the heat loss and thus are termed as Scove kiln. The other improvement is Scotch kiln in which the base, fire tunnels and outer walls are permanently built with bricks. In this factsheet, all these variations are referred as clamps.

Till the end of 18th century, bricks were almost exclusively fired in clamps. However, with the introduction of continuous kilns and mechanisation, clamps were gradually phased out from the developed countries, but these are still prevalent in developing countries.

### ABOUT THE KILN

<table>
<thead>
<tr>
<th>Kiln</th>
<th>Nature of enterprise</th>
<th>Level of mechanization</th>
<th>Brick produced</th>
<th>Production capacity</th>
<th>Operational season</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERMITTANT</td>
<td>ARTISINAL</td>
<td>MANUAL</td>
<td>SOLID</td>
<td>MICRO/ SMALL SCALE</td>
<td>DRY SEASON</td>
</tr>
</tbody>
</table>

### ENTERPRISES USING THIS TECHNOLOGY

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of enterprises</th>
<th>Total production billion bricks/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>~100,000</td>
<td>~50</td>
</tr>
</tbody>
</table>

*Numbers are estimates only.

### NUMBER OF OPERATIONAL ENTERPRISES AND TOTAL PRODUCTION

Out of the total annual production of around 250 billion bricks in India, around 50 billion bricks are produced in clamps.
A clamp does not have a permanent kiln structure. It consists essentially of an organised pile of green bricks interspersed with combustible material.

The base of the clamp is first laid with fired bricks. Generally, in case of coal fired bricks, a thin layer of fuel is spread over the base on which the green bricks are stacked. In case of firewood fired clamps, tunnels are made through the base of the pile to feed firewood. In a rice husk fired clamp, bricks are stacked in parallel columns and the fuel is fed from the top and burned in the gaps between the brick columns.

The clamps are ignited at the bottom. Air required for combustion, enters through the openings provided in the base of the clamp. During burning, the hot air rises up through the bricks and heats the bricks. Smoke and fumes leave from the top of the clamp.

In a clamp, the operator has very little control over the burning rate. The burning rate is affected by the weather particularly by the direction and speed of the wind.

Because of heat loss to the surroundings, bricks located on the surface are usually under-fired. Also bricks located near to the fuel layer are usually over-burnt.

In bigger coal fired clamps, to attain the required firing temperature throughout the brick stacking, fuel is also added in the spacings/holes provided in the brick stacking.

For stability of the clamp structure, usually the upper part of the clamp has a trapezoidal shape.

Photograph of rice husk fired clamp
FACTSHEETS ABOUT BRICK KILNS IN SOUTH AND SOUTH-EAST ASIA

CLAMPS

AIR EMISSIONS AND IMPACTS

FUELS AND ENERGY

FINANCIAL PERFORMANCE

PRODUCT QUALITY

OCCUPATIONAL HEALTH AND SAFETY

MEASURED EMISSION FACTORS

**MEASURED EMISSION FACTORS**

| g/kg of fired bricks | Clamps do not have a chimney stack and therefore, stack emissions can’t be measured. |

**MEASURED PM EMISSIONS**

Not available

**EMISSION STANDARDS**

Notified for PM only

**COMMENTS ON EMISSIONS**

Emission values are not measured for clamps.

### COMMONLY USED FUELS

- **Coal** (Central & Western India)
- **Biomass** (Firewood, rice husk, etc.) (Southern India)

### SPECIFIC ENERGY CONSUMPTION

Energy consumed for firing 1 kg of fired brick

Range: 2.0 - 4.0 MJ/kg of fired brick

<table>
<thead>
<tr>
<th>Country</th>
<th>PM (mg/Nm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>No emission standard has been notified for clamp kilns.</td>
</tr>
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**SPECIFIC ENERGY CONSUMPTION**

Energy consumed for firing 1 kg of fired brick

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<table>
<thead>
<tr>
<th>MJ/kg of fired brick</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>0</td>
</tr>
</tbody>
</table>

**Production capacity**

10,000 to 200,000 bricks per batch

**Brick size**

230 mm x 115 mm x 75 mm

**Number of Operators required**

-10

**Payback Period**

Simple Payback: NA

Discounted Payback (@ 6.5%): NA

**Types of product that can be fired in the kiln**

- Solid bricks
- Hollow/Perforated bricks: X
- Roof tiles: X
- Floor tiles: X

**Product Quality**

As per the local market perception

- GOOD: 50%
- INFERIOR: 30%
- LOSSES & BREAKAGES: 20%

### AIR EMISSIONS AND IMPACTS

#### EMISSION STANDARDS

Notified for PM only

#### COMMENTS ON EMISSIONS

Emission values are not measured for clamps.

#### SPECIFIC ENERGY CONSUMPTION

Energy consumed for firing 1 kg of fired brick

Range: 2.0 - 4.0 MJ/kg of fired brick

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<td>3</td>
</tr>
<tr>
<td>2</td>
</tr>
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<tr>
<td>0</td>
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-10

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As per the local market perception

- GOOD: 50%
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### FUELS AND ENERGY

**COMMONLY USED FUELS**

- **Coal** (Central & Western India)
- **Biomass** (Firewood, rice husk, etc.) (Southern India)

**MEASUREMENT OF FUELS AND ENERGY**

Because of inefficient combustion and no heat recovery feature, clamp kilns are inefficient. In clamps, the green bricks are first heated up during firing process and then left for cooling with no heat recovery. Consequently all the heat is lost to the surrounding area.

**MAIN CAUSES FOR HEAT LOSS**

Heat loss from the kiln surfaces, loss of heat contained in the fired bricks and incomplete combustion are the main source of heat loss in clamps.

#### FINANCIAL PERFORMANCE

**CAPITAL COST OF KILN TECHNOLOGY**

As the clamps do not have a kiln structure, no capital cost is considered for setting up of a clamp.

**Capital cost breakdown**

- **Construction Material**: NA
- **Labour**: NA
- **Equipment**: NA

### OCCUPATIONAL HEALTH AND SAFETY

#### Exposure to Respirable Suspended Particulate Matter

During the firing of clamps and during unloading of bricks, the workers are exposed to high concentration of particulate pollutants. These workers have the risk of developing respiratory tract infections and cardiovascular diseases.

#### Exposure to Thermal Stress

In case of clamps where continuous feeding of fuel is required, firemen are exposed to the radiation from flames and kiln surfaces. Firemen are exposed to thermal stress and consequent risk of eye & skin diseases and dehydration among workers.

#### Risk of accidents

During stacking and unloading of bricks there is danger of falling off the brick setting. Workers stacking and unloading the bricks have risk of injuries.

#### Compliance with ILO standards and remarks on migratory labour and conditions of labour

Practices followed at clamps do not comply with the International Labour Standards on occupational health and safety drawn up by ILO. Most of the small scale clamp kilns are family based enterprises. However, in larger units, majority of the workers are seasonal migrants and they along with their families work on the kilns. They live in temporary housing with poor access to basic amenities like safe drinking water, electricity, education, health and sanitation.
Facts about clamp kilns, the most commonly used intermittent kilns in the region.

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>CLAMPS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR EMISSION (g/kg FIRED BRICK)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO2</td>
<td>NA</td>
<td>As clamps do not have a chimney stack, stack emissions are not measured. However measurements in similar intermittent kilns like down draught kilns indicate that emissions from clamp are relatively on the higher side.</td>
</tr>
<tr>
<td>Black Carbon</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>PM</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>FUEL &amp; ENERGY (MJ/kg fired brick)</td>
<td>2.10</td>
<td>Because of inefficient combustion and no heat recovery feature, clamp kilns are inefficient.</td>
</tr>
<tr>
<td>FINANCIAL PERFORMANCE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital Cost (USD)</td>
<td>NA</td>
<td>As the clamps do not have a kiln structure, no capital cost is considered for setting up of a clamp.</td>
</tr>
<tr>
<td>Production Capacity (bricks per batch)</td>
<td>10,000-200,000</td>
<td></td>
</tr>
<tr>
<td>Simple Payback</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>PRODUCT QUALITY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Types of product</td>
<td>Only Solid Bricks</td>
<td>Only solid bricks can be fired in clamps. Heat loss from the kiln surfaces results in poor quality of bricks in outer layers, while bricks stacked near the fuel layers are usually over fired.</td>
</tr>
<tr>
<td>Good Quality Product</td>
<td>-50%</td>
<td></td>
</tr>
<tr>
<td>OHS Exposure to dust</td>
<td></td>
<td>Clamp kiln enterprises have poor OHS conditions and it is a major shortcoming of this technology.</td>
</tr>
<tr>
<td>Exposure to Thermal stress</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk of accidents</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

REFERENCES
3 Presentation by Punjab State Council for Science and Technology, India on the findings of the study on ‘Revision of Comprehensive Industry Document for Brick Kilns’.
4 Ibid.
5 Report on ‘Occupational health and safety study (OHSS) of brick industry in the Kathmandu valley’ by Department of Environmental Sciences and Engineering (DESE), Kathmandu University, Nepal.
6 Ibid.
7 International Labour Standards are instruments drawn up by ILO in the form of conventions (the basic principles to be implemented) and recommendations (more detailed guidelines). Details on the standards for OHS can be found at http://www.ilo.org/global/standards/subjects-covered-by-international-labour-standards/occupational-safety-and-health/lang–en/index.htm. A list of all such instruments on OHS with their status is available at http://www.ilo.org/dyn/normlex/en/f?p=400:100:0::NO:::Occupational_safety_and_Health

ACKNOWLEDGEMENT
The project team would like to acknowledge the financial support received from the Swiss Agency for Development and Cooperation for preparation of the fact-sheets.

Note: In the initial stage of this initiative of developing factsheets on brick kiln technologies, factsheets are developed for South and South-East Asia and Latin America regions. Factsheets on brick kiln technologies of other regions will be developed over time.

Disclaimer: The country borders indicated on the map do not necessarily reflect the FDFA’s official position. The red dotted line represents approximately the Line of actual Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.

FACT SHEETS PREPARED BY
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Shokil Kanungo

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INTRODUCTION AND HISTORY

The down draught kiln is an intermittent kiln in which the bricks are fired in batches. In this kiln, the hot gases from the burning fuel are first deflected to the roof of the kiln and then are drawn downwards by the chimney draught through the green bricks to fire them. Till the end of 18th century, bricks were almost exclusively fired in freely stacked heaps of clamp kilns. However, in early 19th century, various technological modifications were tried aimed at improving the product quality and energy efficiency of the kilns. In the process, first up draught and then the down draught kilns were developed.

One of the advantages of this kiln is that the fuel and fuel residue do not come into contact with the kiln charge and therefore no pollutants are deposited on the surface of the products.

GEOGRAPHICAL DISTRIBUTION

India

Pakistan

Bhutan

Burma

Nepal

Bangladesh

About the Kiln

Kiln | Nature of enterprise | Level of mechanization | Brick produced | Production capacity | Operational season
--- | --- | --- | --- | --- | ---
INTERMITTENT | INDUSTRIAL | MANUAL | SOLID | SMALL Between 0.5-1 million bricks | DRY SEASON

Enterprises using this Technology

Country | Number of enterprises | Total production billion bricks/year
--- | --- | ---
India | ~300 | ~0.24

% Contribution to the total brick production in India

Out of the total annual production of around 250 billion bricks in India, only around 0.24 billion bricks are produced by down draught kiln technology.

*Numbers are estimates only.*
Down draught kiln is an intermittent kiln in which bricks are fired in batches. It consists of a firing chamber/kiln (1.1) connected with a chimney (1.2) through an underground flue duct (1.3). Fireboxes (1.4) are provided at the bottom of the chamber on both sides where burning of fuel takes place. The kiln structure is permanently built with fired bricks and the inner surface of the kiln is constructed with refractory bricks.

The bricks stacked in the chamber/kiln are not in direct contact with the flames. The hot gases from the burning fuel are deflected to the roof of the kiln (3.1). They are then drawn downwards by the chimney draught through the green bricks to fire them (3.2).

Fuel (usually firewood, twigs and branches) is fed in the fire-boxes by a single fireman. The fuel feeding is continued for around 30 hours. Afterwards the fireboxes are shut off and it is left for cooling for 2-3 days. The total time required for a batch from loading & firing of green bricks to cooling and unloading of fired bricks is around 7 - 10 days.

There is uniform heat distribution in a DDK and therefore, the percentage of good quality products is high.

DDK has limited heat recovery features. During firing, the kiln structure also gets heated up along with the bricks and while cooling, the heat contained in the bricks and kiln structure gets lost into the atmosphere.
FACTSHEETS ABOUT BRICK KILNS IN SOUTH AND SOUTH-EAST ASIA

DOWN DRAUGHT KILN (DDK)

AIR EMISSIONS AND IMPACTS

FUELS AND ENERGY

FINANCIAL PERFORMANCE

PRODUCT QUALITY

OCURRENTAL HEALTH AND SAFETY

MEASURED EMISSION FACTORS

<table>
<thead>
<tr>
<th>g/kg of fired bricks</th>
<th>CO2</th>
<th>Black Carbon</th>
<th>PM</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>282.4</td>
<td>0.29</td>
<td>1.56</td>
<td>5.78</td>
</tr>
</tbody>
</table>

As emission factors are measured for only one kiln, range of values for emission factors is not available.

MEASURED PM EMISSIONS

Average: 531 mg/Nm³

(Range: 240–1088 mg/Nm³)

EMISSION STANDARDS

Notified for PM only

Country | PM (mg/Nm³)
---------|----------------
India    | 1200

COMMENTS ON EMISSIONS

Incomplete combustion in a down draught kiln results in the high emission of air pollutants.

SPECIFIC ENERGY CONSUMPTION

Energy consumed for firing 1 kg of fired brick

Average: 2.97 MJ/kg of fired bricks

(Range: 2.80 – 3.14 MJ/kg of fired brick)

MAIN CAUSES FOR HEAT LOSS

The main sources of heat loss in a down draught kiln are incomplete combustion and the heat losses from the kiln structure, hot-fired bricks and flue gases.

Inferior ~ 10%

Losses & Breakages - 5%

Good ~ 85%

Product Quality

As per the local market perception

Capital cost breakdown

Construction Material 84%

Labour 19%

Equipment 1%

Capital cost of kiln technology

For annual production capacity of 0.6 - 1.0 million bricks (excluding land and working capital cost).

20,000 to 30,000 USD

Production Capacity

20,000 to 40,000 bricks per batch

Brick size

230 mm x 115 mm x 75 mm

Number of Operators required

10-12

Payback Period

Simple Payback: -10 years

Discounted Payback (@ 6.5%): -12 years

BETTER HEAT DISTRIBUTION IN THE KILN RESULTS IN UNIFORM TEMPERATURE ACROSS THE KILN CROSS SECTION. THIS RESULTS IN UNIFORM QUALITY OF BRICKS ACROSS THE KILN CROSS-SECTION.

Energy consumed for firing 1 kg of fired brick

Average: 2.97 MJ/kg of fired bricks

Types of products that can be fired in the kiln

Solid bricks

Hollow/Perforated bricks

Roof tiles

Floor tiles

Compliance with ILO standards and remarks on migratory labour and conditions of labour practices followed at down draught kiln enterprises do not always comply with the International Labour Standards on occupational health and safety drawn up by ILO.

Exposure to Respirable Suspended Particulate Matter

The firemen feeding fuel and cleaning the fireboxes (removal of ashes) are exposed to a high concentration of air pollutants.

Firemen have the risk of developing respiratory tract infections and cardiovascular diseases.

Exposure to Thermal Stress

In a down draught kiln, the fuel is fed through fireboxes which remain open during the entire duration of fuel feeding. The firemen are thus directly exposed to the flames.

The firemen bear significant thermal stress and risk of consequent diseases and dehydration.

Risk of accidents

In a down draught kiln, the risk of accidents is low.

Low risk of injuries to workers.
FACTSHEETS ABOUT BRICK KILNS IN SOUTH AND SOUTH-EAST ASIA

1. **CONCLUSION**

Performance of down draught kiln is compared with the most commonly used intermittent kiln technology in the region which is clamps.

<table>
<thead>
<tr>
<th>PARAMETERS</th>
<th>DOWN DRAFT KILN</th>
<th>CLAMPS</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AIR EMISSION</strong> (g/kg FIRED BRICK)</td>
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<td></td>
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<td>NA</td>
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</tr>
</tbody>
</table>
| **FUEL & ENERGY** (SEC (MJ/kg fired brick)) | 2.97 | 2.1 | Though the SEC of down draught kiln is higher compared to clamps, the quality of fired bricks in a down draught kiln is usually better compared to clamps.
| **FINANCIAL PERFORMANCE** | | | As the clamps do not have a kiln structure, no capital cost is considered for setting up of a clamp. |
| Capital Cost (USD) | 20,000 – 30,000 | NA | |
| Production Capacity | 20,000 – 40,000 bricks/batch | 10,000 – 200,000 bricks/batch | |
| Simple Payback | -1.0 years | NA | |
| **PRODUCT QUALITY** | | | All types of products can be fired in a down draught kiln while only solid bricks can be fired in a clamp. |
| Types of product | All types of products | Only solid products | |
| Good Quality Product | 85 % | -50 % | |
| **OHS** | | | Down draught kiln offers better OHS conditions as compared to clamp kilns. |
| Exposure to dust | | | |
| Exposure to Thermal | | | |
| Risk of accidents | | | |

**REFERENCES**

3. Presentation by Punjab State Council for Science and Technology, India on the findings of the study on ‘Revision of Comprehensive Industry Document for Brick Kilns’.
6. Ibid. 3
7. Report on ‘Occupational health and safety study (OHS) of brick industry in the Kathmandu valley’ by Department of Environmental Sciences and Engineering (DESE), Kathmandu University, Nepal
8. Ibid.