

# Information Handbook and Standard Operating Procedure (SoP) Manual for Zig Zag Operations of **BRICK KILNS**



AUGUST 2025





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Standard Operating Procedure (SoP)  
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# Association Letter



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स्थापित सन् 1981

“ऊर्जा बचाओ, प्रदूषण भगाओ”

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### संदेश

ईट निर्माता परिषद की ओर से हमें यह मानक कार्य प्रणाली (SOP) दस्तावेज़ प्रस्तुत करते हुए हर्ष हो रहा है, जिसे अलायंस फॉर एन एनर्जी एफिशिएंट इकॉनमी (AEEE) द्वारा तैयार किया गया है।

उत्तर प्रदेश का ईट उद्योग न केवल आजीविका और स्थानीय अर्थव्यवस्था को सशक्त बनाता है, बल्कि राज्य के सतत विकास में भी महत्वपूर्ण भूमिका निभाता है। साथ ही, यह क्षेत्र ऊर्जा खपत, उत्सर्जन और दक्ष प्रौद्योगिकी अपनाने जैसी चुनौतियों का सामना कर रहा है।

यह SOP ईट भट्टा स्वामियों और संचालकों के लिए एक उपयोगी मार्गदर्शिका है, जो ऊर्जा दक्षता बढ़ाने, उत्पाद की गुणवत्ता सुधारने तथा पर्यावरणीय प्रभाव को कम करने में सहायक सिद्ध होगी। साथ ही, इस पहल और कार्यशाला के माध्यम से मजदूरों की सामाजिक-आर्थिक स्थिति में सुधार, कार्यस्थल की सुरक्षा और बेहतर जीवनस्तर सुनिश्चित करने की दिशा में भी ठोस कदम उठाए जा रहे हैं।

हमें विश्वास है कि यह SOP दस्तावेज़ सभी हितधारकों के लिए एक मूल्यवान साधन सिद्ध होगा और उद्योग को अधिक उत्पादक, ऊर्जा कुशल, सामाजिक रूप से उत्तरदायी और टिकाऊ भविष्य की ओर अग्रसर करेगा। हम ईट निर्माता परिषद की ओर से AEEE के तकनीकी सहयोग और निरंतर साझेदारी हेतु हार्दिक आभार व्यक्त करते हैं।

*X. Sandey*  
ईट निर्माता परिषद

अध्यक्ष

दिनांक: 16 अगस्त 2025

अध्यक्ष  
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# Abbreviations

AEEE	Alliance for an Energy Efficient Economy
BEE	Bureau of Energy Efficiency
FCBTK	Fixed Chimney Bull's Trench Kiln
GKS	Greentech Knowledge Solutions
SOP	Standard Operating Practices
GHG	Green House Gases
INR	Indian Rupee
Kg	Kilo Gram
KW	Kilo Watt
MSME	Micro Small and Medium Enterprises

# Acknowledgements

*This is a draft of the Information handbook and Standard Operating Procedure (SoP) manual for Zig Zag operations of Brick Kilns prepared by Alliance for an Energy Efficient Economy (AEEE). This document is undergoing peer review and will be finalised through further consultation with Brick Kiln Associations, Brick kiln owners, Experts and Govt officials before being officially published. Full list of reviewer and contributors will be provided at that time.*

Alliance for an Energy Efficient Economy (AEEE) supports policy implementation and enables the energy efficiency market with a not-for-profit motive. AEEE promotes energy efficiency as a resource and collaborates with industry and government to transform the market for energy-efficient products and services, thereby contributing toward meeting India's goals on energy security, clean energy, and climate change.

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**Disclaimer:** This report is based on the data collected during the survey conducted by AEEE, suggestions from experts and best available information in the public domain. Every attempt has been made to ensure the correctness of the data. However, AEEE does not guarantee the accuracy of the data or accept responsibility for the consequences of the use of such data.

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# About the Information Handbook and Standard Operating Procedure Manual

## 1.1 Background

The brick kiln sector, despite being one of the largest unorganized industrial sectors in India, suffers from a general lack of systematic record-keeping, particularly with respect to energy consumption, fuel use, and emissions data. Additionally, there is a noticeable gap in awareness and application of standard practices that could significantly improve operational efficiency and environmental performance. Along with these challenges, the sector still using the outdated and inefficient technologies, which results in higher emissions along with lower percentage of Class I bricks. These shortcomings hinder the sector's transition towards cleaner, more energy-efficient technologies. The Government of India, through its notification vide GSR 143 (E), mandates the use of Zig Zag technologies across all brick kilns in India, which is an energy-efficient and climate-friendly firing method.

To facilitate this transition, the Alliance for an Energy Efficient Economy (AEEE) first conducted a scoping assessment of brick-clusters in East UP and three clusters in Ghazipur, Lucknow and Varanasi have been selected for the targeted intervention to improve energy efficiency, higher productivity, and lowering of emissions. AEEE then conducted various activities to address the critical issues specific to the cluster. Recognising this critical need, AEEE conducted a detailed field survey in the three key brick kiln clusters. The objective was to assess the adoption level of Zig Zag technology, as well as to identify the current operational gaps and opportunities for improvement.

The survey covered a total of 150 brick kilns in the selected three districts to assess the adoption level of Zig Zag, profile of the brick kilns, operational challenges faced by the kilns owners, technical and financial barriers, and the need for capacity building and awareness for kilns owners. There are two techniques to manage airflow in Zig Zag kilns - Natural Draft (ND) and Induced Draft (ID). Natural draft

kilns relies on the natural upward draft created by a chimney to move air and exhaust gases through the kiln while Induced draft kiln uses fans to force air through the kiln, providing greater control over airflow and combustion. The survey also captured the type of airflow these kilns are currently using. The key points from the survey related to the adoption of Zig Zag are:

- ▶ Lucknow demonstrated the strongest uptake, with approximately 91% of the surveyed kilns using Zig Zag technology.
- ▶ Varanasi followed closely, with around 83% of the surveyed kilns adopting the improved method.
- ▶ Ghazipur, however, showed relatively lower uptake, with 65% of the surveyed units having adopted the Zig Zag technology.

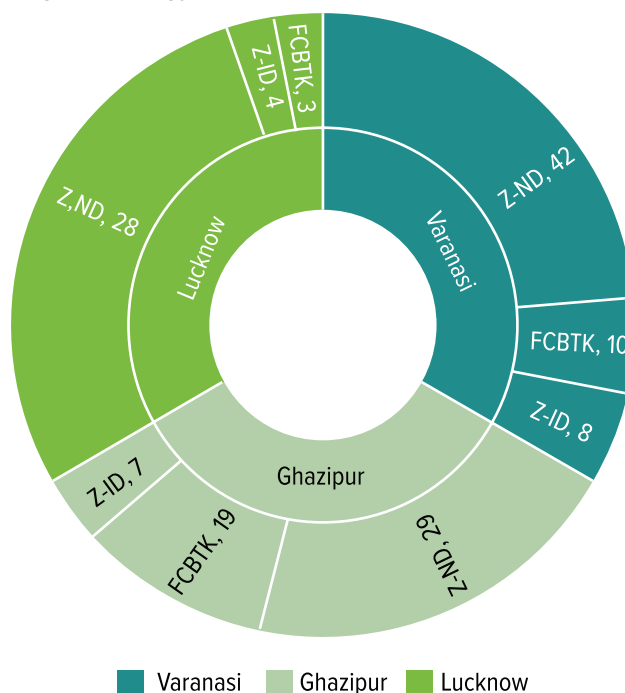


Figure 1: Distribution of Surveyed Kilns in Three Districts of UP

- ▶ However, despite this progress, the inconsistent monitoring practices, lack of trained manpower, and weak enforcement of environmental regulations continue to act as barriers to fully realising the energy and environmental benefits of this transition.

The AEEE survey also revealed the following critical issues:

- ▶ **Lack of standardized operating procedures:** Despite the significant adoption of Zig Zag kiln technology in some districts, most kiln owners and operators do not follow standardized guidelines for kiln design, firing, or maintenance.
- ▶ **Underrealized benefits:** Although Zig Zag kilns have the potential to reduce coal consumption by 20–30% and significantly cut particulate and black carbon emissions, these benefits are often not fully achieved due to poor construction practices, lack of skilled supervision, or improper operation.
- ▶ **Lack of technical guidance for kiln owners:** Many owners rely on informal sources or untrained contractors for kiln construction or retrofitting, leading to poor design, inefficiencies, and non-compliance with environmental norms.

Drawing on hands-on experience in the field, AEEE has crafted this Information Handbook and SOP to bridge existing knowledge gaps and guide kiln operators through every step of adopting and effectively operating Zig Zag technology. This document is presented in two parts based on the target audience.

The first part focuses on brick kiln owners who have to take a decision on the conversion. The second part focuses on the operators to understand the standard practices to improve the efficiency of the Zig Zag kilns. Ultimately, this document is aimed to serve as a practical tool to support the transition of the brick kiln sector towards more energy-efficient, cleaner, and climate-resilient operations, contributing to state-level air quality improvements and national climate goals.

## 1.2 Objective

The primary objective of developing this Information handbook and Standard Operating Procedure (SOP) is to bridge the existing knowledge and practice gap in the brick kiln sector, particularly concerning energy efficiency, operational improvements, and emissions reduction. By offering practical and field-tested insights from the initial planning and construction phases through daily operation, this document will empower owners, contractors, and operators to embrace structured practices, achieve technical consistency and make informed decisions, ultimately paving the way for cleaner, more efficient and fully compliant brick-kiln operations. While this document is prepared as a direct response to the findings of a field-based survey conducted by the Alliance for an Energy Efficient Economy (AEEE) across three major brick-producing districts of Uttar Pradesh, Varanasi, Ghazipur, and Lucknow, the document applies to brick kilns across the state. This document aims to:


1. Provide a comprehensive guideline for kiln owners, supervisors, and contractors on best practices for design, construction, and firing of Zig Zag kilns.
2. Promote uniformity and technical standardization in kiln operations, ensuring that the intended energy savings and emission reductions of Zig Zag technology are actually realized in practice.
3. Build technical capacity at the grassroots level through accessible, easy-to-follow instructions that can be used for training and daily operations.
4. Encourage sustainable and cost-effective kiln modernization, especially in districts like Ghazipur where adoption remains low, by highlighting case studies and demonstrating economic and environmental benefits.
5. This document is intended to be used by kiln owners across Uttar Pradesh and other state wherever, kilns are being converted from FCBTK to Zig Zag kiln.

This document covers the following areas:

- ▶ An overview of the conversion process from traditional Fixed Chimney Bull's-Trench Kilns (FCBTK) to modern Zig-Zag kilns, including key differences and retrofit versus new-build cost comparisons.
- ▶ A detailed breakdown of the advantages that Zig-Zag technology offers in terms of thermal efficiency, emissions reduction and brick quality.
- ▶ Step-by-step guidance on planning and executing a successful kiln conversion, from site preparation through structural modifications.
- ▶ Best-practice Standard Operating Procedures (SOPs) for Zig-Zag kiln operation, highlighting common performance gaps and the importance of structured workflows.



- ▶ Practical recommendations for optimizing fuel preparation, feeding strategies and airflow management to maximize combustion efficiency.
- ▶ Techniques for minimizing heat loss through insulation, draft control and maintenance routines to improve energy performance.
- ▶ A framework for ongoing monitoring and performance assessment, covering critical kiln parameters and data-driven decision-making.



**PART 1**  
**Information Handbook**  
**Guidance for Kiln Owners for**  
**Conversion to Zig Zag Kilns**



# Conversion from FCBTK to Zig Zag kilns

## 2.1 Differences between FCBTK and Zig Zag:

The Fixed Chimney Bull's Trench Kiln (FCBTK) and the Zig Zag kiln represent two commonly used technologies in the brick manufacturing sector, each with distinct design and operational characteristics.

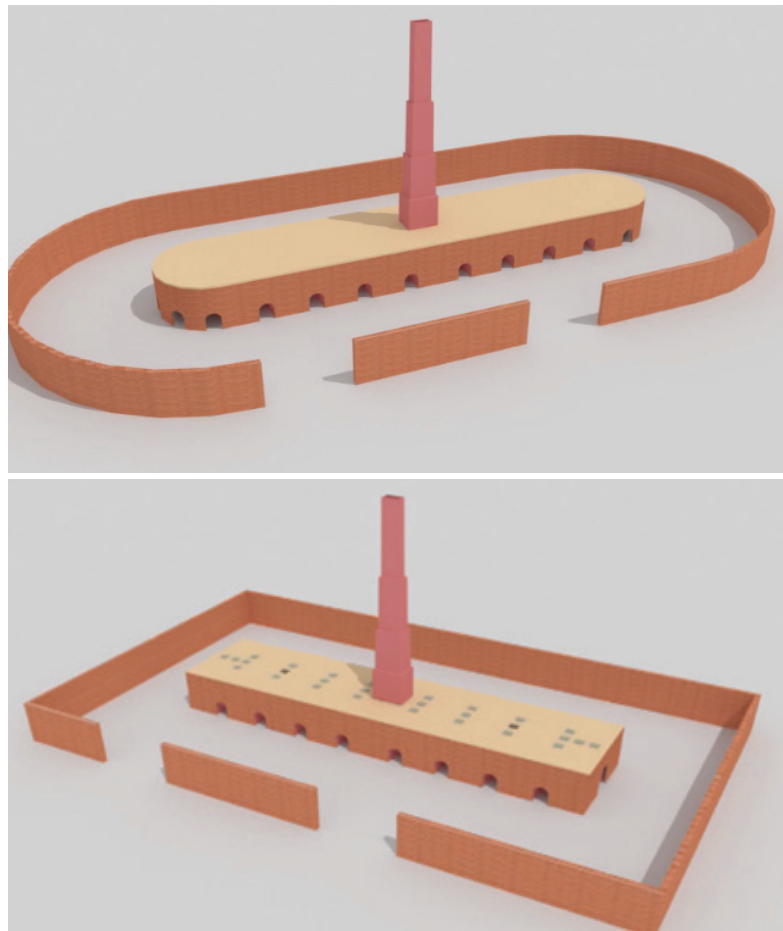
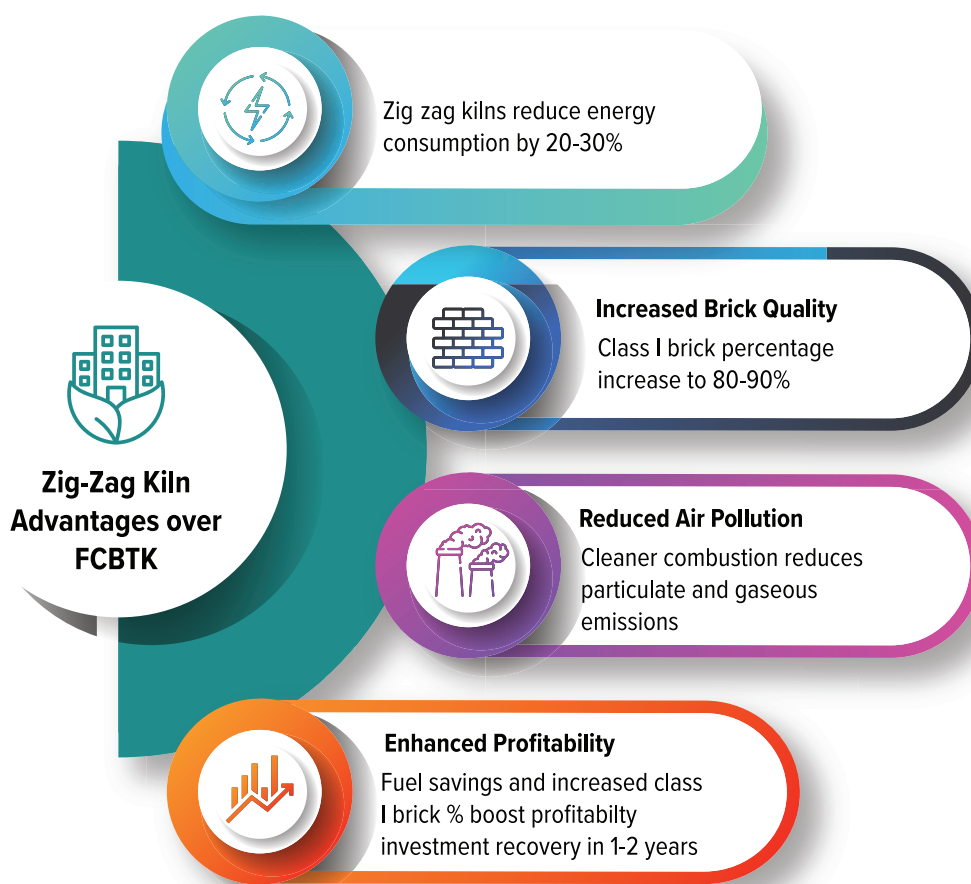


Figure 3: FCBTK (Top) Vs Zig Zag (Bottom) layout

**Table 1: Comparison of FCBTK vs Zig Zag**

S.N.	Parameter	FCBTK	Zig Zag Kiln
1	Kiln Shape	Oval or circular	Rectangular
2	Brick Setting	Column or blade setting	Chamber-based setting
3	Firing Zone Length	Short (2–3 lines; 3–6 feet)	Long (6 chambers; 30–36 feet)
4	Coal Feeding Spoon Size	Large (1.0–1.5 kg per spoon)	Small (200–400 g per spoon)
5	Coal Particle Size	Larger particles (up to 25 mm)	Crushed/powdered coal (up to 5 mm)
6	Draught System	Natural draught via chimney	Combination of natural and induced mechanical draught (ID fan)

## 2.2 The Main Advantages of Zig Zag Kiln over FCBTK



**Figure 4: Advantages of Zig Zag over FCBTK**

## 2.3 Cost of a new Zig Zag kiln:

- ▶ Before initiating construction of a brick kiln, the owner should obtain a detailed Bill of Quantities (BoQ) and cost estimate from credible and experienced technology providers or kiln contractors.
- ▶ It is essential to review the overall budget and its key sub-headings carefully, such as material quantities and costs, as well as manpower or labor costs.
- ▶ Significant variation in cost estimates may occur depending on the design approach, the technical specifications, and the extent of retrofitting or new construction proposed. Therefore,

comparing multiple estimates and verifying their components is recommended to ensure value for investment and technical adequacy.

- ▶ For reference, an indicative BoQ is provided in Table 2 for the construction of a new Zig Zag kiln with a daily production capacity of 30,000 bricks.

**Table 2 Typical bill of quantities and budget for a new Zig Zag kiln (30,000 bricks per day capacity) (Based on the discussion with Zig Zag technology expert)**

S.no.	Item	Approx. Cost in Rs Lacs
1	Civil work and Labour cost for complete Kiln & Chimney Construction	10
2	Consultancy Fee	2.5
3	Equipment (Feed Hole Covers+ Shunt Box)	3.5
4	Misc. (Sand, Cement, Stone, Iron)	2.0
5	Bricks (size 4"x3"x9") – 9 Lakhs pcs. @ Rs.6/- per pc.	54.0
	Total	72.0 Lacs

## 2.4 Typical process of conversion from a FCBTK to Zig Zag kiln:

The decision to change from FCBTK to Zig Zag kiln is a very important decision for a brick kiln owner. Typically, the process requires around 6 -9 months to plan and execute. An investment ranging from Rs 20 to 80 lakhs is required, hence it is important for a brick kiln owner to plan and execute this process carefully. Below is the basic process to convert the FCBTK to Zig Zag Technology.

### Key aspects to explore

- ▶ Differences in design, construction, and operations between Zig Zag kilns and FCBTK
- ▶ Common challenges faced during conversion
- ▶ Available technology providers or kiln contractors in the region
- ▶ Typical duration and ideal timing for conversion
- ▶ Approximate cost and investment required
- ▶ Options for training or sourcing skilled manpower for kiln operation

## 1. Gaining Basic Understanding of Zig Zag Kiln Technology

The first step is to build foundational knowledge about Zig Zag kilns. The kiln owner should visit nearby Zig Zag kilns preferably both natural draft and induced draft types to observe operations, interact with kiln owners, supervisors, and understand real-world functioning.

## 2. Finalizing Key Operational Parameters

Once the decision to convert is made, the owner should finalize certain baseline parameters that influence kiln design:

- ▶ Size of dry green brick (e.g., 9" x 4.5" x 3")
- ▶ Target daily production capacity (e.g., 30,000 bricks/day)
- ▶ Whether to retrofit an existing FCBTK or construct a new Zig Zag kiln
- ▶ Preference between induced draft or natural draft system

These parameters directly influence the kiln's layout and dimensions.

### 3. Due diligence to select a competent technology provider:

The brick kiln owner should short-list a few kiln contractors/ technology providers and carry out due diligence for selecting a competent technology provider. The due diligence can cover the following aspects:

- a. The scope of services offered by the kiln contractor:
  - i. Only kiln construction
  - ii. Kiln construction, training of workers, commissioning and technical support during the first year of operation.

It is better to choose a kiln contractor who, in addition to kiln construction, also provides training to workers and commissioning/technical support during the first year of operations.

- b. Technical and business capability of technology provider: The brick kiln owner should either visit a few kilns constructed by the technology provider or speak on phone to the owners of such kilns. The main purpose is to get feedback about the quality of the work and the overall technical and business capability of the contractor.
- c. Review of the proposed bill of quantities and cost estimate
 

Preference should be given to contractors offering complete support beyond just construction.

### 4. Design of the kiln:

Once the contractor has been selected and has visited the site, he is expected to provide the final design and drawing of the kiln. The contractor will also provide a time plan. The given design and time plan needed to be critically examined by the brick kiln owner. An example design suitable for kilns in Eastern UP is shown in Figure 5, depicting a kiln with a daily capacity of 30,000 bricks. A structural consultant should be consulted for the design of the chimney.

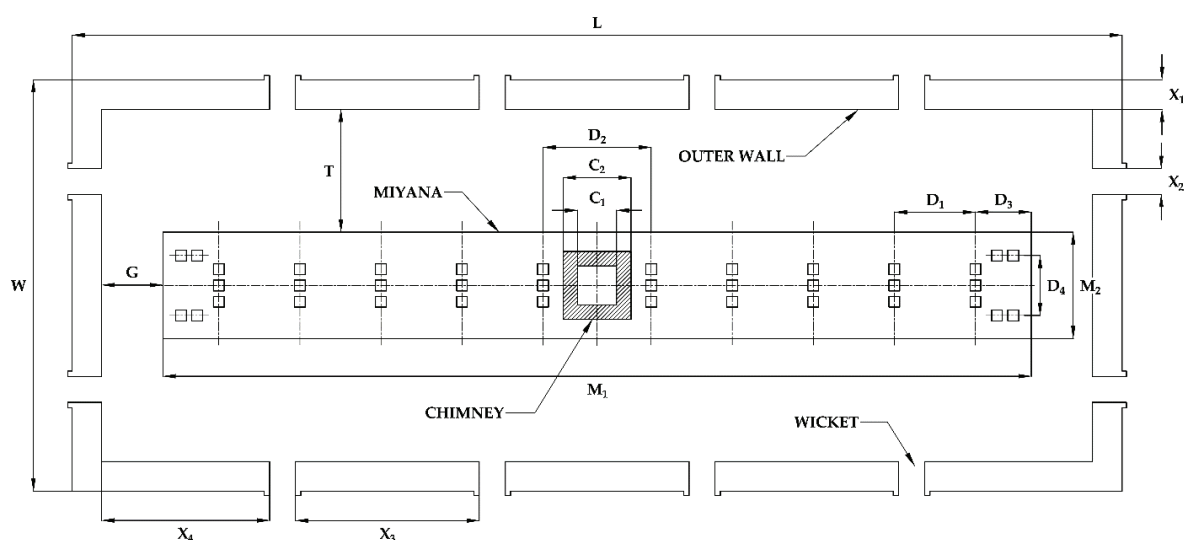
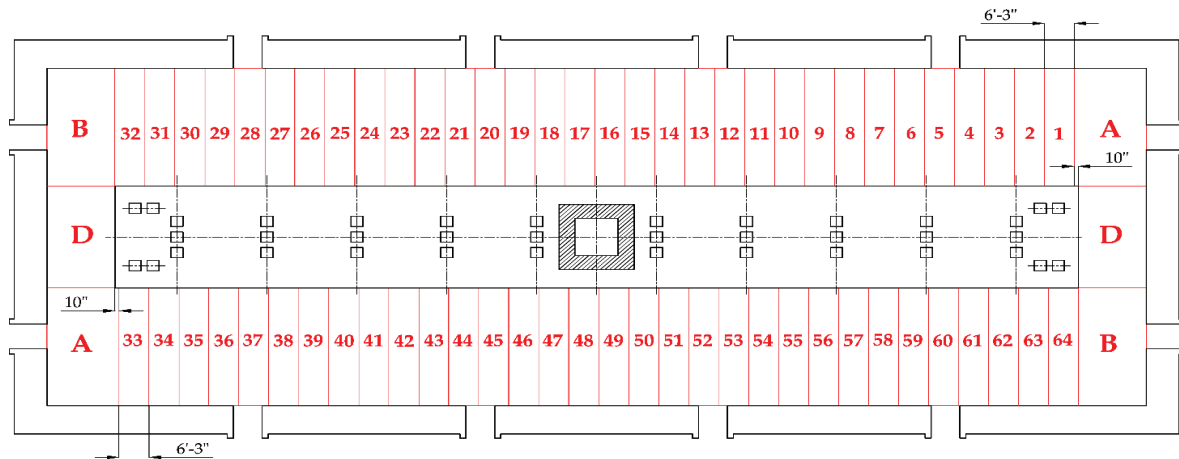


Figure 6: Safe storage of bricks



**Figure 5: Example of a design of Zig Zag kiln**

1. L : Outer Length of the kiln = 218 feet
2. W : Outer width of the kiln = 84 feet
3. X1 : Outer wall thickness = 6 feet at the ground level
4. X2 : Gate/Ghati width = 5 – 6 feet for manual/small vehicle for loading & unloading bricks
5. X3 : Distance between two ghatis in the outer wall = 36 feet to 54 feet
6. X4 : Distance from corner to the first ghati = 38 feet
7. T : Width of trench = 26 ft 3 inch
8. G : Width of Gali = 13 ft 1.5 inch
9. M1 : Length of Miana = 192 ft 10 inch (32 chambers on each side)
10. M2 : Width of Miana = 23 ft 6 inch
11. C1 : Internal diameter of chimney = 10 feet
12. C2 : Outer width/diameter of chimney= 16 feet
13. D1 : Distance between centers of side nali = 18 feet
14. D2 : Distance between holes on each side of chimney = 24 feet
15. D3 : Distance between the edge of the miyana and its adjacent side nali =12 feet 5 inch
16. D4 : Distance between side nali in a gali = 15 feet 11 inch
17. Height of the chimney = minimum 135 feet (natural draft kiln) and minimum 90 feet for induced draft kiln.

## 6. Demolition of the existing kiln and storing of materials for reuse:

It is common that most of the Zig Zag kilns are retrofitted from existing FCBTKs. The first step is to demolish partly or fully the existing kiln, clear the site and store the material properly for future use. (figure-6 and 7).



Figure 7: Demolition of Miyana



Figure 6: Safe storage of bricks

## 7. Construction of the kiln<sup>1</sup>:

Some of the good practices for the construction of the kiln are as follows

- a. **Chimney:** The design of the chimney should be done in consultation with a qualified structural engineer. However, some general guidelines for construction based on the best practices observed in the field are listed below.
  1. The depth of the foundation pit is kept at least **5 feet** from the floor level of the trench (trench level).
  2. The floor of the foundation pit is compacted and evenly levelled.
  3. A layer of river sand is spread over the floor. Layers of plain cement concrete (PCC), reinforced cement concrete (RCC), and a mixture of mortar and brick pieces are placed in sequence, one on top of the other, over the sand layer.
  4. The base of the chimney walls is constructed (in step footing) from the top of the 'mortar and brick pieces' layer till the trench level. High quality (good load bearing capacity) Class-1 bricks are used for the construction of the foundation.
  5. From the trench level up to at least 50-feet height, good quality Class-1 bricks are used for constructing the chimney.
  6. Mud mortar (Gara) is used. The mortar must be aged for at least 2–3 days prior to its usage. It should be in the form of a homogeneous paste (texture similar to toothpaste). Only a thin layer of mud mortar is applied.
  8. RCC bands are provided in the chimney at regular height intervals.
  9. The inner surface of the chimney wall is plastered with mud mortar, and the outer surface with cement mortar to prevent infiltration of ambient air.
  10. To monitor air pollution, four sampling ports, which are mutually perpendicular to each other, are provided.
  11. The sampling port is generally in the form of a pipe of about 4-inch internal diameter. The pipe extends outwards from the exterior chimney wall (approximately 6-inch projection). An easily removable cover is provided to close the port when not in use.

<sup>1</sup> Brickguru (2017): Knowledge Briefs on the construction of Zig Zag kilns. Greentech Knowledge Solutions & Prayag Clay Products Ltd.

12. To access the ports, a work platform is provided all around the chimney. Minimum platform width should be 4 feet regardless of the diameter of the chimney. The height of the ports from the floor of the work platform should be between 3 and 4 feet.
13. For safety, a guardrail is provided around the platform. The work platform should be strong and should be able to support a weight of about 500 kg (2-4 persons + weight of the monitoring equipment).
14. Access to the work platform is provided through a caged ladder.
15. Power supply points (220 V, 15 A, single phase AC circuit with grounded outlet) are provided at the platform and chimney base.
16. Lightning protection system and earthing are installed on the chimney to shield it from structural damage or electric shock caused by lightning.
17. Ensure that the holes left on the chimney walls to put the scaffolding are properly closed with bricks and mortar after removing the scaffoldings.

#### b. Flue ducts and miyana:

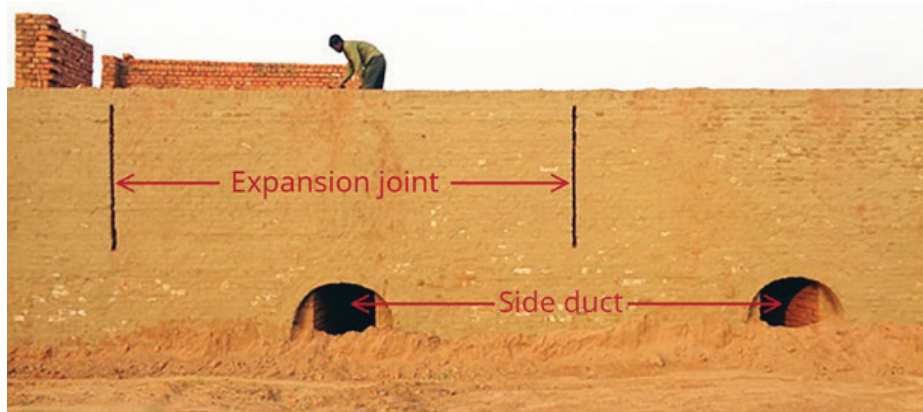
- ▶ At least 1-foot-deep foundation pit is dug for the construction of flue gas ducts and miyana.
- ▶ The foundation pit floor is compacted and evenly levelled.



**Figure 8: Central duct arch covered with plastic sheet (**

- ▶ Mud mortar (Gara) is used. The mortar must be aged for at least 2–3 days prior to its usage. It should be in the form of a homogeneous paste (texture similar to toothpaste).
- ▶ The arch of the duct is constructed with Class-1 bricks.
- ▶ The arch of the central duct is covered from outside with plastic sheet before filling the soil (Figure 8).
- ▶ Care should be taken during construction to ensure that the brick joints are never in a straight line between the inner and outer surfaces of the walls so as to minimise the leakage of flue gases.

- ▶ The inner side of miyana walls is made in a step footing arrangement, but the outer side is straight.
- ▶ The corners of the miyana are reinforced by L-shaped iron rods at regular intervals from the bottom.
- ▶ The outer side of miyana walls is plastered with mud.



**Figure 9: Expansion joint**

- ▶ Expansion joints are made on the outer side of miyana walls to reduce the possibility of cracks developing in the walls due to thermal stress developed during firing of the kiln (Figure 9).
- ▶ One expansion joint is provided between two side ducts.
- ▶ The central duct is made at the middle of the miyana. The remaining space between the miyana walls and the central duct is filled and levelled with soil. Soil is filled in layers. Once the soil is filled in a layer of about 1 foot, it should be compacted, and only after that the next layer of soil is filled. This will minimise the possibility of vacant spaces being left between the walls.

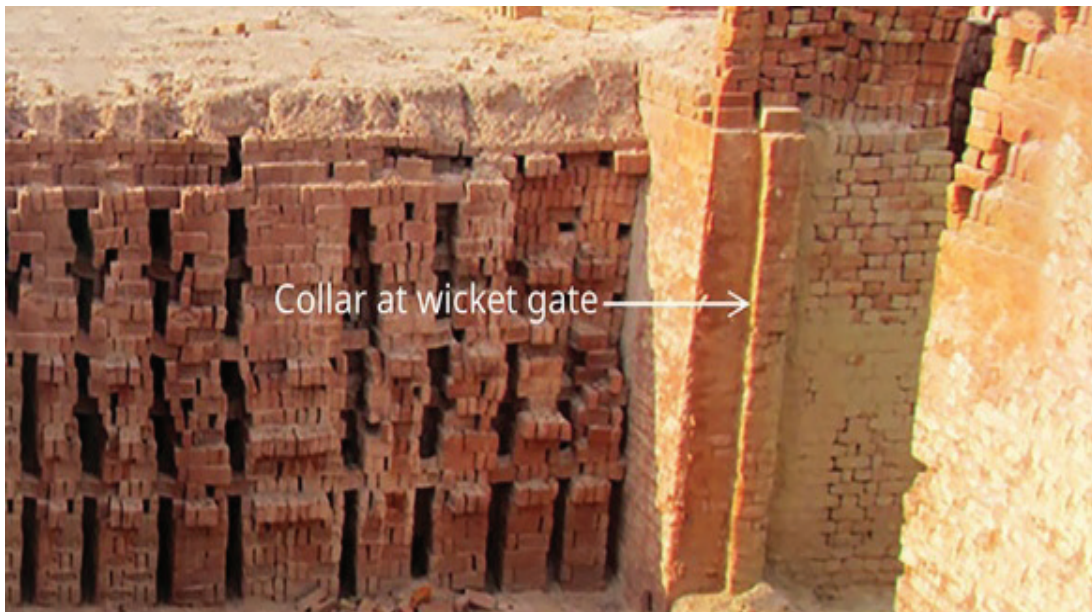
### **C. Construction of Outer Walls and Ghatis:**

The outer walls and ghatis (wicket gates) form a critical structural and thermal component of a Zig Zag kiln. Proper construction is essential to ensure durability, minimize heat loss, and manage thermal stress during kiln operation. The standard construction process involves the following steps:



**Figure 10: Outside wall of the kiln stepped on the outside**

- ▶ A foundation pit at least 1 foot deep is excavated for laying the base of the outer wall.
- ▶ The floor of the foundation pit is compacted and leveled uniformly to ensure structural stability.
- ▶ Mud mortar (gara) is used for wall construction. The mortar must be aged for 2–3 days prior to use and prepared to a homogeneous, toothpaste-like consistency.
- ▶ The outer wall is constructed as a two-layered wall, with the cavity between the inner and outer layers filled with soil. This insulating design helps to reduce heat loss during kiln operation (Figure 10).
- ▶ Both the inner and outer walls are built using a step-footing arrangement, allowing for uniform elevation and enhanced strength.
- ▶ The soil infill between the two wall layers is placed in compacted layers (~1-foot-thick each), simultaneously with wall construction. This helps avoid the formation of air gaps and improves insulation.



**Figure 11: Collar provided for ghati closure**

- ▶ Once the walls are erected, they are plastered with mud to smoothen the surfaces and further reduce thermal losses.
- ▶ To manage thermal stress and prevent cracking, expansion joints are provided along the inner face of the outer wall.
- ▶ A minimum of one expansion joint should be constructed between every two adjacent wicket gates.
- ▶ Collars (support structures) are constructed on both sides of each wicket gate (ghati) to reinforce the opening (Figure 11).

## 8. Training of the manpower for brick stacking and firing

Once the kiln has been constructed and green bricks are being made for firing, the brick loaders and firemen need to be trained in the brick loading and firing operations. If possible, selected firemen and brick loaders should be sent to an operating Zig Zag kilns for around 2 weeks to get trained. A good technology provider generally helps in organizing this training. The technology provider should provide 1-2 trained supervisors to assist in commissioning and operations of the kiln for about a fortnight. Working under these supervisors for about a fortnight helps in training of all brick loaders and firemen working on the kiln.

## 9. Initial firing of bricks

As discussed earlier, a Zig Zag kiln primarily has two sections in the kiln trench (between miyana and the outer wall) for green brick stacking and firing. They are called the ‘Sidhaan’ & the ‘Gully’ region. In ‘Sidhaan’ the brick stacking is done in chamber format whereas in the ‘Gully’ region the brick stacking is done as straight line like in FCBTK. The gully is almost half the width of the ‘Sidhaan’. For example, a kiln of production capacity of 30,000 bricks per day will have a ‘Sidhaan’ width of **24 feet**, so its ‘Gully’ would be half around **12 feet**.

The initial firing begins in the “Gully” region, where the bricks are arranged in a straight line to accelerate flame propagation. Because this section is narrower, the fire builds more quickly and requires less fuel than it does in the wider “Sidhaan” area.

The initial firing pattern in a Zig Zag kiln is similar to that of a FCBTK. Almost 6-8 lines of coal feeding lines are provided with intermittent wood feeding lines at intervals for fire building and strengthening the fire. The fire is started in D1 line (Figure 12) with wood, rubber tyres etc. Once the fire strengthens, L1 line is fed first with sawdust and then with coal. Similarly, D2 is fed with wood and gradually L2 and L3 with saw dust and coal. This process continues till the fire strengthens, elongates up to 12-15 lines and then transferred to ‘Sidhaan’. The whole process of starting the fire and transferring it to ‘Sidhaan’ into chambers takes almost **36-48 hours**.

The coal used for initial firing should be with high volatile matter and low ignition temperature thus helping in faster burning, fire building and moving ahead.

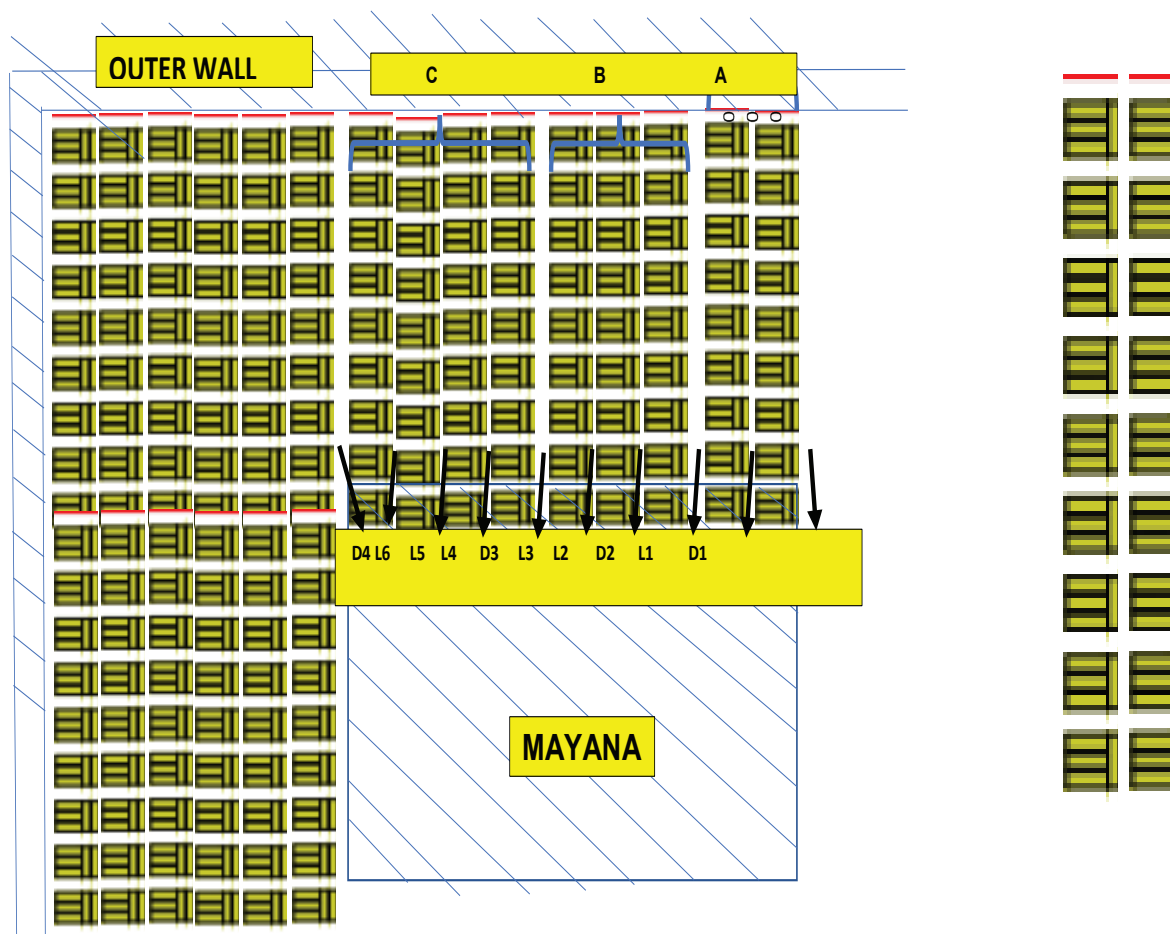


Figure 12: Initial Firing Gali brick setting design

## Initial Firing Brick Setting Explained

- ▶ A, B & C are straight line Brick setting sections.
- ▶ D1 is 9-inch clear space to feed wood, rubber tyre, etc. to start a fire - DUMFA 1
- ▶ L1 is normal line to feed saw dust & coal to strengthen the fire.
- ▶ D2 is 9-inch clear space to feed wood, coal, saw dust, etc. to move the fire forward- DUMFA 2
- ▶ L2 & L3 are normal lines to feed saw dust & coal to further strengthen the fire.
- ▶ D3 is 9-inch clear space to feed wood, rubber tyre, etc. - DUMFA 3.
- ▶ L4, L5 & L6 are normal lines to feed saw dust & coal to further strengthen the fire.
- ▶ D4 is 9-inch clear space to feed wood, rubber tyre, saw dust, etc. - DUMFA 4.





**PART 2**  
**Standard Operating  
Procedure for Kiln Operators**  
**Improving Zig Zag Kiln Performance**

# Standard Operating Practices of Existing Zig Zag kilns

## 3.1 Importance of SOPs for Efficient and Compliant Kiln Operations:

The two main operating parameters which are of interest to a brick maker are the fuel cost and the quality of bricks.

### Fuel cost

Fuel cost is the largest input cost in brick making. In Eastern UP, the fuel cost ranges from Rs 1.5 – Rs 2 per brick and contributes to around 30-40% of the input cost of bricks. A 20% reduction in fuel cost from Rs 2.0/ brick to Rs 1.6/brick, can potentially save Rs 12 lakhs per year in fuel cost for a kiln producing 30 lakh bricks per year.

### Quality of bricks

The bricks produced in brick kilns of East UP are generally divided into five categories:

**Table 3: Types of Bricks**

**Class I:** Good quality fired bricks. They have good compressive strength and metallic ring<sup>2</sup> and lower water absorption.



**Class II & III:** Underfired bricks have lower compressive strength compared to Class I.



**Overfired bricks:** These bricks have been exposed to high temperatures within the kiln. Because of excessive firing, they have smaller final size. Usually they are also not straight and have been disfigured.



**Broken bricks:** The breakage of bricks could be due to issues with green bricks or due to improper kiln operation.



The typical selling prices of different types of bricks in Eastern UP are given in Table 4. These numbers have been captured through the survey. The class I bricks fetches the highest price.

**Table 4: Typical selling price of bricks in East UP**

Type of Brick	Selling Price <sup>3</sup> (Rs/1000 bricks)
Class I	7000
Class II	6000
Class III	3500
Broken	2000

2 Ring refers to the ringing sound produced when two bricks are struck against each other. A properly fired brick will have a metallic sound

3 As per AEEE assessment

A traditional Zig Zag kiln in the East UP produces around **60-70% of Class I bricks**. On the other hand, a well operated Zig Zag kiln could increase the percentage of Class I bricks to almost 85%-90%. As shown in the example given in Table 5, for a kiln producing 30 lakhs bricks per year, an increase of around Rs 12 lakhs in revenue is possible by following the SoP mentioned in this document.

**Table 5: Comparison of revenue based on improvement in quality of bricks (traditional Zig Zag vs Zig Zag following SoPs)**

	Typical Zig Zag kiln			Zig Zag kiln (SoP)		
	% of bricks	No of bricks	Revenue (Rs)	% of bricks	No of bricks	Revenue (Rs)
Class I	70%	21,00,000	1,47,00,000	85%	25,50,000	1,78,50,000
Class II	15%	4,50,000	27,00,000	8%	2,40,000	14,40,000
Class III	10%	3,00,000	10,50,000	4%	1,20,000	4,20,000
Broken	5%	1,50,000	3,00,000	3%	90,000	1,80,000
Total			1,87,50,000			1,98,90,000

**The Standard Operating Practices helps a Zig Zag kiln owner in increasing profits by:**

- Improving the energy efficiency, thus reducing the fuel cost.
- Increasing the % of Class I bricks, thus increasing the revenue.

**In East UP, for a Zig Zag kiln producing 30 lakhs brick per year, an additional profit of around Rs 20 lakhs per year can be achieved by following the SoP.**

**As SoP results in consumption of less fuel as well as cleaner combustion of fuel, it also results in lowering the air pollution.**

### 3.2 Key operational short-comings observed in Zig Zag kiln operation

Some of the key operational short-comings observed in Zig Zag kiln operations during the survey are:

#### Periodic fuel feeding by two firemen simultaneously

The fuel is fed through the feed holes provided at the roof of the kiln by firemen. In several Zig Zag kilns, fuel is fed by two firemen simultaneously (Figure 13) at intermittent intervals i.e., the two firemen feed coal simultaneously for an interval of 10-15 minutes, this is followed by a non-feeding interval of 15-20 minutes. Intermittent feeding by two firemen simultaneously results in accumulation of fuel in the kiln, which does not get sufficient air for combustion, resulting in incomplete combustion, unburnt fuel and black smoke.



**Figure 13: Periodic fuel feeding by two firemen simultaneously**



**Figure 14: Dense single Zig Zag brick setting**

### Dense Single Zig Zag Brick Setting

Several induced draught Zig Zag kilns in the region have adopted a dense brick setting pattern (Figure 11) with a single Zig Zag air path. In such settings, the typical packing density<sup>4</sup> ranges between 1050–1150 kg/m<sup>3</sup>, with a packing fraction<sup>5</sup> of approximately 60–65%.<sup>6</sup>

While dense settings allow for higher brick throughput per batch, they also lead to increased pressure loss within the air flow path. This impedes the uniform transfer of heat across the kiln cross-section, resulting in inefficient combustion, higher fuel consumption, and a lower yield of Class I bricks. Therefore, optimizing the brick setting pattern is crucial for improving thermal efficiency and product quality in Zig Zag kiln operations.

### 3.3 Air Leakage in the kiln

The Zig Zag kiln operates under negative gauge pressure, making it especially vulnerable to air leaks. Common leakage points include metal-sheet dampers used for airflow control (Figure 15), wicket gates sealed with only a single-brick wall (Figure 16), an ash-insulation layer thinner than six inches on the kiln roof, and brick masonry in the fan ductwork. Such leaks lead to significant heat loss, reduced airflow through the kiln circuit, slower flame propagation and delayed cooling of the fired bricks.



**Figure 15: Use of Sheet Metal dampers result in air leakage around the edges of the damper**



**Figure 16: Wicket gate closing with single brick thick wall result in air leakages from gaps between the bricks**

4 Packing density (kg/m<sup>3</sup>) is the weight of green bricks stacked per m<sup>3</sup> of the kiln chamber volume.

5 Packing fraction of brick setting (in %) can be defined as the volume of bricks stacked in a chamber to the volume of the chamber

6 Greentech Knowledge Solutions (2018) report to SADC.

### 3.4 Fuel preparation and use

In many kilns, it was observed that after crushing, the crushed fuel was not sieved, resulting in crushed coal having many large-sized coal particles i.e. diameter  $> 5$  mm (Figure 17). Also, the kilns were found to use coal as fuel in the front chambers also. Both these practices result in some coal remaining unburnt on the kiln floor (figure 18) as well as emissions of black smoke.



Figure 17: Large sized Coal particles in the crushed coal



Figure 18: Unburnt coal on the kiln floor

#### Poor quality green bricks loaded in the kiln:

In many kilns it was observed that proper quality control is not being followed while loading green bricks into the kiln. In some cases, the green bricks were not fully dried, in some cases they were of irregular shape and size and in some cases, they were damaged by rain (Figure 19). The loading of poor-quality green bricks in the kiln may lead to unstable/irregular brick columns, causing obstruction to the air flow and heat distribution. Poor-quality green bricks are one of the main causes of broken fired bricks.



Figure 19 Green bricks damaged by rain being loaded into the kiln



# Standard Operating Practices: Components

The day-to-day operations of a Zig Zag kiln can be divided into five components:

- ▶ Setting green bricks in the kiln.
- ▶ Fuel preparation and feeding.
- ▶ Managing air flow through the kiln.
- ▶ Minimizing heat loss from the kiln.
- ▶ Monitoring brick kiln performance.

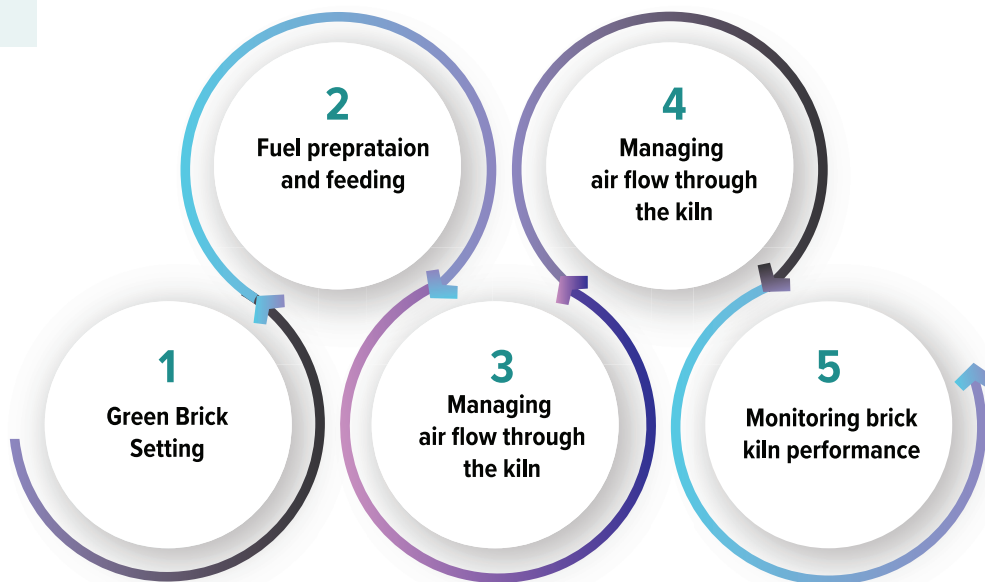


Figure 20 Components covered under the Standard Operating Practices.

## 4.1 Standard Operating Practices for Zig Zag kilns: Setting Green Bricks

- Green Bricks:** Green bricks loaded in the kiln should have a regular shape and size; the kiln floor should be paved and leveled (Figure 21). This is to ensure that the brick columns are vertically straight, the gap between them is uniform from top to bottom. The regular shape of the brick columns and uniform gaps between the bricks are essential for ensuring proper air flow and uniform heat distribution across the kiln cross-section.



Figure 21: Regular shape bricks and paved leveled floor

- Double Zig Zag brick setting:** The bricks in a Zig Zag kiln are set in chambers (Figure 22 and Figure 23). The SoP for double Zig Zag brick setting is explained in subsequent paragraphs. The main specifications of the kiln are:
  - Length of the miyana = 192 feet 10 inch
  - Width of trench = 24 feet
  - Length of one chamber = 6 feet
  - Number of chambers stacked in one straight length of the kiln =32 chambers

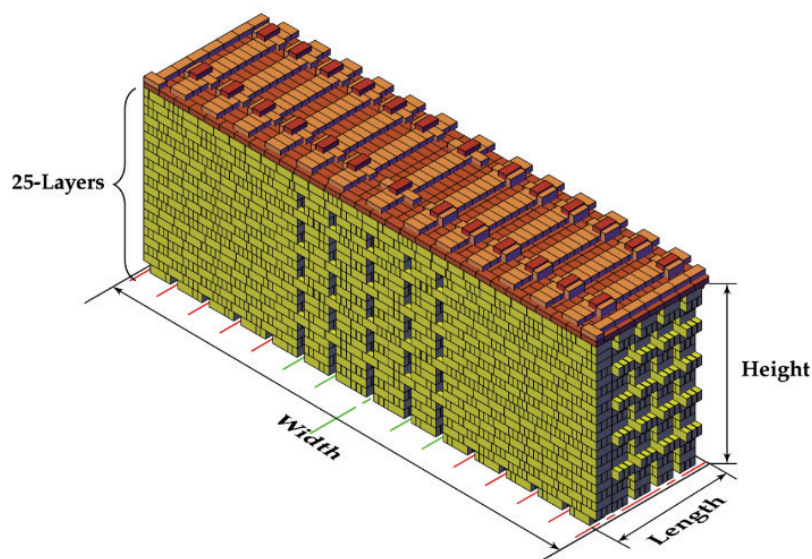


Figure 22: View of a double Zig Zag brick setting chamber

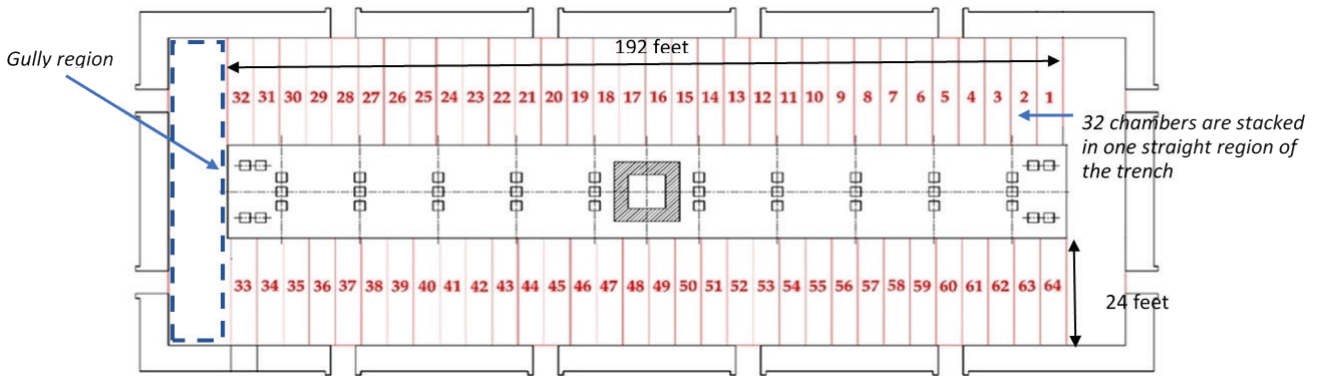


Figure 23: Numbering of channels

- 3. Double Zig Zag brick setting (openings for air flow):** To create double Zig Zag air movement, the openings for air flow in the chambers are provided alternatively on the side and center (Figure 24). The number and area of the openings are determined based on the draught available and the desired rate of fire travel.



Figure: Double Zig Zag brick setting: Openings for air flow located on the side of the chamber

- 4. Dimensions of the chamber:** The arrangement of columns in a chamber is given in Figure 25. The calculations of the chamber dimensions as per the given setting are given in Table 6.

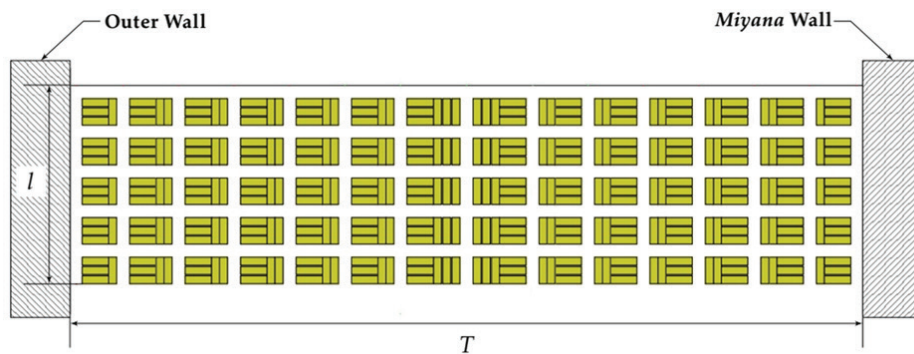
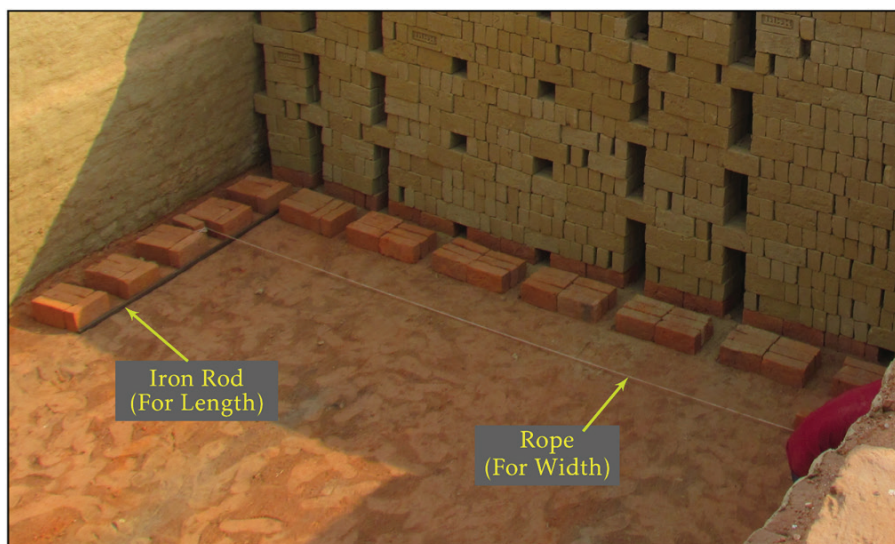


Figure 25: Arrangement of columns in a chamber (plan view)

**Table 6: Calculation of dimensions of the chamber**

Chamber Length (L)	$= (\text{Number of rows} \times \text{Length of row}) + (\text{Number of gaps} \times \text{Width of gaps})$ $= (5 \times 9") + (5 \times 5") = 45" + 25" = 70"$ $\approx 72" \text{ (6 feet) approx.}$
Chamber Width (T)	$= (\text{Number of 4-brick column} \times \text{Width of 4-brick column}) +$ $(\text{Number of 5-brick column} \times \text{Width of 5-brick column}) +$ $(\text{Number of 6-brick column} \times \text{Width of 6-brick column}) +$ $(\text{Number of gaps} \times \text{Width of gap})$ $= (2 \times 12") + (10 \times 15") + (2 \times 18") + (15 \times 5") = 24" + 150" + 36" + 75"$ $= 285" = 23 \text{ feet } 9 \text{ inch i.e., approx. } 24 \text{ feet}$
Chamber Height (H)	$= (\text{Number of layers of bricks} \times \text{Width of bricks})$ $= (25 \times 4.5")$ $= 112.5" = 9 \text{ feet } 5 \text{ inch}$

- 5. Laying the first layer on the ground:** For proper air flow and heat distribution, it is important that the column dimensions and gaps between the columns are uniform in all the chambers. To ensure this, simple tools like a pre-measured iron rod (having a length equal to the chamber width) and rope are used (Figure 26).
- The bottom layer is laid first which helps in maintaining uniform placings of the columns and uniform gaps
  - Pre-measured iron rod is used for guidance of chamber length and gaps in laying the bottom layer of bricks
  - A rope is used for guidance in laying the bricks in a straight line in a row along the chamber width.



**Figure 26: Laying the bottom layer of the brick setting**

- 6. Bandhan & Jodi:** The adjacent brick columns are interconnected with bricks at various levels along the kiln height. The purpose of these interconnections is to provide stability to the brick stacking and help with fuel distribution. There are two types of interconnections: a) column to column (interconnects two adjacent columns of a row) that are called as *jodi*, and b) row to row (interconnects two adjacent rows) that are called as *bandhan* (Figure 27). The *jodi* and *bandhan* are provided at five

levels in the brick setting. Their location depends on the number of layers/ radda in the brick setting. The locations of *jodi* and *bandhan* for different numbers of *radda* are given in Table 7.

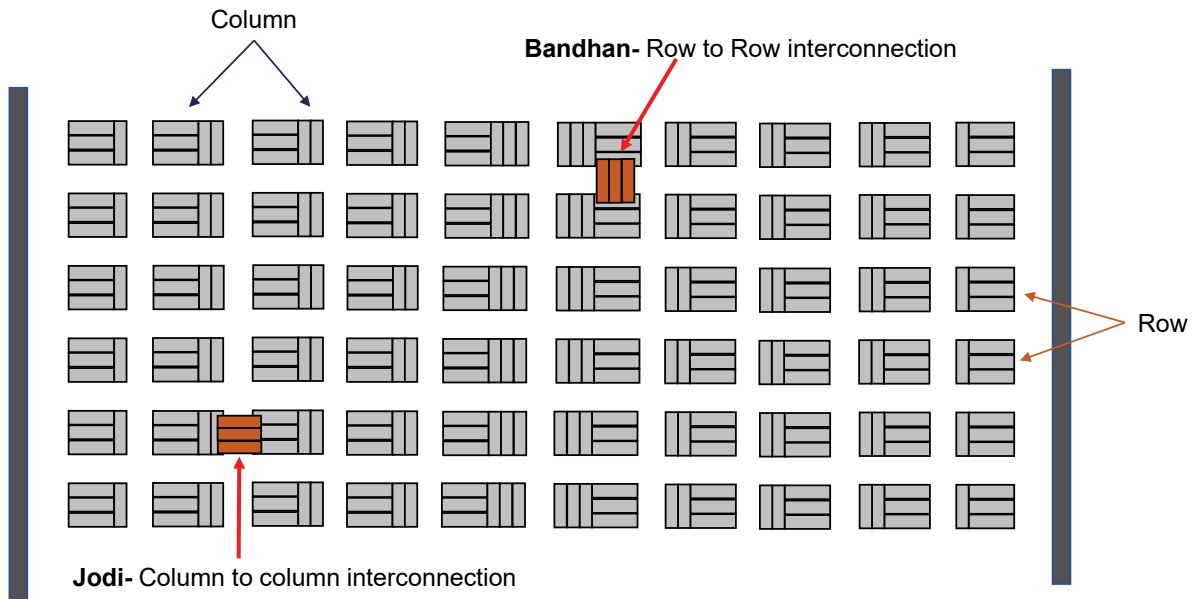


Figure 27: Jodi and Bandhan

Table 7: Location of Bandhan & Jodi

Total No. of layers in the brick stacking (number of radda)	Type of interconnection	Layer numbers at which the five interconnections will be provided (counting starts from the bottom)				
		1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	4 <sup>th</sup>	5 <sup>th</sup>
21 layers	Column to Column (Jodi)	5	9	13	17	20
	Row to Row (Bandhan)	5	8	13	16	21
22 layers	Column to Column (Jodi)	6	10	14	18	21
	Row to Row (Bandhan)	6	9	14	17	22
23 layers	Column to Column (Jodi)	7	11	15	19	22
	Row to Row (Bandhan)	7	10	15	18	23
24 layers	Column to Column (Jodi)	8	12	16	20	23
	Row to Row (Bandhan)	8	11	16	19	24
25 layers	Column to Column (Jodi)	9	13	17	21	24
	Row to Row (Bandhan)	9	12	17	20	25

7. **Temporary roof of the kiln:** As a Zig Zag kiln does not have a permanent roof, a temporary roof is constructed over the bricks setting. Apart from providing a safe surface on which workers can move, the roof of the kilns needs to be leak proof (do not allow the outside air to leak into the kiln) as well as provide thermal insulation to reduce heat loss from the kiln.

The temporary roof consists of three layers

- jali*, which forms the base for the roof consist of a layer of bricks on edge (Figure 28)
- patan*, a layer generally of fired bricks forming the roof with flat bricks (Figure 29)
- ash layer (30).

For reducing the heat loss, the thermal insulation provided by the ash layer should be adequate and the thickness of the ash layer should be at least 9 inches.



Figure 28: Jali Layer



Figure 29: Patan layer of fired brick



Figure 30: Ash Layer

## 4.2 Standard Operating Practices for Zig Zag kilns: Fuel and Fuel Feeding

1. **Storage of Coal:** Coal is the most expensive raw material, and it should be stored properly. The floor of the fuel storage area should be paved with bricks. The coal crushing machine and both the raw and the crushed coal should be stored under a shed to protect them from rain (31).



**Figure 31: Paved and shaded coal storage and crushing area**

- 2. Coal properties:** A variety of Indian and imported bituminous coals (Indonesian, USA, Australian and South African) are used in Zig Zag kilns in India. For getting good energy performance, the coal should have high calorific value, low ash content and high volatile matter content (Table 9).

**Table 9: Typical coal properties**

Parameter	Value
Moisture	5-10%
Ash Content	10-20%
Volatile Matter	25-35 %
Fixed Carbon	40-60%
Gross Calorific Value	5500 -7000 kcal/kg

- 3. Coal particle size:** Coal should be crushed and sieved to ensure that the coal particle size is < 5 mm (32).



Figure 32 Crushed coal with particle size less than 5 mm

#### 4. Fuel feeding:

- ▶ The fuel should be fed into 6 chambers (Figure 33).
- ▶ The fuel used consists of crushed/powdered coal and saw-dust. The fuel-mix depends on the temperature of the chamber. The fuel-mix for different chambers is given in Figure 34.
- ▶ In the freshly opened chamber, only saw-dust should be used to ensure complete combustion. The feeding of coal should be started only when the chamber temperature is  $> 700^{\circ}\text{C}$ .
- ▶ Fuel feeding should be done continuously by one fireman (Figure 35).
- ▶ In a shift, there are two firemen. One fireman feeds continuously for 30 minutes. After 30 minutes his place is taken by the second fireman, while he takes a rest. The fireman starts feeding from one end of the fuel feeding zone and travels towards the other end of the zone.

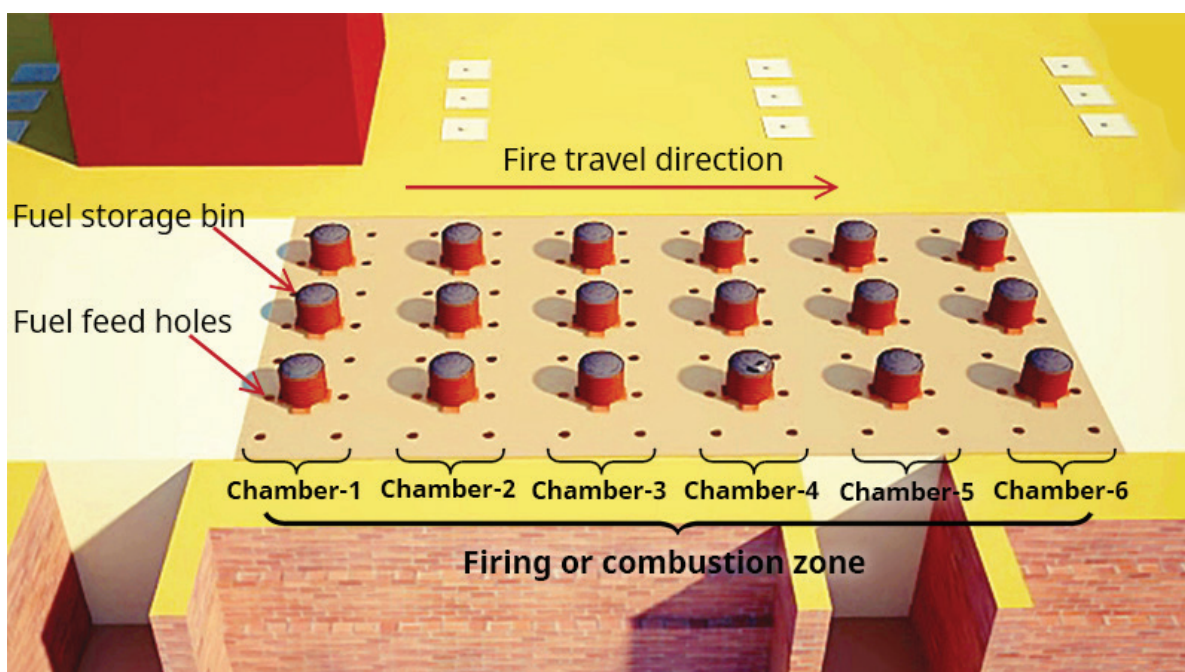


Figure 33 Six-chambers for feeding fuel, dotted black line shows the movement of the fireman







<p>Chamber - 1</p>  <p>Sawdust &amp; coal 800°C - 845°C</p>	<p>Chamber - 2</p>  <p>Coal 935°C - 1020°C</p>	<p>Chamber - 3</p>  <p>Coal 1030°C - 1035°C</p>
<p>Chamber - 4</p>  <p>Coal 970°C - 1010°C</p>	<p>Chamber - 5</p>  <p>Sawdust &amp; coal 830°C - 910°C</p>	<p>Chamber - 6</p>  <p>Sawdust 480°C - 635°C</p>

Figure 34 Recommended fuel-mix for the six chambers



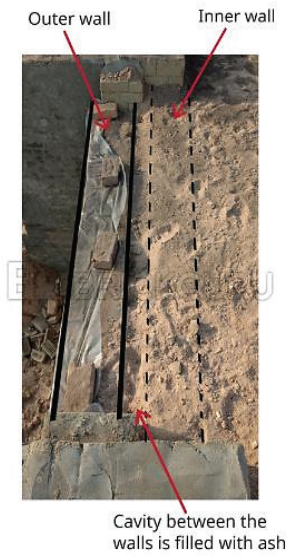
Figure 35 Single fireman continuous fuel feeding.

### 4.3 Standard Operating Practices for Zig Zag kilns: Managing air flow through the kiln

**1. Preventing Air Leakages:** As the Zig Zag brick kiln operates at negative gauge pressure, there are high possibilities of air leakages into the kiln from the surrounding atmosphere. The air leakage can happen through wicket gates, kiln wall, ash layer on top of the kiln, shunt, damper, and fan system. Air leakage can result in heat losses, reduced air flow rate through the kiln circuit, slow fire travel rate, and slow cooling rate of fired bricks. The following practices should be adopted to prevent air leakage into the kiln:

- ▶ The wickets (*ghati*) should be closed with double wall with cavity in between filled with ash (Figure 36).
- ▶ The kiln top should be uniformly covered with 9 inch thick ash layer.
- ▶ Ash or soil should be properly laid along the base edges of the shunt to cover any gaps between the shunt and the kiln surface.

- ▶ Instead of conventional dampers (Figure 37), Variable Frequency Drive (VFD) controlled fan should be used.



**Figure 36: Double-wall with cavity in between filled with ash for closing ghati**

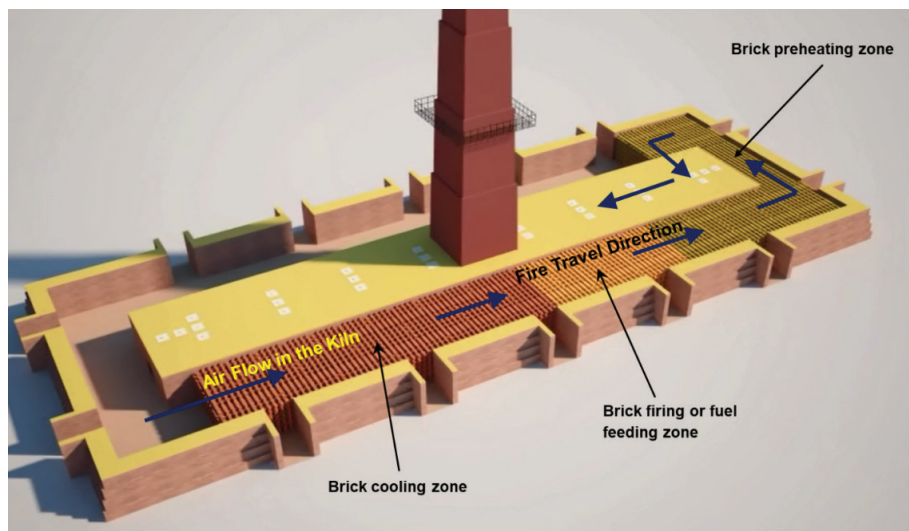


**Figure 37: Use of conventional dampers increases the possibility of air leakage**

**2. Length of Cooling Zone:** Cooling zone is the region in which the hot bricks after firing gets cooled by exchanging heat with the cold air entering the kiln (Figure 38). For proper fire movement and complete combustion of coal, the right amount of cold air has to be provided from the brick cooling zone. The length of the cooling zone should be around 15-18 chambers behind the firing zone. That means the fired bricks should be unloaded from the kiln, 6-7 days after they have been fired. Longer cooling zone will cause higher pressure losses across brick setting and result in reduced air flow though the kiln. Reduced air flow rate will cause

- ▶ Slower fire travel rate and hence reduced production capacity of the kiln
- ▶ Lower cooling rate of fired bricks and higher heat losses from the cooling zone

Therefore, long cooling zone should be avoided.



**Figure 38: Different zones and air flow in a Zig Zag brick kiln**

- 3. Brick Setting:** Following precautions must be taken while setting green bricks in the kiln to ensure proper air flow:
- The columns and rows in a chamber should be in line so that the gaps/*jhiris* should be clear for passing of fire & air.
  - The *Jodi & bandhan* should be at the right level during brick setting in a chamber.
  - The *raddas*/layers of bricks in a chamber should be according to the chimney/ ID fan suction capability. In case of higher draught, the number of *raddas* can be increased.
  - The plastic sheet/damper must be provided after every 3 chambers.
  - The passage/gates in a chamber should be in straight line and with a clear gap of 5 inch for passing of fire/air.
- 4. Induced Draft Fan:** Following guidelines should be adopted in the design, installation, and operation of the fan system in induced draught Zig Zag kilns to get adequate draft, reduce power consumption and maximise the life of the system:
- ▶ The inlet and outlet ducts of the fan should be of metal and designed properly to prevent air leakage through it, and the curves/turns in the air flow should be smooth (Figure 39).
  - ▶ The fans in Zig Zag kilns are required to handle high volume of gases at low pressure differential. In this case, straight/radial blades should be preferred over forward-curved or backward-curved blades.
  - ▶ Proper involute design (diffusing type) should be used (Figure 40).
  - ▶ Use of variable frequency drive (VFD) should be preferred to control the speed of the fan and thus draught instead of dampers (Figure 41).
  - ▶ The flue gases contain sulphur oxides and moisture, and condensation also happens in the fan system resulting in corrosion of the fan. The blades and inner surface of the fan should be suitably coated to prevent corrosion (Figure 42).
  - ▶ There should be provision for drainage at the bottom of fan casing to drain out the condensate from the flue gases.
  - ▶ Ensure good quality power supply (adequate voltage, etc.) to run the fan at desired rpm and to deliver adequate power.



Figure 39: Proper way of fan inlet design



Figure 40: Polymer coating on inner side of fan duct

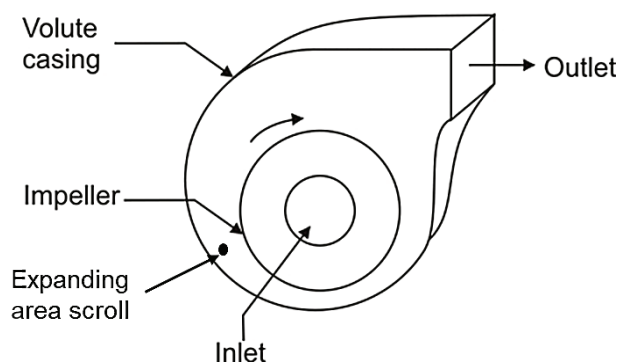


Figure 41: Diffusing involute design



Figure 42: VFD Panel<sup>7</sup>

5. **Position of Shunt:** In a natural draught Zig Zag, two shunts/connectors should be used. The first shunt should be 5-7 chambers ahead of the first firing chamber in which saw dust is being fed. The second shunt should be on the next hole ahead of the first.

#### 4.4 Standard Operating Practices for Zig Zag kilns: Reducing heat loss

1. **Insulated Fuel Feedhole Covers:** Standard uninsulated fuel feedhole covers can reach temperatures of 350°C or higher, leading to considerable heat loss through radiation. The adoption of insulated fuel feedhole covers (Figure 43), where glass wool insulation is sandwiched between the top and bottom metal sheets, helps significantly in reducing thermal losses at these points.



Figure 43 Insulated fuel feed hole covers

2. **Insulated Shunts:** The use of insulated shunts (Figure 44) is particularly recommended for natural draught Zig Zag kilns. In these systems, the draught pressure is directly influenced by the temperature of flue gases in the chimney. If flue gases cool significantly during their transfer from the kiln trench to the chimney, draught strength weakens, adversely affecting combustion. Insulated shunts help to preserve the temperature of flue gases, thereby maintaining effective natural draught and improving overall kiln performance.

<sup>7</sup> Source: [https://upload.wikimedia.org/wikipedia/commons/8/8c/Small\\_VFD\\_2.jpg](https://upload.wikimedia.org/wikipedia/commons/8/8c/Small_VFD_2.jpg)



**Figure 44: Use of insulated shunt**

3. **Ash Layer Thickness:** The ash layer thickness should be minimum 9 inches. The thick ash layer helps in reducing heat loss from the roof of the kiln.
4. **Ghati closing with double wall:** The *ghati* should be closed with a double wall having a cavity which is filled with ash.
5. **Regular maintenance of the kiln:** To reduce heat losses from the kiln, the kiln structure should be regularly maintained:
  - ▶ Expansion joints should be provided in the kiln walls to avoid bulging of the walls
  - ▶ The kiln walls should be plastered at regular interval with clay plaster to fill cracks
  - ▶ The chimney should be plastered both internally and externally at the time of construction and after every few years the external plaster needs to be repaired or redone as per the requirement.
  - ▶ The kiln floor should be paved with fired clay bricks and should be kept levelled through regular maintenance.
  - ▶ The flue ducts should be inspected every year before the initiation of fire and cleaned of any accumulated ash and debris.



# Standard Operating Practices for Zig Zag kilns: Monitoring of Kiln Parameters

- 1. Temperature Measurement:** Maintaining the required temperature range in the combustion/firing zone is essential for getting good quality brick products. Conventionally, the temperature is assessed by seeing the colour of the bricks and flame in the firing zone, which is prone to errors. Also, through naked eye, it is difficult to distinguish any temperature differences between the top part and the bottom part of the kiln.

It is recommended to measure the temperatures in the firing zone regularly - twice daily in the morning (6-8 am) and evening (6-8 pm). The temperature should be measured at the top, middle and bottom of the setting, using a 3 m long K-type thermocouple of 6 mm diameter (Figure 45 and Figure 46 ). Based on the measured temperature, the fine tuning of fuel feeding and other operating parameters is done.

The temperature of the flue gases exiting the kiln should also be measured to control the heat loss through hot flue gases. This can be measured by installing a temperature meter on the shunt (Figure 47 and Figure 48).



Figure 45 Temperature measurement in brick setting



Figure 46 K-Type thermocouple and temperature monitor



Figure 47 Flue gas temperature measurement on shunt

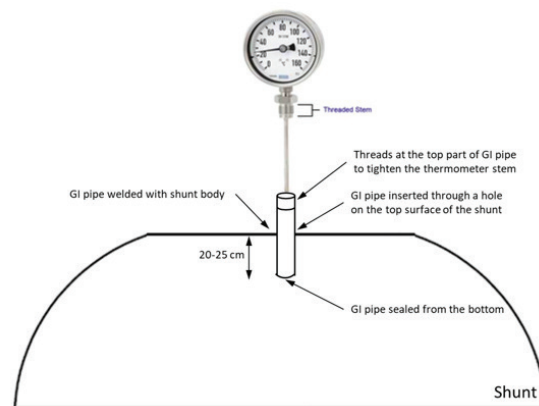


Figure 48 Installation of thermocouple on shunt

# Conclusion

The Standard Operating Procedures presented in this handbook provide a clear, actionable roadmap for kiln owners and operators to realize the full benefits of Zig Zag technology. By adopting these recommendations, brick kilns can transform both their environmental footprint and their bottom line in the following ways:

## Performance Monitoring

- ▶ **Regular Measurements:** Use simple temperature tools (K-type thermocouples) and checklist-driven inspections to track key parameters twice daily. Early detection of deviations allows for timely corrective actions, preventing fuel wastage and quality lapses.
- ▶ **Data-Driven Adjustments:** Record and analyze fuel use and Class I output weekly to fine-tune operating variables and benchmark progress over time.

## Maintenance & Heat-Loss Mitigation

- ▶ **Insulation Upgrades:** Install insulated feed-hole covers and shunts and maintain a robust ash layer (> 9 inches) on the roof to lock in heat. These simple measures can cut heat losses by up to 10–15%.
- ▶ **Air-Leak Sealing:** Reinforce wicket gates with double-wall closures and repair cracks in walls and ducts to preserve negative pressure and maximize draft efficiency.

## Economic Impact

- ▶ **Fuel Savings:** Following these SoPs can reduce coal consumption by 20–30%. For a kiln producing 30 lakh bricks per year, this translates to annual fuel cost savings of around ₹6–8 lakhs.

- ▶ **Quality-Driven Revenue:** Increasing Class I brick yield from 70% to 85–90% can boost annual revenues by around ₹12–20 lakhs, based on typical market prices and production volumes.

### Structured Implementation

- ▶ **Training & Capacity Building:** Deploy hands-on workshops for supervisors and workers to master fuel-efficient firing, airflow management and kiln maintenance. Well-trained teams consistently achieve higher Class I yields and lower fuel costs.
- ▶ **Standardized Workflows:** Follow the prescribed step-by-step sequence from site preparation through daily operations, to eliminate ad hoc practices that deteriorate efficiency. Consistency in brick setting, fuel feeding and draft control fosters predictable, optimized performance.

By embedding these SOPs into daily operations, brick-kiln stakeholders can build a self-reinforcing cycle of efficiency gains, cost reductions and higher profitability while contributing to cleaner air, reduced carbon emissions and India's broader climate goals

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