Atmospheric Pollution Control in Coke Ovens

N. K. GHOSH and L. PARTHASARATHY
R&D Centre, SAIL, Ranchi – 834 002

ABSTRACT

Production of iron through BF route is still a dominant route and coke is a major raw material and energy source for the blast furnaces. The process of coal carbonization in slot ovens is one of the major sources of atmospheric pollution in an Integrated Steel Plant. Coke making process involves coal preparation, carbonization and coke handling operations. To meet the demand of Blast Furnaces of SAIL plants, about 12 million tones of coal are carbonized every year in 26 operating coke oven batteries in the different plants.

The coke making process is a well-documented source of pollution in terms of gaseous and particulate emissions. CPCB norms for emissions from the different sources of coke oven have been notified through gazette notifications. However, it is very important that the methodology and frequency of measurement are to be standardized for all the coke oven plants in India.

SAIL is well aware of the problems of pollution in coke oven batteries and a number of measures have been introduced to meet the challenges of emission control from coke ovens viz. smokeless charging, water-jet cleaning of doors, introduction of selective crushing/groupwise crushing of coals, new door design, water sealing of A.P. caps, introduction of tall ovens etc. The paper discusses some of these measures adopted in coke ovens for the control of pollution.

Key Words : Pollution control in coke ovens, carbonisation, blast furnace route, emission norms.

INTRODUCTION

The major process industries are coming under great pressure to reduce emissions to air as public awareness of environmental issue has increased in India. Metallurgical coke making in by product recovery ovens is one of the major sources of atmospheric pollution in an integrated steel plant where coke and coke oven gas are the major sources of energy. Right from the receipt, unloading, handling, crushing, carbonization and subsequent coke handling, the coke making process generates dust. The charging, pushing and coke quenching operations give rise to hot air plumes, dust and gaseous emission. Unlike other process industries control of coke oven emission is difficult due to large number of emission sources, which are often transient. In a coke oven battery, every 10-15 minutes one operation of oven charging, pushing and coke quenching takes place and about 90 ovens/day are undergoing the above cycle of operations. In SAIL plants about 12 million tonnes of coal are carbonized every year in 26 operating coke oven batteries to meet the demand of the Blast Furnaces. Energy requirement of the steel plant for heating purposes is mostly supplied by product coke oven gas and tar and pitch mixture.

In early nineties, environmental regulation for coke oven emission was practically non-existent and thus standard method of estimation was also not available to assess extent of emissions in these batteries. With the help of foreign consultants and newly created Environmental Management Division, SAIL started assessing measurement of different parameters during the mid - nineties.

SAIL introduced a number of measures in the coke oven batteries and is in the process of introducing more measures during rebuilding of the existing batteries to meet the emission control norms.

SOURCES OF POLLUTION IN COKE MAKING PROCESS

Coal Preparation

Normally, a steel plant receives and handles 5000-10,000 tonnes of coking coals per day. Apart from unloading and storing of this huge quantity of coals, crushing the coal blend to 80% below 3 mm size (to maintain blend size granulometry) in hammer mills produces a huge quantity of dust, which escapes to the atmosphere. The problem aggravates in the summer season.

Carbonisation in Coke Ovens

While many design and process improvements have been initiated, carbonization remains one of the major sources of pollution. In a coke oven battery, every 10-15 minutes one operation of oven charging, pushing and coke quenching takes place and about 90-100 ovens/day per battery are undergoing the above cycle of operation. About 2500 pushings are conducted every day in all the batteries of integrated steel plants of India, producing about 30,000-35,000 tonnes of coke per day. The vulnerable sources of pollution in the process of carbonization are shown in Fig. 1. These are mainly during oven charging and coking through charging holes, ascension pipes, oven doors, windows and chimney stacks and also during coke pushing. Mostly hot plumes, dust and noxious gases are emitted during carbonization.

Coke Sorting

The process of coke sorting i.e. cutting and screening the coke to proper size for blast furnace is also associated with dust emission.

Benzol Recovery Plant

Crude benzol is recovered from coke oven gas by absorbing in solar oil/coal tar oil. Crude benzol is further fractionated to recover benzene, toluene and xylene in benzol rectification plant. These processes emit carcinogenic vapour in the form of benzene, toluene, xylene etc. apart from generation of acid sludge whose handling and disposal is troublesome.

Norms for Coke Oven Emissions

CPCB entrusted the job of preparing norms of coke oven emissions to MECON who in consultation with different steel plants and International Standards such as USA (CAAA-1990)[1], Germany (TA-Luft-1986) etc. suggested the norms to CPCB. The norms are given in Table 1. It may be noted that norms is similar to Title III of the Clean Air Act Amendments of 1990 of EPA than European Norms, which gives the norms in g/t of coals. However, in CPCB norms the number of parameters are very high. American norms have provided track option for coke oven operators is "Maximum Achievable Control Technology" (MACT) track and "Lowest Achievable Emission Rate" (LAER) track. In MACT tract the mandate is that coke producers meet MACT - level standards by 31.12.1995 and comply with stricter MACT by 1.1. 2003. LAER track gives 4 milestones, 1st set of LAER standards by 15.11.93, 2nd by 1.1.98, 3rd by 1.1.10 and 4th by 1.1.20. Most of producers have opted for LAER Norms for coke oven emissions. Table 2 and Table 3 give basic norms for MACT and LAER track for existing batteries. Present CPCB norm is applicable for batteries with HPLA system.

Table 1 : Environment protection (Amendment) rules, 1997 (CPCB norms)

Parameter	Standards	
	New Batteries	Existing Batteries
Fugitive Visible Emissions		
a) Leakage from door (PLD), %	5	10
b) Leakage from charging lids (PLL),%	1	1
c) Leakage from AP Covers (PLO),%	4	4
d) Charging emission, Second/charge	16	50
Stack Emission of Coke Oven		
a) SO_2, g/Nm³	800	800
b) NO_X, g/Nm³	500	500
c) SPM, mg/Nm³	50	50
Sulfur in coke oven gas used for heating, g/Nm³	800	800
Emission for quenching operation, SPM, g/t of coke	50	50
Benzo-pyerine (BOP) concentration in work zone		
a) Battery top, µ/m³	5	5
b) Other areas, µ/m³	2	2
c) Ambient standards, ng/m³	10	10

Table 2 : MACT visible emissions limits

Description	On 12/31/1995	On 01/01/2003	Remarks
Leaking doors,%	6.0	5.5	$\geq$ 6m
Leaking doors, %	5.5	5.0	Foundry ovens
Leaking doors, %	5.5	5.0	>6m
Leaking lids, %	0.6	0.6	All sizes
Leaking off takes,%	3.0	3.0	All sizes
Charging, Seconds	12	12	All sizes

Table 3 : MACT and LEAR visible emissions limits

Description	MACT Date 11/15/93	LAER - 1 Date 01/01/98	LAER - 2 Date 01/01/2010	Remarks
Leaking doors,%	7.0	4.3	4.0	$\geq$6m
Leaking doors, %	7.0	4.3	4.0	Foundry ovens
Leaking doors, %	7.0	3.8	3.3	< 6m
Leaking lids, %	0.8	0.4	0.4	Charge holes
Leaking off takes, %	4.2	2.5	2.5	Off take lids
Charging, Seconds	12	12	12	Coal charge

Measurement of Emissions

In a coke oven battery the main emission sources are leakage from doors, charge hole lids and ascension pipes, charging emissions, pushing emissions, quenching emissions and emission from waste gases. The emission of pollutants is generally characterized by both the concentrations and flow rate of the pollutant stream. This analysis of emission is difficult to apply to coke oven doors, charging lids, ascension lids etc. as these emission sources are large in number and emissions are transient in nature. For example, a typical coke oven battery of 70 ovens will have emission sources of 140 doors, 70 windows, 210/280 charging lids and 70/140 ascension pipe caps.

The emission rates from the coke oven doors are highly dependent on progress of carbonisation and the gap between the knife-edge and door frame. The emission rates during charging are dependent on time, pressure fluctuations and gap size around the telescopic sleeves and charging lids. The monitoring of particulate concentration would be also a function of the location of sampler, wind conditions and other emissions that may interfere.

The gazette notification for the CPCB norms has provided the norms for the emissions from the different emission sources of coke ovens. However, the methodology and the frequency of measurement have not been spelt out. Based on the experience gained over the years, discussions among the SAIL plants, RDCIS, CET & MECON, frequency and methodologies for different measurements have been worked out. This has helped the plants of SAIL to follow a uniform practice.

Frequency of Measurement

Frequency of measurement of emissions from the sources is as follows:

* Fugitive visible emissions (PLD, PLL, PLO & charging emission)	Once in a week in each battery
* Stack emission from coke ovens (SPM, SO_x & NO_x)	Once in a month for each battery
* SPM emission during charging	Not applicable to SAIL plants as no stamp charging plant exists
* SPM emission during coke pushing	Not applicable as land based gas cleaning system not provided.
* 'S' in coke oven gas	Not required as SO_2 in stack is measured.
* Emission from quenching operation	Methodology not available. Collecting samples from just above the quenching car at the time of quenching in the quenching car may not be representative as laminar floor is to be ensured. Further interaction with laboratories/coke plants abroad is required.
* BaP measurement	Once in a quarter

Measurement of Fugitive Emissions

Inspections by a representative of Environmental Control Department/Coke Oven Shop are required to assess the emission control performance for charging emissions and leakage from doors, lids and off-takes as per the frequency shown above.

Emission Control Measures in SAIL

Coke oven designers, technologists and research institutes are relentlessly trying to control the pollution emanating from coke ovens and controlling the emissions after its occurrences. The main thrust is on reduction in the incidence of emissions by incorporating better design, improved operational practices and introduction of new technologies. The control measures mainly try to tackle the problem associated with the emissions during the coal handling and crushing, oven charging, door closing, pushing and coke quenching. SAIL has introduced/ in-process of introducing a number of measures to reduce emission from coke ovens, which include high pressure water jet cleaning of doors, frame cleaning mechanism, smokeless charging, leak proof doors and use of high capacity ovens. Besides these, stricter operational control in by-products plant, acid sludge treatment, utilization of tar decanter sludge and upgradation of BOD plants are on the priorities of SAIL.

Some of the emission control methods are described briefly in the following paragraphs:

Reduction of Dust Emission through Moisture Addition

The bulk density of coal charge, energy requirement for coke making, flowability of coal charge etc. guide the extent of moisture in coal blend. Studies have revealed that the bulk density of the charge for the desired crushing level (80% through 3.0 mm) is more or less the same at a moisture level of 7.5-8.5%.

At Bhilai Steel Plant water sprays have been installed in the coal tippling station and under each silo dozing the coals for blend preparation. Sprinklers were also installed in the open yard meant for storing of coal. Moisture addition was controlled automatically with the help of solenoid valves and the blend moisture was maintained at 7.0-7.5% as against the earlier figures of 6.0-6.5%. The above measures resulted in significant improvement in working environment and operation in the coal preparation plant and coke ovens. Systems for water spraying are also practiced at other SAIL plants[2].

High Pressure Liquor Aspiration System

During the process of charging wet coal into the ovens, large volume of gases and fumes are generated. This results in increase of gas pressure inside the oven, leading to gas leakage from the available openings. In order to reduce the leakage, aspiration can be induced at the base of the ascension pipe. It is necessary to maintain negative pressure throughout the period of charging. In high-pressure liquor aspiration system (HPLA), the aspiration is created by injecting ammoniacal liquor at a pressure of 20-30 kg/cm^2 through spray nozzles located in the goosenecks. By the use of HPLA system it is possible to achieve 60% reduction in charging emissions. HPLA systems have been introduced at BSP, BSL, DSP and RSP.

Group Wise Crushing of Coals and Pre-screening

The important technological operation of crushing of coals is a source of dust pollution in the coke ovens. Generally, the coals constituting the blend are crushed together to a level of about 80% through 3 mm to obtain the feed for charging into the ovens. The fines (-0.5 mm) generated should be kept around 35-40% to maintain bulk density etc. Groupwise crushing of coals, in which the groups of coals of different grindability indices are crushed separately to different levels of crushing, can avoid over crushing of softer coals and thus reduce fines generation. By adopting group wise crushing of coals, it is possible to achieve reduction of fines (-0.5 mm) generation by about 14% (Table 4). Similarly, selective crushing of coal using pneumatic classifier at DSP and pre-screening of fines before crushing at BSP has reduced over crushing of coal fines and restricted generation of dust (-0.5 mm).

Table 4 : Decrease in dust (–0.5 mm) generation due to group wise crushing

Size, mm	Size Analysis of Blend, %	
	Conventional crushing	Group wise crushing
+6	6.6	4.7
6-3	12.8	13.5
3-0.5	42.2	47.9
-0.5	38.4	33.9
-3mm	80.6	81.8

Development of New Door Design

The leakages from coke oven doors form a great source of pollution in the coke oven batteries. Self sealing type of doors work on the principle that tar fogs generated during the carbonization process will form a gasket between the knife edge and sealing surface and thereby plug minor imperfection e.g. gap between the two surfaces. If the gap is within 0.2 mm, it is sealed off with condensed tar vapour within an hour of charging. High gas pressure near the knife-edge does not allow tar seal to form, if the gap is more than tolerable limits (more than 0.5 to 1 mm) self-sealing by tar vapour is not likely to occur.

In the conventional doors, gases generated during carbonization process rise up along the inner side of the knife ledge and find their way through the standpipes into the hydraulic mains. Since the passage of escape of gases is very narrow, there is build up of pressure at the knife-edge. The differential pressure at the knife-edge is 100-150mm w.c. just after charging.

RDCIS and BSL have jointly developed a modified door design, in which an additional passage for escape of gases has been provided by modifying the brick holders, shape and size of the bricks. The modified doors have already established the following:

i) Leakage from knife edge was minimum

ii) Differential pressure at the knife-edge in the modified doors was as low as 10-15 mm w.c. just after charging as against 100-150 mm w.c. for conventional door.

iii) Temperature at the outside surface of door body was found to be 60-70°C which is comparable to that obtained with conventional doors[3].

It is very important that the design of the door should ensure gas pressure for the gases to rise to the top, flexible sealing elements to take of the relative movement of scaling face and joints, etc. Regular cleaning of the doors and door frames is a necessity even for improved door designs to control leakages.

High Capacity Ovens

Construction of high capacity ovens is on the increase over the years. In India, up to 1970, most of the coke oven batteries were of the standard size of 4-4.5m heights. In 1972, the first 5 metre ovens were built at Bokaro Steel Plant. In 1988, the first 7 metre Soviet/MECON designed battery was commissioned at Bhilai. In 1996 second 7 metre tall oven commissioned at Bhilai. With these two batteries, nearly 4 older batteries have been replaced. In 1989, a 7 metre tall battery with only dry quenching facilities was commissioned in Vizag Steel Plant and at present three 7 metre tall batteries are in operation. The world scenario is also towards installation of high capacity ovens.

Table 5 presents the comparative productivity figures of small and high capacity ovens. From the table it is clear that the number of pushing operations, total oven openings, length of sealing faces to be cleaned etc. significantly get reduced as we compare small ovens with high capacity ovens. While the length of cleaning surface to be cleaned (for 2 million tonne per year coke production) for small ovens is 14.0 km/day, it is reduced to 5.0 km/day for the biggest oven at Huckingen[4]. Total opening cycles per day also drastically reduces from 3870 to 1152, thus helping in reducing the atmospheric pollution in coke ovens.

Combustion Control of Coke Ovens

Maintenance of proper temperature in heating walls by burning coke oven/blast furnace gas in heating flues is of utmost importance to achieve proper carbonization, coke yield and coke quality. Improper heating leads to green pushing, over coking, wastage of heating gas and may lead to sticker ovens. Green pushing (where coke mass temperature is not sufficient i.e. coking not completed) results in evolution of thick black smoke to the atmosphere during pushing. The black smoke (CO, CO_2, carbon soot, hydrocarbons & tar vapours) pollutes the atmosphere of the coke ovens and adjacent areas.

Efficient combustion control systems are being introduced (RSP, BSP and BSL) for proper combustion and heat control of coke ovens. The system measures end coke mass temperature with the help of infrared sensors located near the quenching tower. Correlation have been developed between this temperature and the actual coke mass temperature in the ovens. This data is used to adjust the gas flow rate to attain proper flue temperature in the heating walls. This saves not only heating gas but eliminates green pushing, sticker formation and improves coke quality also.

Development of an effective combustion control methodology and introduction of this in coke oven battery can result in reducing the specific heat consumption by about 5.0% and reduce the incidences of green pushing.

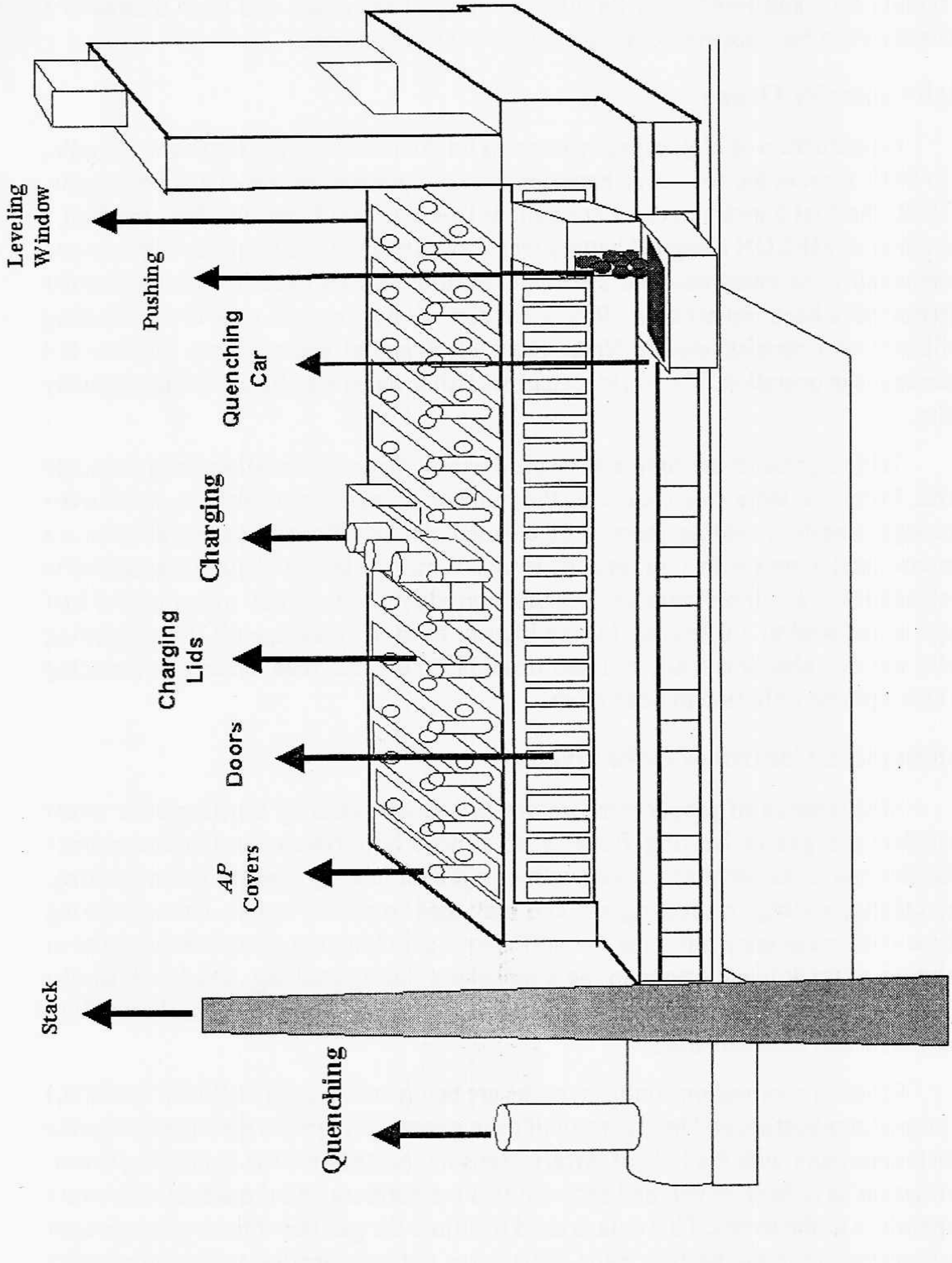

Fig. 1: Major emission points in Coke Oven Battery

Table 5 : Comparative productivity figures for different size of ovens

Parameters	Smal Oven	Large Oven (Oghishima)	Huckingen	Prosper	Kaiser Stuhl III
Dimension (Usable), Height, m	4.50	7.65	7.85	7.10	7.63
Length, m	11.7	16.4	17.2	15.9	18.0
Width, m	0.450	0.435	0.550	0.590	0.610
Useful volume (m^3)	22.1	52.2	70.0	62.3	78.9
Productivity, Coke/Oven, t	12.7	32.0	43.0	39.8	48.7
No. of ovens	322	123	120	142	120
Total oven openings	2898	984	1080	1278	1080
Length of sealing faces, km	10.5	5.1	6.0	6.2	5.5
No. of pushing/day	430	171	128	138	115
Total of opening cycles/day	3870	1368	1152	1242	1035
Length of sealing faces for cleaning	14.0	7.0	5.0	6.6	5.3

(Capacity :Coke, 2Mt/year)

CONCLUSIONS

Coke oven batteries are considered to be one of the major contributors towards atmospheric pollution in the steel industry. The coal preparation, oven charging, pushing and quenching operations emit a lot of dust, gas, tar, tar fog into atmosphere that are considered to be harmful to the human system. Due to the large number of emission sources, their transient nature, long life of coke oven batteries etc., control of emission from coke ovens is a difficult task.

Over the years a large number of emission control measures in the coke ovens have been introduced by SAIL in the form of water jet cleaning of doors, HPLA system to reduce charging emissions, groupwise crushing of coals, new design doors, water sealing of stand pipe lids, introduction of effective combustion control system in coke ovens, etc.

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