Energy Conservation and Pollution Control in Brick Kilns

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Abstract

This paper empahsises the need for energy conservation and pollution control in Indian brick industry. It discusses some of the technical options available for energy conservation and pollution control. Information on design and operation of relatively efficient brick kilns, such as, fixed chimney kiln, zig-zag kiln and Vertical Shaft Brick Kiln have been included. Some key results of field monitoring of brick kilns carried out by TERI are also presented in the paper. The main barriers in the dissemination of efficient technology in brick industry are also discussed.

1.0 Introduction

Indian brick industry with an estimated coal consumption of 15 - 20 million tons per year, is the third largest consumer of coal in the country after power plants and steel industry. Burning of coal results in the release of several air pollutants in atmosphere such as, carbon dioxide (CO_2) , carbon monoxide (CO), sulphur dioxide (SO_2), nitrogen oxides (NO_x) and particulate matter. At local level (in the vicinity of a brick kiln) some of these pollutants are injurious to human health, animal and plant life. At global level, pollutants like CO_2 contributes to the phenomena of global warming and climate change.

With growing environmental consciousness at all levels of society, the pollution caused by the brick industry is coming under close scrutiny from environmentalists and the government. Government of India took first step towards controlling pollution from brick kilns with the notification of emission standards for brick kilns in April 1996 (emission standards are presented in annexure 1).

Pollution control and energy conservation are interrelated -- the key to controlling combustion related pollution in brick industry lies in increasing the efficiency of fuel use in brick kilns. The combination of energy saving and reduction in pollution is a win-win situation, in which industry benefits because of savings in energy costs and better working conditions; and the country and society gains due to reduction in pollution as well as savings of precious natural resource in the form of fuel.

2.0 Brick kilns

Green bricks are heated to anywhere between 600 to 1100^{o} C in a kiln to get the fired product. Several types of kilns are employed for firing bricks, which can be classified into intermittent and continuous categories (figure 1).

In intermittent kilns, fire is allowed to die out and the bricks to cool after they have been fired. The kiln must be emptied, refilled and a new fire started for each load of bricks. In intermittent kilns most of the heat contained in the hot flue gases and the fired bricks is lost. In a continuous kiln, fire is always burning and bricks are being warmed, fired and cooled simultaneously in different parts of the kiln. Heat in the flue gas is utilised for heating green bricks and the heat in fired bricks is used for heating air for combustion as a result, continuous kilns are generally more efficient.

Several types of kilns are used in India for firing bricks, usually the type of brick kiln employed depends on the scale of production and type of fuel used (table 1).

Table 1. Types of brick kilns in India

Category on the basis of production volume	Annual Production (bricks/year)	Type of kiln	Main fuel
Small	< 10 lakh	Clamp, Scotch, Scove, Downdraught	Biomass - firewood, rice husk, dung. Coal and lignite
Medium	10 - 25 lakh	Moving chimney BTKs, Clamps etc.	Coal
Large	> 25 lakh	Fixed chimney, moving chimney BTKs, High Draught.	Coal

3.0 Energy performance of brick kilns

Specific fuel consumption, in terms of tons of fuel consumed for firing one lakh bricks is the popular way of expressing performance brick kilns in India. The mode of expressing performance in this manner may be of interest to brick manufacturers, however, it is difficult to compare performance of brick kilns on this basis, because of:

i) the varying weight of fired bricks which may vary from about 2 kg to 3.75 kg in India;

ii) the difference in quality and hence calorific values of various fuels used for firing bricks.

Specific energy consumption or the energy consumed for firing one kg of fired brick is a better way of comparing performance of brick kilns. The typical specific energy consumption figures for various types of brick kilns in India are presented in table 2.

Table 2. Typical specific energy consumption in brick kilns in India

Kiln	Specific Energy Consumption (MJ/kg of fired product)
Clamp - biomass	1.9 - 2.5
Clamp - coal	1.2 - 1.75
Moving chimney BTK	1.2 - 1. 75
Fixed chimney	1.1 - 1.4
Zig - zag	0.8 - 1.1
VSBK	0.7 - 1.0

Out of the total heat supplied to a kiln, only the heat which is not recoverable afterwards (latent heat at 15 ^{o} C of the mechanical and combined water in the green bricks and the heat required to complete other irreversible reactions in the clay) is the useful energy component [Clews, 1969]. Rest of the energy supplied to a brick kiln is wasted, in Indian kilns the percentage of heat that is wasted generally varies from 40 - 90%. The main energy loss components in brick kilns are: heat loss in flue gases; convection and radiation heat loss from kiln surface; heat required for heating of ground and kiln structure. The difference between specific energy consumption among various kilns is primarily due to differences in the magnitude of these heat losses.

4.0 Efficient brick kiln designs and their performance

Among existing kiln designs in use in India, fixed chimney kilns; kilns based on zig-zag firing; and VSBK are the three brick kiln designs having lowest specific energy consumption. The design features, operation and monitored performance of these kilns are presented in this section.

4.1 Fixed chimney kilns

Variations in chimney dimensions and in flue duct design and arrangement, results in different types of fixed chimney designs. The most popular fixed chimney design (which we will refer as "traditional fixed chimney") is found all over north and east India. After the announcement of the emission standards, two new designs -- Priya/PSCST[1] and CBRI[2] (figure 2 and 3), which are essentially an improvement over the traditional fixed chimney design have also been developed. In all the three designs the chimney is located in the center of the kiln. The main features of the three designs are given in the table 3.

Table 3. Main features of fixed chimney designs

	Traditional	Priya/PSCST	CBRI
1. Chimney height	65 - 100 ft	120 ft	120 ft
2. Chimney cross-sectional area			
a. Top opening	5 - 12 sq. ft.	16 -25 sq. ft.	NA
b. Bottom opening	50 - 80 sq. ft.	225 sq. ft	
3. Flue duct cross-section area	2 ft x 5 ft	4 ft x 4 ft	NA
4. Gravity settling chamber	No provision	Provided at the base of the chimney	Two -- one on each side of the chimney.

[1] Design developed by Priya Bricks which was also adopted by the Punjab State Council for Science and Technology (PSCST) for dissemination in Punjab.
[2] Design developed by the Central Building Research Institute, Roorkee for the All India Bricks and Tiles Manufacturers Federation (AIBTMF). [The Hindu, 1999]

It should be noted that apart from differences in chimney height which results in change in draught (table 4) and the provision of gravity settling chambers no major difference exists between the various designs.

Table 4. Draught available in different kilns

Kiln	Chimney height	Draught * (mm of water column)
Moving chimney BTK	40 - 55 ft	2.8 - 3.9
Traditional fixed chimney	65 - 100 ft	4.6 - 7.1
Priya/ PSCST	120 ft	8.5
CBRI	120 ft	8.5

*draught calculated at average flue gas temperature of 100 ^{o}C and ambient temperature of 25 ^{o}C

The adoption of fixed chimney do not automatically results in energy savings and sometimes the performance of the fixed chimney kilns may be comparable or even worse than a moving chimney kiln. Proper operation of the kiln is the key to achieve the energy savings.

Principle of operation of fixed chimney kilns

The kiln can be divided into three zones -- brick cooling, preheating and combustion zones. In the cooling zone air picks up heat from the fired bricks while in the pre heating zone, green bricks are heated by the hot combustion gases. In both these cases the mode of heat transfer is convection. Convective heat transfer depend on the temperature difference between the gas and the solid as well as on the speed with which the gas passes the solid.

In the combustion zone the fuel is fed from the top through the fire holes. Most of the solid fuel drops down to the bottom of the setting and burns on the floor of the kiln. The combustion of fuel depends on: a)the properties of the fuel; b) temperature and size of fuel particles; c) availability of air for combustion; and d) fuel feeding rate etc.

Control of air flow

As mentioned above amount of air flow through the kiln controls both combustion as well as heat distribution in the kiln. In general higher is the air flow rate higher is the fire travel in the kiln. The air flow in the kiln is achieved with the help of chimney. The hot gases inside the chimney are lighter than the ambient air outside the kiln, the difference in weight between the hot air column inside the chimney and outside air produces a pressure difference which is known as draught (figure 4). This pressure difference results in air movement in the kiln. The setting in the kiln provides resistance to air flow and therefore the quantity of air flowing through a kiln depends both on the draught produced as well as resistance provided by brick setting, flue ducts and chimney. The effect of various parameters on air flow is given in table 5.

Table 5. Parameters affecting air flow

Parameter	Effect on air flow
Height of the chimney ↑	↑
Temperature of flue gases ↑	↑
Ambient temperature ↑	↓
Setting density ↑ (density increase)	↓
Length of preheating and cooling zone ↑	↓

Cold air leakage is also an important parameter affecting air flow in kilns. The chimney puts the kiln under suction and so cold air tends to be drawn through any cracks and fissures in the kiln structure. Most of the cold air leakage takes place in the flue ducts through the cracks in the temporary partition walls erected to seal the flue ducts not in use (figure 5). Cold air drawn in reduces the average temperature of the hot gases in the stack and so reduces the static draught. In addition, energy is consumed in moving air unnecessarily through the kiln and up the chimney.

TERI monitored two fixed chimney kilns to measure the amount of air infiltration in the flue ducts. The amount of oxygen was measured at the flue duct entry (point A in figure 5) as well as at the base of the chimney (point B). The difference in excess air provided the amount of air infiltrating in the flue ducts (table 6)

Table 6. Monitored values of air infiltration in flue ducts in fixed chimney kilns

Parameter	Kiln 1	Kiln 2
Excess air at the entry to flue duct (point A) during non - charging	134%	115 %
Excess air at the bottom of the Chimney (point B) during non-charging	338%	158 %
Air infiltration in flue duct (percentage increase over air flow in the kiln)	87%	20 %

The amount of air infiltrating can be reduced by:

- Erection of temporary partition walls to exclude the part of main flue duct not in use
- Plastering the temporary partition walls with a plaster of mud and dung
- 9 inch thick (two brick thick) partition wall instead of commonly used 4.5 inch wall.

However, it should be mentioned, that the task of erection of temporary walls inside the flue ducts is not an easy task. In the case of traditional kilns, the firemen has to descend into the duct which is almost 8-9 ft deep. He does not get fresh air supply for breathing and is exposed to flue gases at 80 -100 ^{o}C. Therefore the tendency is to finish the job in as little time as possible. In the case of Priya/PSCST design, flue ducts are elevated and hence the firemen do get some fresh air supply. However, as the area of the duct is larger, more effort and time is required for erecting the wall. The amount of air infiltration can be reduced to certain extent by the measures given above. However, until and unless suitable valves, sliding doors which can be operated from the top or sides are installed, the problem of air leakage will continue in fixed chimney kilns.

In addition to air leakage in flue ducts, the air also leaks through -- the cloth damper (*tripal*) provided to seal one end of the kiln; through openings in the ash insulation and cracks in the wicket walls (please refer figure 5). It is important to plug all these points and keep the air leakage to a minimum.

The resistance offered by the brick setting depends both on the density of setting as well as the length of the setting (number of chambers in operation). At present in most of the kilns (kilns in Calcutta area) the length of the cooling zone is maintained at 200 - 250 ft which is more than desired and setting is also tighter. As a result the flow rate of air through the kiln is less and the fire travel rate is generally not more then 5-6 m/ day. To reduce energy consumption, the length of the cooling zone should be reduced to 150 -180 ft (figure 6) and the setting should be made more open so that a fire travel rate of at least 8 m per day is achieved.

Coal charging and coal properties

Another area of kiln operation which requires attention is coal feeding operation. At present coal is generally fed intermittently, with intervals between two successive feeding operation ranging from 20 minutes to 50 minutes. At any given time, coal is generally fed in 2 to 3 rows, and due to heavy charging of coal, black smoke can be observed coming out during and just after the coal feeding operation.

When a fairly large charge of coal is fed , smoking is liable to occur for two reasons: (1) the coal bed is deepened and the diffusion of air into the coal becomes difficult (figure 7) ; (2) the addition of cold fuel reduces the temperature of the fuel bed, some times below the ignition temperature of the fuel resulting in incomplete combustion. Hence, it becomes important to feed coal in small quantities, continuously, instead of heavy intermittent charging which is followed now. For achieving better combustion, following actions are suggested:

a) increase in number of fuel feeding lines from 2-3 to 3-5 ;

b) continuous charging, instead of intermittent charging, which can be achieved either by the use of mechanical stoker or in case of manual operation by allowing only one person to charge at a time;

c) following the feed pattern shown in figure 8;

d) using small size spoons for fuel feeding (500 - 700 g/spoon).

The other factor which affect combustion is the particle size of the fuel. The time for combustion of solid fuel depends on particle size. The practice of feeding large sized fuel particles and lumps results in wastage. In general the particle size should be less them 10 mm for getting good efficiency.

Performance of improved fixed chimney designs

TERI monitored performance of two fixed chimney kilns, one of traditional design being operated with traditional operating practices. The other kiln was of Priya/PSCST fixed chimney design and the operation practices being followed incorporated some of the improvements suggested in operation earlier in the paper. Both kilns are located in same brick cluster near Calcutta. The results of the monitoring are shown in table 7.

The data presented shows that fuel savings of the order of up to 5 tons of coal per lakh bricks is possible by improvements in kiln design and operation. Annual savings of about Rs 3.5 lakh are possible for a kiln producing 35 lakh bricks in Calcutta region (annexure 2).

Table 7. Comparison of performance of two fixed chimney kilns near Calcutta

	Traditional kiln with traditional operation	Improved kiln (Priya design) & improved operation
1. Excess air		
a) during coal feeding	≈ 0 (almost no excess air)	≈ 100 - 150%
b) during non feeding period	≈ 100 - 150 %	≈ 200 - 300 %
2. Daily production	≈ 20,000 bricks/day	≈ 27,000 bricks/day
3.Specific fuel consumption	24 -25 tons/lakh bricks	18 - 20 tons/lakh bricks
4. Specific energy consumption at the time of monitoring	≈ 1.35 MJ/kg of fired brick	≈ 1.1 MJ/kg of fired brick

Energy balance of traditional fixed chimney kiln in Calcutta region

Typical energy balance of a fixed chimney kiln in Calcutta area is also presented in table 8.

Table 8. Typical energy balance for a fixed chimney kiln in Calcutta region

Energy balance component	Coal in kg per lakh bricks	%
Irreversible chemical reactions	9,000	36
Removal of mechanical moisture in green bricks (drying of bricks in the kiln)	3,000	12
Sensible heat in flue gases	1,000	4
Sensible heat in fired bricks	1,000	4
Surface heat loss	4,000	16
Unburnt carbon and carbon monoxide loss	1,000	4
Ground heat loss	4,500	18
Misc. and unaccounted	1,500	6
Total	25,000	100

The energy balance presented here is approximate, however, it gives an idea about the relative magnitude of the different components of energy balance. The important losses to be considered are the surface and ground heat losses. When combined together they constitutes to 34 % of the energy supplied. Monitoring of ground temperature below the kiln by TERI at a kiln near Calcutta revealed that the heat penetrates up to 2.5 m below the floor of the kiln. Almost 300 tons of coal costing more than Rs 6 lakh is lost annually per kiln (kiln capacity 30 lakh bricks per year), through surface and ground heat losses These losses can be reduced substantially by :

a) using better insulation -- at least 6 inch ash layer on the top of the kiln and two layer soling at the kiln floor.

b) by reducing the size of the kilns (e.g. adopting zig-zag setting). In the existing kilns a fire travel rate of at least 8 m/day should be aimed against 5 m/ day which is achieved at present. Increase in output helps because surface heat losses remains almost constant whether the output is high or low.

c) to avoid excessive ground heat loss, particular attention should be paid during site selection for the kiln, the kiln should be located on high ground with good drainage, away from water bodies.

The total cost of construction of a new fixed chimney kiln based on improved designs is estimated to be around 8 -12 lakhs. In most of the cases, it is possible to convert existing moving chimney kilns into improved fixed chimney kilns. During conversion, part of the trench can be used as it is. Also bricks recovered from the demolition of old kiln can be used for the construction of the new kiln, these measures reduces the cost of the new kiln.

4.2 Zig- zag kilns

In zig-zag kilns the length of the kiln gallery is increased by zig-zagging the chambers and the fire follows a zig-zag path instead of the straight path followed in a BTK. At one point of time zig-zag kilns were widely used in developed countries particularly in Germany and Australia. In Europe, the interior cross-section of the kiln used to be small in original zig-zag kilns (7.5 ft wide x 7.5 ft high) and the kiln used to have 16-20 chambers each 20-25 ft long. Fan draught was provided and the kiln operated on high draught at a very fast rate of fire travel (50 -100 ft per day). The Habla kiln is a form of zig-zag kiln without crown and in which the division walls between chambers are made of green bricks. The top of the setting is covered by a layer of two or three courses of bricks followed by a layer of ash.

High draught kiln

In India zig-zag firing concept was first introduced in the from of High Draught (H. D) kiln by CBRI during 1970s (figure 9). HD kiln has several similarities with the Habla kiln. This kiln consists of a rectangular gallery which is divided into 24 chambers by providing temporary partition walls with green bricks. The wall of each chamber runs along the width of the gallery except one end, wherein a space of 60 to 65 cm is left for communication to the next chamber. Draught is created by an induced draught fan with a 15 hp motor for proper combustion of fuel. Depending on the design capacity of a kiln, a chamber can hold 7,500 to 15,000 bricks. Normally two chambers are burnt per day and output of 15,000 to 30,000 bricks per day can be obtained. When brought to full firing, the kiln operates on a draught of 50 mm WG. Several problems were encountered in the original H D kiln [Majumdar, 1986]:

i) bricks remains too hot for handling at unloading point, due to this reason the number of chambers was increased to 28 or 32.

ii) dampers in the flues provided in the inner wall communicating with the main central flue being too close to the firing floor, were exposed to high heat resulting in rapid deterioration. To solve this problem dampers made up of a heat-resistant alloy were employed. In some kilns a brick wall was constructed to protect the dampers from direct heat.

iii) As the draught and hence the negative pressure in the kiln is several times more than that observed in BTKs and fixed chimney kilns, the H D kiln is also more susceptible to air leakage. Most of the leakage takes place through the wicket walls and through leaking valves and dampers. The problem of leakage through wicket gates is solved by providing a cavity wall at each wicket, the cavity being loosely packed with ash.

Specific energy consumption of about 0.8 to 1 MJ/kg of fired brick are achievable in H D kilns when the kiln is being operated at full capacity and in proper manner. However, it has been observed that due to shortage of trained manpower and lack of exposure to proper operating practices the performance of several HD kilns is much below the expected level of performance. TERI team conducted monitoring of a HD kiln in Calcutta region and as the kiln was operating at only 50% capacity, the specific energy consumption was found to be high (around 1. 35 MJ/ kg of fired brick).

In general, either electricity supply is not available at brick kiln sites or the supply is not reliable therefore installation of a DG set for electricity generation becomes essential with a High Draught kiln which adds to the complexity and the investment. To surmount these problems, operation of a small size (20 ft trench width), zig-zag kiln without fan draught was tried by Priya bricks in Calcutta (figure 10). This kiln works under draught provided by a chimney. This kiln can also operate without valves, hence further reducing the investment in the kiln. Double zig-zag brick setting was employed in the kiln. Production rates of 15,000 to 20,000 bricks per day at an specific energy consumption of about 1 MJ/kg of fired brick were achieved during field operation.

There are several advantages of zig-zag firing, such as:

- less area requirement;
- lower surface heat losses due to less surface area of the kiln;

- more turbulence results in better mixing of fuel and air and hence results in better combustion;
- Very high fire travel rates are possible and hence one firing circuit can be completed in a short time of 10 -15 days resulting in reduction in ground and structural heat losses.

4.3 Vertical Shaft Brick Kiln (VSBK)

VSBK technology was developed in China and VSBK is a very popular kiln in rural China for small scale production of bricks. It is estimated that around 50,000 VSBKs are operating in China. Since 1990 the kiln has been demonstrated in Pakistan, Nepal, India and some countries of Africa.

Principle of VSBK

The working of VSBK is explained with the help of figure 11. VSBK has a vertical shaft of rectangular or square cross-section. The kiln works as a counter current heat exchanger, with heat exchange taking place between the air moving up (continuous flow) and bricks moving down (intermittent movement). Green bricks are loaded from the top in batches, the bricks move down the shaft through brick pre-heating, firing and cooling zones and unloaded at the bottom. The combustion of powdered coal (put along with bricks at the top), takes place in the middle of the shaft. Air for combustion enters the shaft at the bottom, gets preheated by the hot fired bricks in the lower portion of the shaft before reaching the combustion zone. Hot combustion gases, preheats the green bricks in the upper portion of the shaft before exiting from the kiln through the shaft or chimney.

The brick setting in the kiln is supported on support bars at the bottom of the shaft. Brick unloading is carried out from the bottom of the shaft using a trolley. For unloading, the trolley is lifted (a screw mechanism or chain pulley blocks are used for lifting) till the rectangular beams placed on the trolley touches the bottom of the brick setting and the weight of bricks is transferred on to the trolley. The support bars now freed of the weight of bricks, are taken out. The trolley is then lowered by one batch (4 layers of bricks) — support bars are again put in place through the holes provided in the brick setting for the purpose. With slight downward movement the weight of the brick setting is again transferred back on the support bars. The trolley (with one batch of fired bricks on it) is further lowered till it touches the ground and is pulled out of the kiln on a pair of rails provided for the purpose. In general, the time between two unloading operations is 2-3 hours and the firing time (the time for which a brick resides in the kiln) varies from 20 -30 hours.

Two chimneys located diagonally opposite to each other are provided for the removal of flue gases out of the kiln. A shaft lid is also provided on the top opening of the shaft . The lid is kept closed during normal operation and hence flue gases do not pollute the working area on the top of the kiln. The provision of shaft lid, better ventilation of the working area on the top and higher and bigger chimneys are some of the improvements made in the VSBK technology during its pilot testing in India.

VSBK programme in India

In 1995, the Swiss agency for Development and Cooperation (SDC) launched an Action Research Project aimed at improving efficiency of brick kilns in India. As a part of this project it was decided to field test the techno-economic feasibility of VSBK technology under Indian conditions. For this purpose, four VSBK pilot plants were constructed in India[3]. The first VSBK pilot plant became operational in May 1996. The design and construction work of the VSBK pilot plants was carried out under the guidance of experts from Energy Research Institute of the Henan Academy of Sciences at Zhengzhou, Henan, China. The locations for pilot plants were selected so as to test VSBK technology under different soil-fuel-climate-market conditions. An initial investment of about Rs 2,50,000 to 3,00,000 for a production capacity of about 5000 bricks per day was incurred in the construction of pilot plants. The salient features and the status of the four VSBK pilot plants are given in table 9.

Table 9. Salient features of the VSBK pilot plants in India

	VSBK 1	VSBK 2	VSBK 3	VSBK 4
Location features				
a) Place	Datia	Berhampur	Palghat	Pune
b) State/region	Madhya Pradesh (central India)	Orissa (east India)	Kerala (south India)	Maharashtra (west India)
c) Prevalent local kiln and fuel combination	Clamp with dung and coal as fuel	Clamp & moving chimney BTK with coal as fuel	Clamp with rubber firewood as fuel	Clamp with coal as fuel
Kiln features				
a) Year and month of commissioning	May, 1996	May, 1997	April, 1998	January, 1999
b) Number of shafts	2	2	2	2
c) Shaft cross-section	Shaft 1 1×1m,	Shaft 1 &2 1×1.75 m	Shaft 1 1×1.75 m,	Shaft 1 1×2 m,

[3] VSBK project in India is being coordinated by an NGO - Development Alternatives, New Delhi. The other organisations involved in the setting -up and running of pilot plants are - Gram Vikas, Orissa; The Commonwealth Trust (India) Ltd., Kerala; Damle Clay Structurals Ltd., Pune and Maharashtra Industrial & Technical Consultancy Organisation, Pune.

	Shaft 2 1× 1.5 m		Shaft 2 1×2 m	Shaft 2 1.25×2 m
d) Shaft height	3.5 m in 1996 increased to 4.95 m in 1997.	4.05 m	4.95 m	4.50 m
e) Approx. production capacity of the pilot plant (bricks/day)	4500	6500	7500	8500

Source: DA,1998 and TERI, 1999.

Performance of VSBK pilot plants

The thermal performance of the pilot plants was monitored by TERI during 1996-99. The specific energy consumption in the VSBK pilot plants was found to vary between 0.72 to 1.06 MJ/kg of fired brick (table 10). Apart from one exception, for all the other monitoring the specific energy consumption was less then 0.85 MJ/kg of fired brick.

Table 10. Specific energy consumption in VSBK pilot plants in India (1996-98)

Place/ month & year	Sp. energy consumption (MJ/kg of fired brick)	Moisture content in green bricks (% on dry basis)	Maximum temperature in the kiln (°C)	Specific production (bricks/day/m ^{2} of shaft)
VSBK 1				
May 1996	0.76	3-4	1000 - 1020	3900
Jan. 1997	0.74	3-4	850 - 910	4500
May 1998	0.84	3-4	960 -1020	3700
VSBK 2				
May 1997	0.78	3-4	800 -910	4700
April 1998	1.06	4-5	800 - 900	3450
VSBK 3				
May 1998	0.72	6-8	850	6000

Source: TERI, 1999

It is interesting to compare the energy performance of VSBK with that of fixed chimney kilns. The superiority of VSBK in terms of energy, over fixed chimney kilns, is primarily due to following reasons:

a) Compared to surface heat losses equivalent to 0.15 - 0.4 MJ/ kg of fired brick for fixed chimney kilns , the surface heat loss in VSBK is of the order of only 0.05 MJ/kg of fired brick. The area to be insulated in a VSBK is only 1/5th of the area to be insulated in a fixed chimney kiln for same level of production. Thus it is possible to provide good insulation in a VSBK. A VSBK is insulated by 2 m thick sand fill, along with a layer of firebricks on the inside of the shaft.

b) Fixed chimney kiln also suffers from poor insulation at the base. Generally the floor of fixed chimney kilns is unpaved or paved with a single layer of ordinary bricks. An accurate determination of the heat loss to the ground is difficult but it is estimated to be in the range of 0.1 - 0.3 MJ/kg of fired brick, the ground heat loss is highest at the start of the brick making season and goes on decreasing as the season progresses. In comparison ground heat loss in VSBK is almost negligible, because the contact area of the kiln with ground is small and also the high temperature zone of the kiln is not in direct contact with the ground.

c) Fixed chimney kiln is a moving fire kiln, in which fire moves round the kiln while the bricks remain stationary. Typically 15 to 30 days are required to complete firing of one complete circuit. Due to the movement of fire, the kiln structure and ground gets heated and cooled periodically and never attains a steady state. The periodic heating and cooling of the kiln mass results in significant energy loss. In comparison, in a VSBK, firing zone is stationary and hence the kiln mass attains a steady state temperature profile few days after the initiation of fire.

VSBK has many similarities with modern tunnel kilns, which are extensively used for firing bricks in developed countries. In fact, VSBK can be considered as a vertical tunnel kiln.. However unlike a modern tunnel kiln, VSBK being a natural draught kiln, very precise control of air flow (hence precise control of combustion and heat transfer processes) is not possible in a VSBK.

Some other advantages of VSBK are: a) very less area requirement (15 - 20 % compared to fixed chimney kilns for same production capacity); b) modularity, it is possible to increase the capacity in small increments by constructing new shafts; c) covered by roof and well insulated therefore not affected by changes in weather; d) the kiln can be started and stopped at very short notice and kiln stabilises in a very short time (3-4 days); e) better working conditions as dust pollution and exposure to high temperature is very less compared to fixed chimney kilns.

As the firing operation in VSBK is very fast, good supervision and control over firing process is required. If proper precautions are not taken then problems such as formation of cracks due to rapid cooling of fired bricks, incomplete combustion of internal fuel in bricks etc. can occur. The firing process has to be tailored according to the properties of the clay and the quality of product desired.

5.0 Stack emissions from kilns

Stack emissions in brick kilns consists mainly of coal fines, dust particles, organic matter and small amount of acidic gases such as SO_2, NO_x, H_2S, CO etc. During the course of last two years TERI team monitored stack emissions in different types of brick kilns. The Suspended Particulate Matter (SPM) concentration in different types of kilns are presented in table11.

Table 11. SPM concentration in stack

Type of kiln	Number of kilns monitored	Average SPM concentration in stack (mg/m^3)
1. Traditional fixed chimney kiln, without gravitational settling chamber.	2	500 - 1040
2. Fixed chimney (Priya/PSCST) design	2	141 - 187
3. High Draught kiln	1	270 - 300
4. Zig -zag, natural draught	1	296 - 370
5. VSBK	2	78 - 80 *
CPCB emission standard		750

* Kiln monitored by Development Alternatives. Source: Lakshmikantan et al[1999]

The results of the monitoring shows that the SPM concentration in stack of all the relatively efficient kilns are lower than the emission standard of 750 mg/m^3. However, in poorly operated traditional fixed chimney kilns the SPM concentration in stack can cross the 750 mg/m^3 limit.

In natural draught brick kilns, gravity settling chambers are used to control SPM . Both CBRI and Priya/PSCST designs employs simple gravity settling chambers (figure 2 and 3). In a gravity settling chamber the velocity of the flow is reduced due to expansion of the flow passage. Due to slowing down of flow, bigger particles fall down under the action of gravitational force. Generally flow velocity is reduced to 1-10 ft/s (0.3 to 3 m/s). The pressure drop is low to moderate in gravity settling chambers. Only large particles gets separated in gravity settling chamber and they are effective for separation of particles greater than 30 μm . The efficiency of gravity settling chambers for fine particles (less than 5 μm) is almost zero. Gravity settling is a crude technique and requires lot of space. However, has advantages of simplicity, no moving parts and no requirement for electricity. The efficiency of a simple gravity settling chamber can be increased by introducing baffles. In a baffled the gas follows a multiple redirected flow path. This approach increases the opportunity for particles to be collected by impaction. The advantage of the baffled chamber over the simple open chamber is its decreased size as a result of adding the impaction surfaces. There is virtually no difference in the pressure drop between the open chamber and the baffled chamber.

The introduction of gravity settling chamber do have an effect on the SPM concentration in stack gases as shown by monitoring of a fixed chimney kiln with gravity settling chamber near Calcutta (table 12).

Table 12. Effect of gravity settling chamber on SPM concentration.

	Monitoring 1	Monitoring 2	Monitoring 3
SPM in flue duct before gravity settling chamber (mg/m^3)	296	322	229
SPM in the chimney (mg/m^3)	141	177	184

6.0 Challenges in dissemination of energy conservation and pollution control measures

Till now we have concentrated mainly on proven technical options for energy conservation and pollution control in brick kilns. However, like any other technology dissemination process there are several other issues which are equally important and are likely to control the rate of technology dissemination in this sector. Some of these are:

i) Shortage of trained manpower -- need for training

Trained manpower is required at every stage of technology improvement. Today, brick industry faces a shortage of trained manpower at every level -- there are very few competent consultants for planning and supervising kiln improvements; shortage of trained masons for kiln construction is one of the main reason for delay in the construction of fixed chimney brick kilns; lack of trained manpower particularly firemen and fire supervisors is a major hurdle in the adoption of more modern kilns like HD kiln or VSBK. At present there is no institution to impart formal training in the above mentioned fields. In Punjab, PSCST has started training manpower at various levels. However, several such initiatives are required in different parts of the country. The industry would also have to look at improving the working conditions because then only it can stop migration of talented manpower from the industry and attract new talent.

ii) Traditional and conservative outlook of the industry

Most of the kiln owners are unable to look beyond the immediate future and do not realise the importance of continuous technical improvements, which are necessary if industry has to cope with tougher environmental laws (tougher air pollution standards , restrictions on use of top soil) in future. Increased competition from alternate building materials, new labour legislation's etc. will also make technology improvements a necessity in the industry.

There is an immediate need to generate awareness and educate kiln owners regarding the need for technology improvement. At present, apart from personal contact there is no other way of communication in the industry. Starting of newsletters at national and regional level in vernacular languages and organisation of seminars/ meetings at state and district levels regarding the need and options for technology improvement should be given the highest priority.

iii) Lack of financial resources and lack of access to credit from financial institutions is one of the major barrier in carrying out technology improvements. This is particularly true for small and medium sized kilns.

iv) Lack of R&D

Continuous R&D is required to improve existing technology as well as for finding solution to problems encountered during dissemination. Therefore a R&D and technical support programme also becomes a part of the dissemination effort. Organised in-house R&D in brick industry is rare in India. Some organised R&D has been carried out in government controlled research institutions, but the dissemination of the developed technology has remained poor. Brick industry has to realise that it can not depend on external (government as well as non government) R&D institutions for development of technology. These institutes at the best could provide guidance, testing facilities, monitoring support etc. but it is the industry which will have to take a lead in R&D.

These are some of the issues which should be discussed in this workshop and in other forums of the industry with the objective of preparing an action plan (initially may be of 10 years duration) for dissemination of efficient technology in brick industry. The responsibility of preparing such an action plan lies with the industry associations. The action plan: a) should fix targets to be achieved in the prescribed time period, b) should list down actions required to achieve the targets; c) assess the need for external assistance and the expected role of various institutions. Institutes like TERI are ready to provide any help in the preparation of the action plan and in canvassing support from government as well as bilateral and multilateral development agencies for technology improvement in this vital industry.

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The authors will like to acknowledge the financial support from the Swiss agency for Development and Co-operation (SDC) for brick kiln related work at TERI. Acknowledgments are also due to all the owners and workers of various brick kilns located in West Bengal, Punjab, Uttar Pradesh, Madhya Pradesh, Mahrashtra, Kerala and Orissa which allowed us to carry out monitoring and helped us understand various facets of the industry. In this respect we would like to specially acknowledge the support provided by Mr. Ashok Tahlaramani, owner of Barun bricks, Kulpi, for providing unrestricted access to TERI team to his kiln. We would also like to thank Mr. Rajinder Singh for sharing his vast knowledge on brick kilns with the TERI team and to AIBTMF for helping us in establishing contact with the brick industry.

Annexure 1. Emission standards for brick kiln

Emission standards for particulate matter

Size	Kiln capacity	Max. limit concentration of particulate matter (mg/Nm^3)
Small	less than 15,000 bricks per day (less than 4.5 m trench width)	1000
Medium	15,000 -30,000 bricks per day (4.5 - 7.0 m trench width)	750
Large	More than 30,000 bricks per day (More than 7.0 m trench width)	750

Source: GOI, 1996

Stack height regulation

Kiln capacity	Stack height
Small	Minimum stack height 22 m or Induced draught fan operating with minimum draught of 50 mm W.G. with 12 m stack height.
Medium	Minimum stack height 27 m with gravitational settling chamber or Induced draught fan operating with minimum draught of 50 mm W.G. with 15 m stack height.
Large	Minimum stack height 30 m or Induced draught fan operating with minimum draught of 50 mm W.G. with 17 m stack height.

Source: GOI, 1996

Annexure 2. Savings in energy cost by improved design and operation of fixed chimney kilns in Calcutta region.

Estimated savings in coal per lakh bricks = 5 tons
Annual production = 35 lakh bricks
Annual coal savings = 175 tons
Coal price = Rs 2100/ton
Annual savings in energy cost = Rs 3,67,500.

Annexure 3. Addresses of some institutions engaged in development /dissemination of efficient kilns.

1. *For H D Kiln and CBRI fixed chimney kiln.*
Director, Central Building Research Institute, Roorkee, Uttar Pradesh - 247667

2. *For Priya/PSCST fixed chimney kiln*
i) Punjab State Council for Science and Technology, S.C.O 2931-32, Sector 22-C, Chandigarh - 160 022.
ii) Priya Bricks Consultancy, J-1/160, Rajouri Garden, New Delhi - 110 027

3. *For coal stoker*
Building Materials & Technology Promotion Council,
G - wing, Nirman Bhawan, New Delhi -110011.

4. *For Vertical Shaft Kiln*
i) Development Alternatives, B-32, Tara Crescent, Qutab Institutional Area, New Delhi - 110 016.
ii) Damle Clay Structurals Pvt. Ltd., 6, Rama Madhav, 9 th lane, Prabhat Road, Pune - 411 001, Maharashtra.
iii) MITCON Ltd., Kubera Chambers, Shivaji Nagar, Pune, Maharashtra
iv) Gram Vikas, Mohuda Post, Berhampur - 760 002, Orissa
v) The Commonwealth Trust (I) Ltd., 7/1136, South Mananchira Road, Calicut - 673 001. Kerala

5. *For energy and environment monitoring of brick kilns*
Tata Energy Research Institute (TERI), India Habitat Center, Lodhi Road, New Delhi - 110 003.

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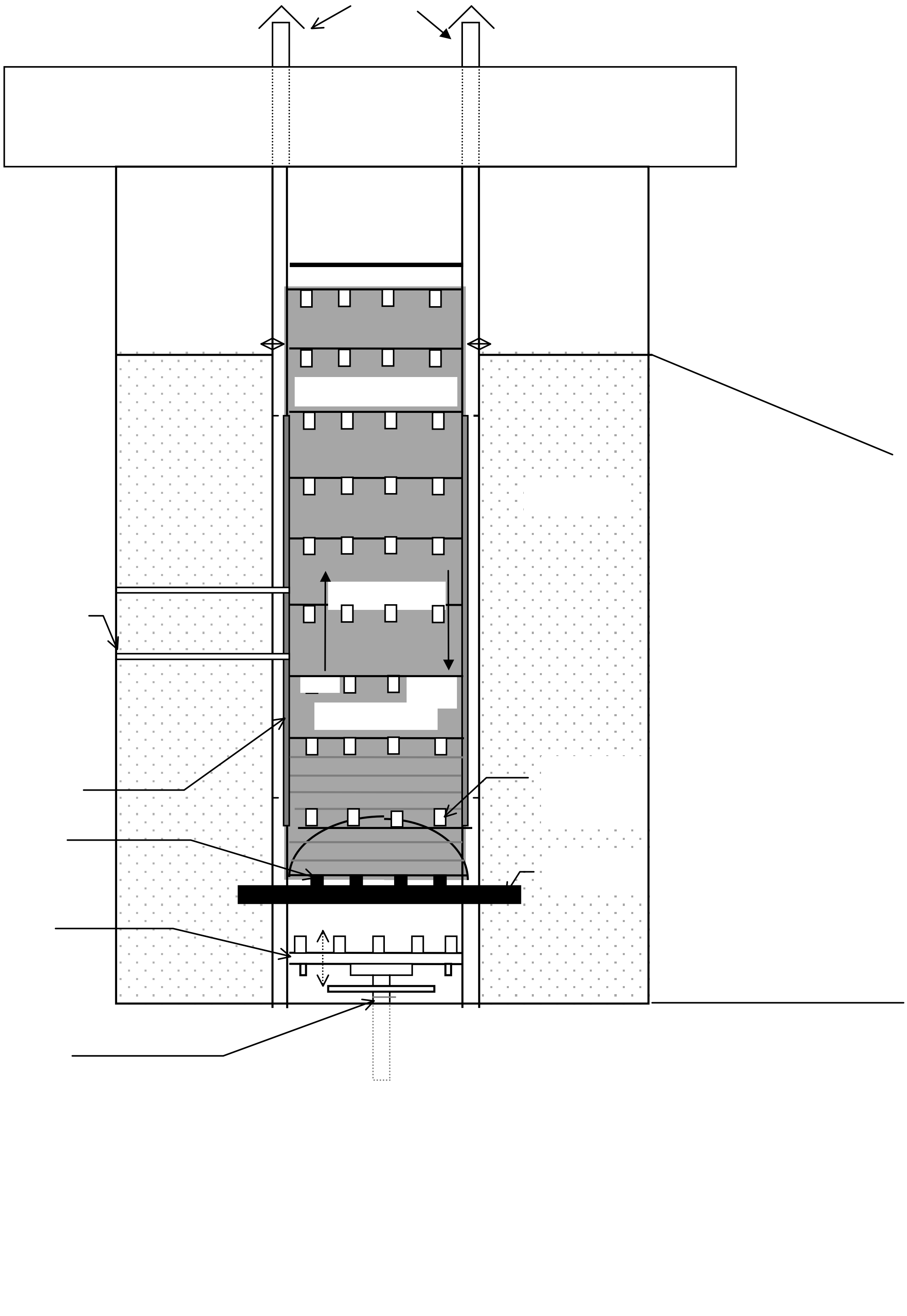
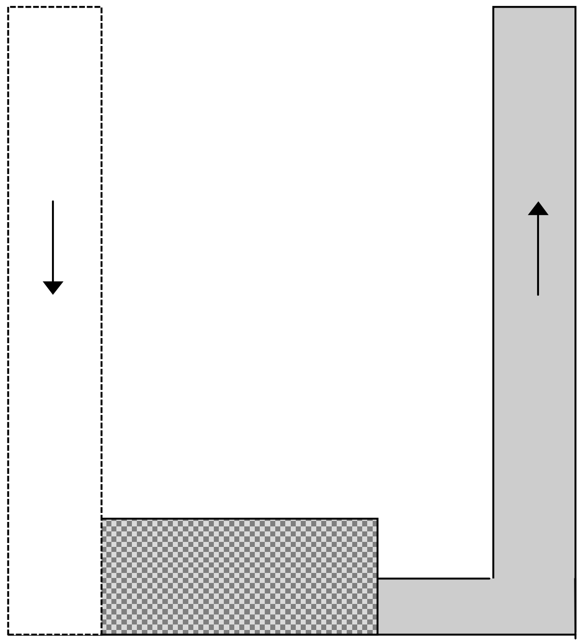




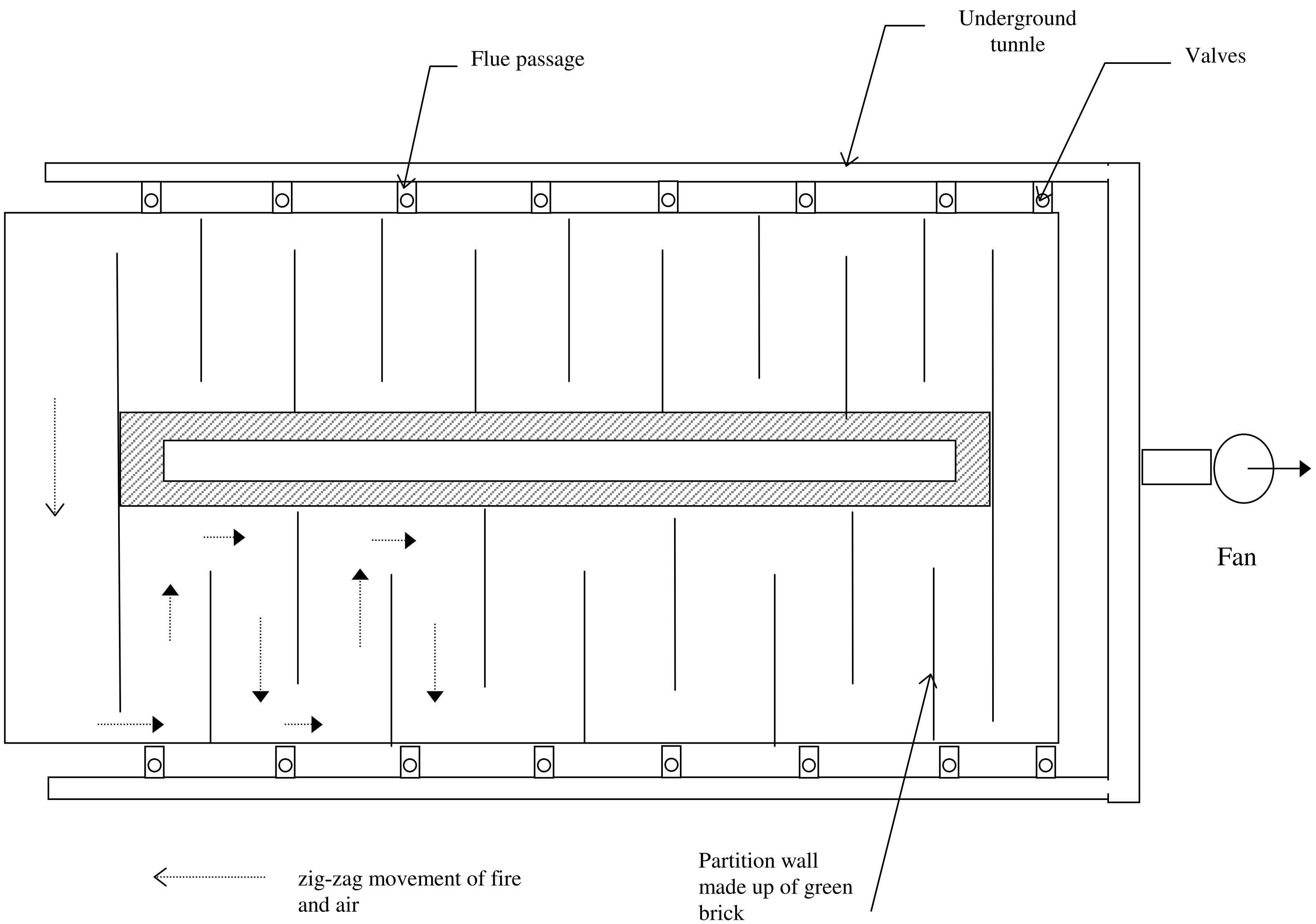


Figure 9. High Draught Kiln (Source. CBRI.1994)

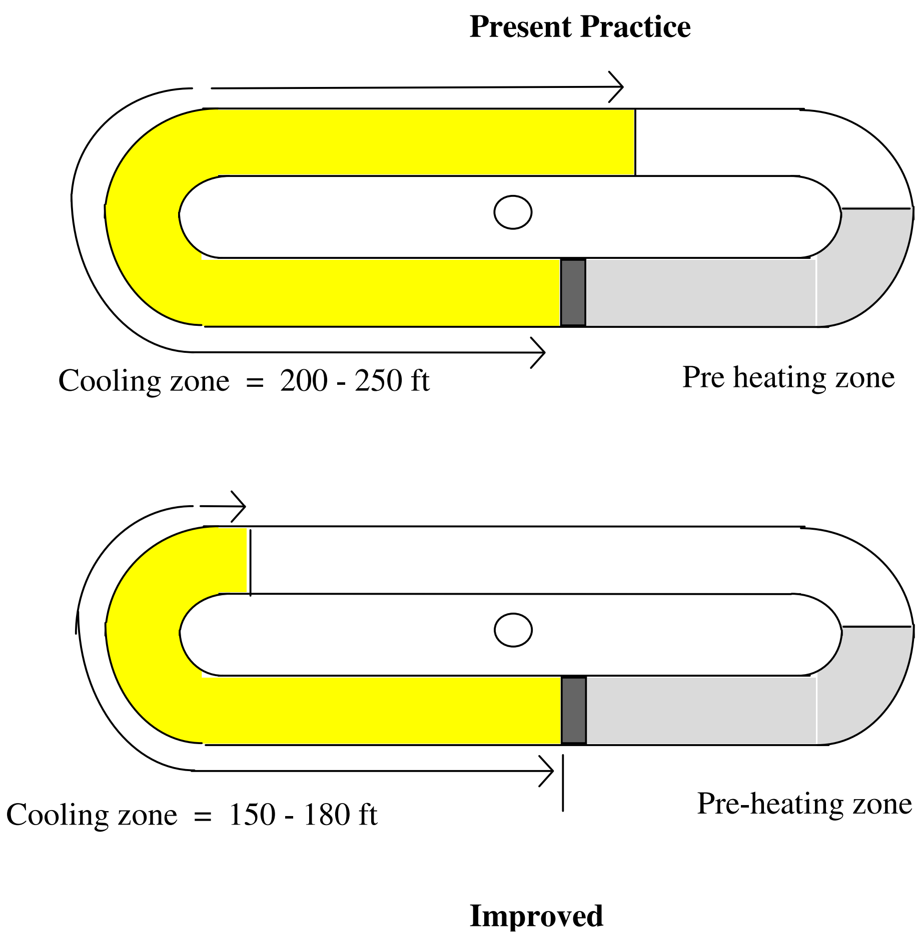


Figure 6. Operating practice - cooling zone length

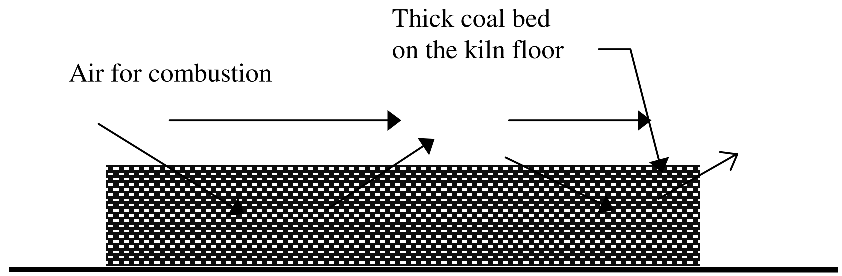


Figure 7. Operating practice - heavy charging of coal , air is not able to diffuse into thick coal bed

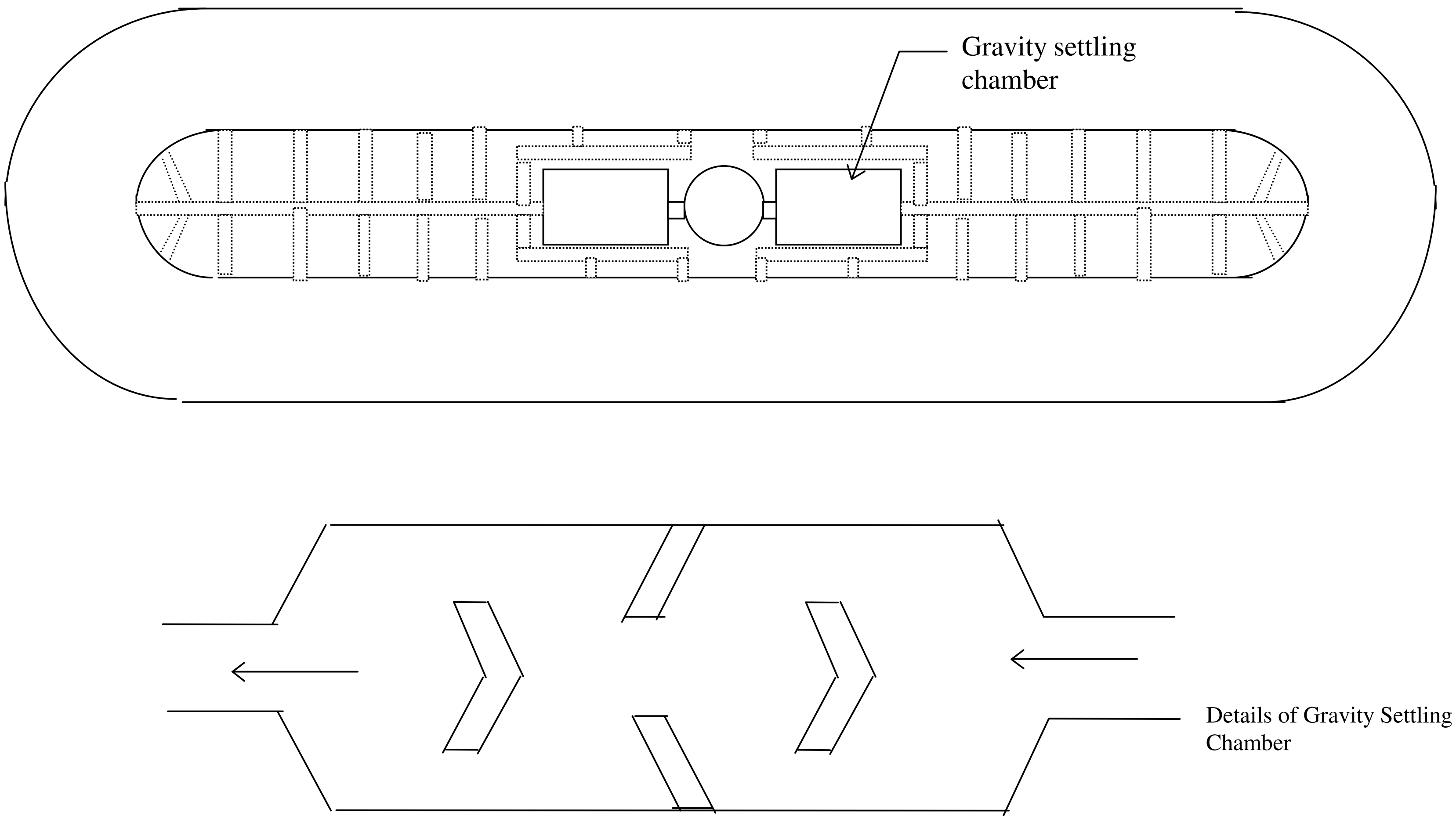
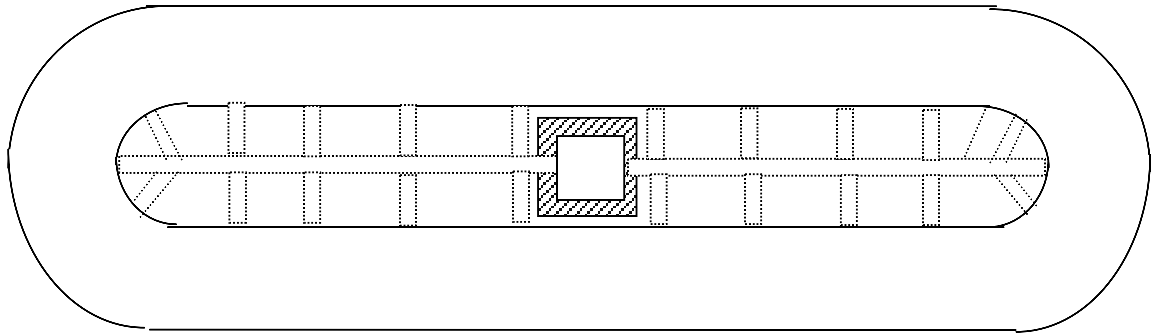


Figure 3. Schematic diagram showing placement of gravity settling chambers in CBRI fixed chimney kiln.

Paper for workshop on " Prospects and Perspective of Brick Industry in the next millennium" to be held at Calcutta on August 7, 1999, Organised by National Institute of Small Mines, Calcutta.



Schematic Plan

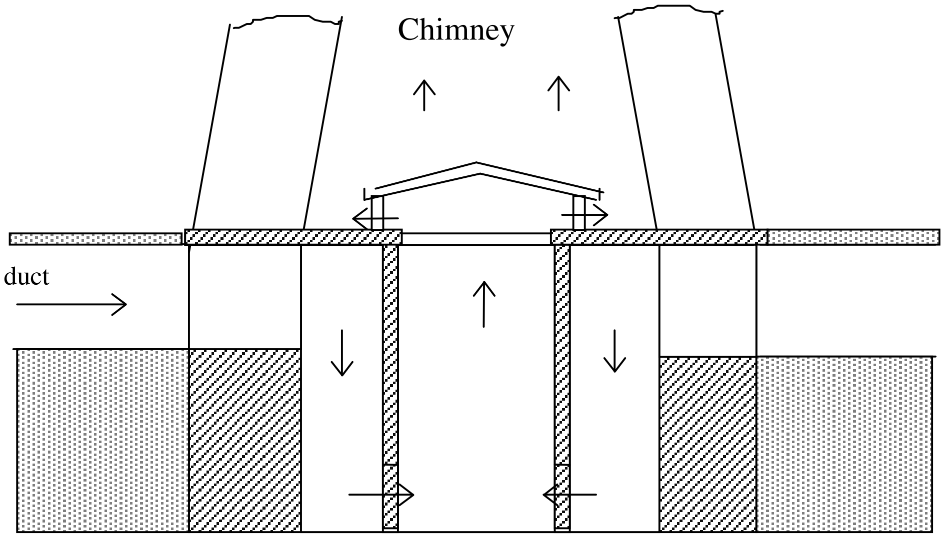
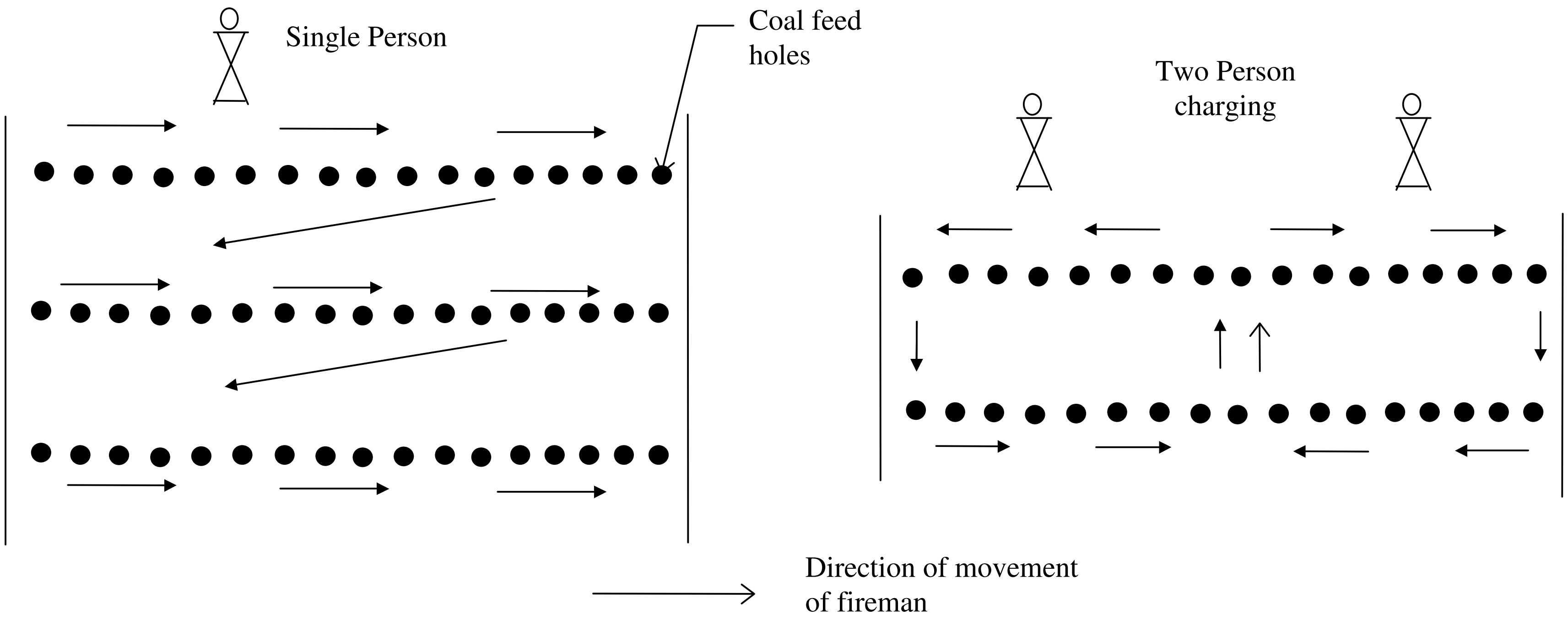


Figure 2. Schematic Plan and details of gravity settling chamber of Priya/PSCST fixed chimney kiln



Improved coal charging practice

Traditional coal charging practice

Figure 8. Improved manual coal charging practice

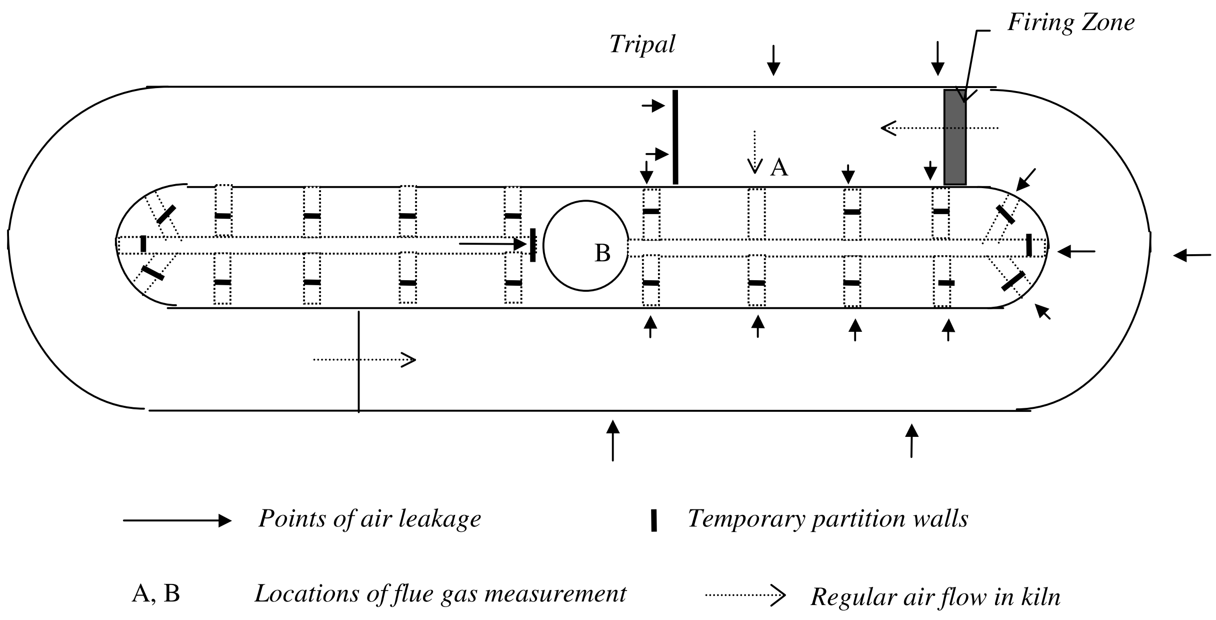


Figure 5. Probable locations of air leakage

Paper for workshop on " Prospects and Perspective of Brick Industry in the next millennium" to be held at Calcutta on August 7, 1999, Organised by National Institute of Small Mines, Calcutta.

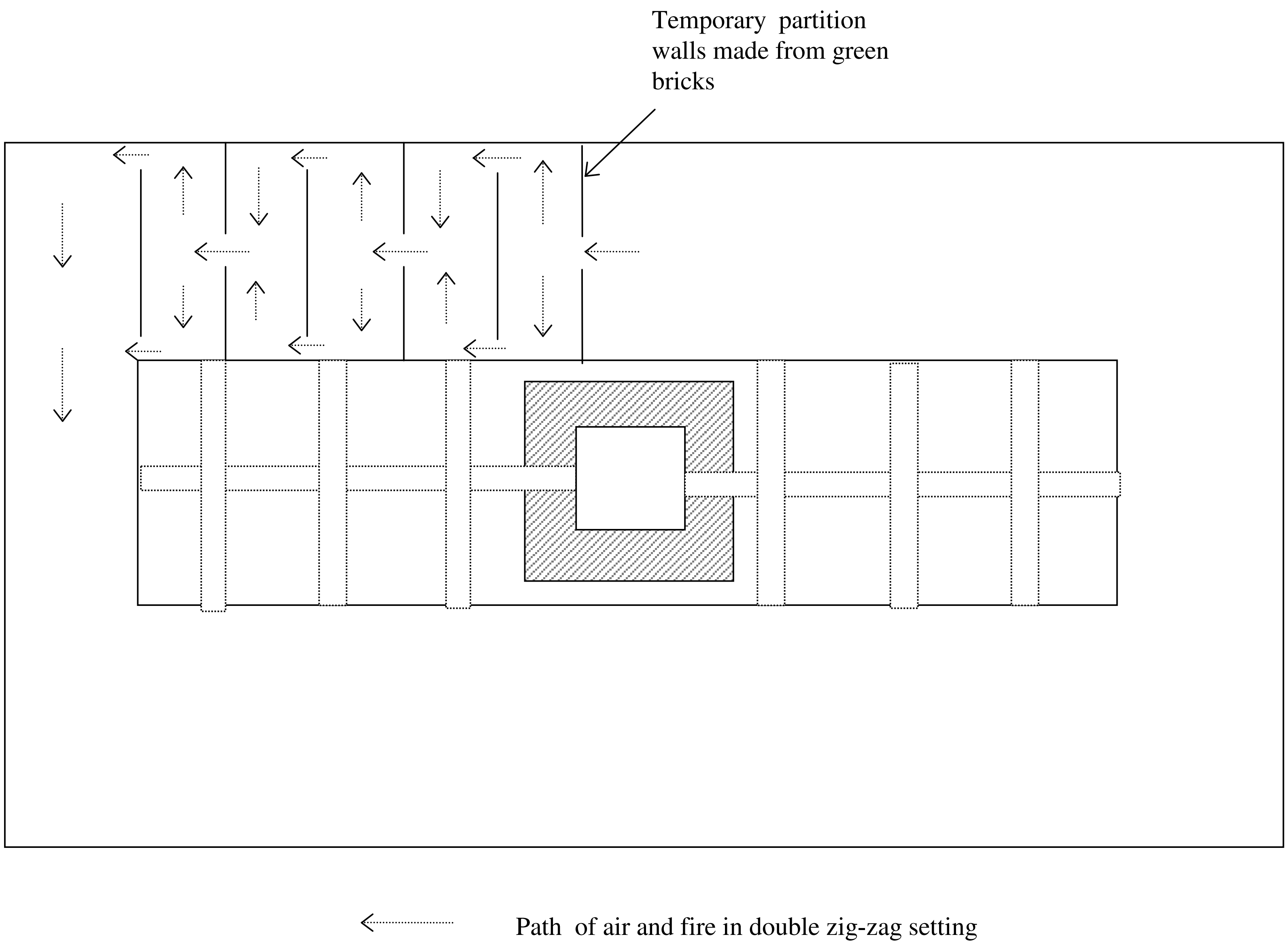


Figure 10. Natural draught zig-zag kiln (with double zig-zag brick setting) - Priya bricks, Calcutta.