Coke Oven Emission Standards - A Comparative Assessment

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ABSTRACT

In USA, Clean Air Act (CAA) came into existence from 1963 onwards. Consent decrees, state implementation plans and Occupational Safety & Health Administration (OSHA) regulations were put in vogue for coke oven emissions in 1970s. These were different for different batteries. Progressively charging practices were changed and many developments were also carried in door, lid, and off-take arrangements. Extensive research (both technical and financial) was carried out for the development of regulatory alternatives in 1980s. Finally CAAA-1990 came into existence after lot of negotiations.

Whereas in India, there were almost no standards (except CO and particulate matter emissions) existed before 1997. The philosophy behind the new standards is new to coke oven designers, suppliers, builders and operators. The environmental aspects so far remained focused on the earlier standards only. Adapting new concept would take time for all the players in the industry. The paper elaborates the methodology adopted for evaluation of coke oven emission standards in USA with respect to the same followed in India and at the end comes out with a proposal for acceptance by the Regulatory Authorities.

Key Words : Coke-oven emission norms, clean air act, MACT standard, LAER option

INTRODUCTION

MOEF (Ministry of Environment and Forests, Govt. of India) had notified the emission standards and guidelines to maintain environment quality in work zone area for byproduct recovery coke oven plants vide notification no. G.S.R. 631 (E) dated October 31,1997. These rules have come into force on the date of publication (i.e. 31.10.1997) in the official Gazette. The subject was, thereafter, discussed at various levels and as desired by Chairman CPCB, a comprehensive report detailing the feasibility and constraints of retrofitting new facilities in the existing batteries for achieving standards was submitted in July, 1999 for perusal.

It was also thought that it would be prudent to study the methodology adopted for evolution of Clean Air Act Amendments of 1990 (CAAA-1990) of USA. The study would facilitate in understanding the various aspects of the standards.

EVOLUTION OF CAAA OF USA [1]

Work on development of standards for coke oven emissions was officially begun in March 1975. The initial effort was directed at limiting particulate emission discharges from coke oven charging and topside leaks at charging lids, off-takes and collecting mains. Many studies were carried out by EPA (Environment Protection Agency) for gathering information and for understanding the subject. Some of these were:

i) Coke charging pollution control demonstration. AISI and office of Research & Development, US EPA, Publication No. EPA-650/2-74-022, March 1974.

ii) Coke oven charging emission control test programme, Volume-I and II. Office of Research & Development, U.S Environmental Protection Agency, Publication No. EPA-650/2-74-062, July, 1974.

iii) By product coke battery compliance evaluation, EPA Contract No. 68-02-1321, Task 13, June 1975.

iv) Study of concepts for minimising emissions from coke oven door seals, Publication No. EPA 650/2-75-064, July, 1975.

v) Source testing of a stationary coke side enclosure. Bethlehem Steel Corporation. EPA Control No. 68-02-1408, February, 1977.

vi) Identity and chemical and physical properties of compounds in coke oven emissions, EPA Contract No. 68-01-4314, September 1977.

vii) Sampling and analysis of coke oven door emissions, Publication No. EPA-600/2-77-213, October 1977.

viii) Stack emission sampling at Wisconsin Steel Company coke oven plant, EPA Contract No. 68-02-1409, November 1977.

ix) Study to develop retrofit information and other data for use in setting stan dards for coke oven emissions, EPA Contract No. 68-02-2612, March 1978.

x) Air pollution emission test, final report, Wisconsin Steel, EPA Contract No. 68-02-2817, May 1978.

xi) Human population exposure to coke oven atmospheric emissions, EPA Contract Nos. 68-10-4314 & 68-02-2835, Revised May 1979.

xii) Cost effectiveness model for pollution control at coking facilities, Publication No. EPA-600/2-79-185, August 1979.

xiii) Coke oven emission testing – Armco Steel Corporation, EPA Contract No. 68-02-2812, October 1979.

xiv) Benzene soluble organics study – coke oven door leaks (draft) EPA Contract No.68-02-2817, December 1979.

xv) Technical Approach for a coke production model, EPA Contract No. 68-02-3071, December 1979.

xvi) A model to estimate hazardous emissions from coke oven doors, EPA Contract No. 68-02-3056 (RT1 No. 1736/2/01) , March 1980.

xvii) Estimation of charging emissions for by-product coke ovens, EPA Contract No. 68-02-3056 (RTI No. 1736/2/02), March 1980.

xviii) Comparison of OSHA's and potential EPA regulation for coke oven batteries, EPA Contract No. 68-02-3056 (RTI No. 1736/2/025), Revised May 1980.

Baseline Regulations (1980) [1]

Earlier, the consent decrees and state implementation plans required varying levels of control for existing batteries. In addition, Occupational Safety and Health Administration (OSHA) regulations required equipment and work practice controls for coke oven emission but has not set a performance level in terms of visible emissions. At that time regulation varied from battery to battery with the most stringent limits applied to new batteries. Most of the existing batteries had limits that followed the guidance of EPA's Reasonably Available Control Technology (RACT) with visible emission limits of :

- 25 seconds per charge
- 10 to 12 PLD (percent leaking doors)
- 3 PLL (percent leaking lids)
- 10 PLO (percent leaking off-takes)

OSHA also enforced a set of requirements for coke ovens, e.g.

For charging

- Stage or sequential charging
- Double mains or jumper pipes
- Written procedure
- Adequate aspiration
- Inspection and cleaning of goosenecks, standpipes, roof carbon buildup, steam nozzles and liquor sprays
- Charging car modifications
- Leveller bar seals

For door leak controls

- Written procedures
- Inspection and cleaning
- Door repair facilities
- Adequate spare doors
- Chuck (leveller) door gaskets

For topside leaks

- Regular inspection, cleaning, repair or replacement of equipment
- Prevention of miscellaneous topside emissions

Technology for the Control of Emission from Charging

Charging practices were progressively changed by the efforts of regulatory agencies and coke oven operators to reduce emissions. Previously, the most common procedure was to isolate the gas-collection system from the oven and charge the coal into the red-hot ovens. When the wet coal enter the hot oven, it displaces the air. This displacement and immediate gasification of moisture and volatile components of the coal cause the oven pressure to rise sharply. Because the gas-collection system is blocked off, the only escape for the smoke, hydrocarbons, gases and steam is to the atmosphere through any opening.

However, various control procedures were adopted progressively to control the charging emissions. These control procedures were mainly incorporation of stage charging, sequential charging and wet scrubbers mounted on charging cars. Detailed analyses were done on many coke oven batteries and improvements brought in charging cars, aspiration system, leveller bars etc.

Technology for the Control of Door Leaks

Control techniques for coke oven door emissions were based on four categories:

- Oven door seal technology
- Pressure differential devices
- Hoods and sheds over doors
- Operating and maintenance procedures

Metal to metal seals were commonly used in the production of metallurgical coke in USA. The major types of industrial seals used were the Koppers and Wilputte seals. To improve the performance of doors, major modifications were carried out in the Koppers & Wilputte doors.

Technology for the Control of Topside Leaks (Charging hole lids and off-takes)

Topside leaks were primarily controlled by

- Replacement of warped lids
- Cleaning carbon deposits or other obstructions from the mating surfaces of lids or their seals
- Patching or replacing of cracked standpipes
- Sealing lids after a charge or whenever necessary with a slurry mixture of clay, coal and other materials (commonly called lute)
- Sealing cracks at the base of a standpipe with the same slurry mixture

In addition, some change in equipment design were required to keep the leaks sealed. Incorporation of heavier lids, lids with better sealing edges and automatic lid lifters are few of these modifications. In addition, manpower was increased for topside work. In general, a battery required 4 lidmen if automatic lid lifters were used and 8 lidmen if the lid lifting was performed manually.

It can thus be concluded that in USA, many modifications were carried out in the batteries progressively from 1975 onwards to reduce the emission levels. Some of these modifications are summarised below:

- Change in hopper size and independent control of coal flow and independently operated drop sleeves on the charging car.
- Addition of automatic lid lifters or access to the charging holes without moving the charging car.
- Addition of human-guided mechanical cleaners for goosenecks.
- Addition of jumper pipes that move with the charging car on batteries with only one collecting main.
- Increase of clearance between the coal bunkers and the battery to allow for volumetric hoppers.
- Complete repaving of the battery top and replacement of lid rings and lids.
- Replacement of gooseneck and pipes.
- Addition of second collecting mains to batteries with single collecting mains
- Addition of mechanical scrapers and/or decarbonization air on the pusher ram.
- Installation of leveler bar smoke boot.
- Replacement of seals on doors as needed.
- Replacement of doors as needed.
- Replacement of refractory in oven walls where necessary.
- Modification of self-sealing Koppers doors by adding stop blocks and replacing plunger springs with a more temperature resistant alloy.
- Replacement of cast iron jambs with ductile iron jambs.
- Replacement of original door seals with Ni-Cu-Ti alloy seals
- Modification of self-sealing Wilputte doors by adding stop blocks, replacing plunger springs with more temperature resistant alloy and proving guide blocks.
- Modification of hand-luted doors by enlarging the door plug and replacing the jambs with ones that more easily accommodate luting.

Development of Regulatory Alternatives (1984) [1]

Regulatory alternatives are alternate course of actions that EPA could take to regulate emission sources. The regulatory alternatives for limiting emissions from wet-coal charging, lids and off-takes of coke ovens were formulated on the basis of the demonstrated performance of control systems.

Detailed environmental impact analysis was done on the following basis:

- Estimation of rate of emissions based on the existing visible emission limits for each battery
- Estimation of rate of emissions for each battery with each regulatory alternatives
- Estimation of nation wide emissions

An elaborate exercise was also done on cost and financial impact (batteries and nationwide). The cost analysis was associated with control of emissions from wet-coal charging and leaking doors, lids and off-take systems. It may be mentioned here that emission control at coke plants had improved significantly over the last 10 years (before proposed regulatory alternatives) as the industry developed and implemented new control equipment in response to regulations promulgated by OSHA, state agencies and technology-forcing consent decrees negotiated on a plant-to-plant basis by USEPA.

During their various studies, EPA found out that major equipment modifications were already done in most of the batteries as a result of OSHA regulations, state regulations and consent decrees. Accordingly, it was considered that the effect of a National Standard would require a nominal improvement in control for most of the batteries. This improvement in control would be small compared to the improvement made earlier from a poorly controlled status to then existing baseline status. However, nationwide cost for Regulatory Alternative was projected as

- 4.7 Million USD/year for charging emission control
- 5.4 Million USD/year with potential capital requirement of 6 Million USD for door emission control
- 1.6 Million USD/year for lid emission control
- 7.6 Million USD/year with a potential capital requirement of 5.2 Million USD for off-take emission control.

During 1980s USEPA made significant progress in regulating air pollution emissions. However, progress in a number of areas did not meet expectations of many groups, leading to efforts to amend CAA once again. Focusing on examples such as the failure of numerous metropolitan areas to achieve the photochemical oxidant (ozone) standard and USEPA'S regulation of only seven hazardous air pollutants, congressional leaders began pushing for amendment of CAA to correct its perceived deficiencies.

Accordingly, came the Clean Air Amendments of 1990 (CAAA) with the following major themes: [2]

- Title I : Attainment and Maintenance of National Standards.
- Title II : Mobile Sources and Alternative Fuels
- Title III : Air Toxics
- Title IV : Acid Rain
- Title V : Operating Permits
- Title VI : Stratospheric Ozone and Global Climate
- Title VII : Enforcement

Titles - I, III, IV, V, VIII contain provisions that directly or indirectly impact the US coke industry, with Title III having the most serious implications. The salient features of Title-III are given below.

CAAA Air Toxic Title (Title III) [2,3,4]

This title charged EPA with developing standards for both existing and new coke oven batteries. The existing coke oven batteries include reconstructed and replacement batteries and the new coke oven batteries would primarily be "green field" batteries on which construction begins after proposal of the standards for new sources. In December 1992 EPA proposed Maximum Achievable Control Technology (MACT) Standards and Lowest Achievable Emission Rate (LAER) Standards for coke oven batteries . Operators of existing coke oven batteries could opt for any one of these two standards. The provision also authorised the US Department of Energy and EPA to jointly undertake a coke oven production technology study and required the owners/ operators on LEAR track to publicly disclose in 2020 the results of any risk assessment performed by EPA for that batteries. The details of these requirements are discussed below:

For existing battery

<u>MACT OPTION</u>

This standard could be no less stringent than

- 8 percent leaking doors (PLD) with no door exclusions
- 1 percent leaking lids (PLL)
- 5 percent leaking off-takes (PLO)
- 16 seconds of visible emissions per charge(16 s/c)

All of the above were to be 3 day rolling averages with the exception of the charging limit of 16 s/c, which was the logarithmic average of 10 consecutive charges. EPA is required under this option to review and if appropriate, revise the existing source MACT standard every seven years.

The time table for implementation of this standard are given below :

• By 31.12.1995	• To meet the standard
• By 31.12.2003	• To meet residual risk standard (if such a standard is needed to protect public health or the environment)
• EPA to review MACT standard every seven years	

LAER OPTION

In 1990 during the congressional debate over the CAAA, the EPA released data indicating that most coke plants would not be able to meet a residual risk standard in 2003, even with best technology then available and would potentially be forced to shutdown or curtail operations. The conclusions reached from these data were of great concern to the industry because, with over half of the existing batteries being old, coke producers would face a decade of major investments (perhaps as much as 1 billion USD annually) to modernise.

Consequently, the coke industry sought an extension of the residual risk standard to 2020 to provide financial markets the assurance of a full 20 years of coke plant utilization (i.e. to 2020) before a potential shutdown standard would take effect. After lot of deliberations, LAER track options were agreed. Time table for implementation of this standard is given below :

• By 15.11.1993	- Special MACT standard (8 PLD, 1 PLL, 5 PLO & 16 s/c)
• By 01.01.1998	- 1st LAER, technology based standard (3 PLD, 1 PLL, 4 PLO & 16 s/c)
• By 01.01.2010	- 2nd LAER, technology based standard
• By 01.01.2020	- Residual Risk Standard (If such a standard is needed to protect human health or the environment)

For new coke oven batteries

The CAAA coke oven provision required the EPA to evaluate Jewell-Thompson non-recovery coke oven batteries, other non-recovery technologies and other appropriate emission control and coke production technologies towards establishing MACT standards for new coke oven batteries. It may be mentioned here that except from doors, emission occurs from all other sources in non-recovery ovens.

Coke oven production technology study

The CAAA coke oven provision authorized Federal Funding of upto 30 Million USD (upto 5 Million USD per year over a six year period beginning 1992) for studies of coke oven emission control technologies. The studies were to be jointly undertaken by US Department of Energy (DOE) and the EPA. They were authorized to enter into agreements with companies to develop, install and operate emission control technologies with potential for significant reductions in coke oven emissions. As of December 1996, actual appropriation totaled 3.825 Million USD.

Public disclosure of coke oven battery residual risk assessments

The CAAA provision requires batteries qualifying for LAER track (until 2020) to disclose to their local communities by the end of 1999 the results of any risk assessment performed by EPA. EPA, however, have not prepared any such assessments so far for these batteries and have no plans to do so and consequently, no such disclosures have been made.

Implication of Emission Standards

Each company had to make its final decision to select either the MACT or LAER track by 1st January 1998, provided that the company had elected to 'straddle' both tracks (i.e. to meet the requirement of both MACT &LAER track until the last possible moment). It would obviously have been much easier for companies to make decision if definitive guidance was available before 1998 on how residual risk standards would be established. However, it remained uncertain till October 2000 how the EPA would react to the various proposals mooted for residual risk standards. Consequently, companies had to make their track selection decision in the absence of any definitive residual risk guidance. However, with definitive guidance still lacking, all of these plants had opted for the relative security of the LAER track (and, thereby, opted to avoid having to face a federal residual risk standard until 2020).

This resulted in a total of 18 of 23 plants now operating that had to make a track selection decision, electing to have all of their batteries (55 batteries) on LAER track. A lesser number of plants (4 plants) have elected MACT track for all five of their batteries. One plant has elected to place one battery on LEAR track and one battery on the MACT track.

Regardless of which alternative the plants would choose, their costs to continue operating would be high. The EPA estimated that the industry would spend 66 to 510 Million USD in capital cost and 25 to 84 million USD in total annualized costs.

OTHER STANDARDS [2,3,4]

On 16th July 1992 EPA published a list of categories of other major sources of hazardous air pollutants for which the agency will promulgate standards by 15th November 2000. In the case of coke oven batteries, these were:

- Pushing emissions
- Quenching emissions
- Combustion stacks

AISI/ACCI Coke Oven Environmental Task Force (COETF), however, provided EPA, discussing the non-feasibility of EPA's plans to set performance standards for combustion stacks. COETF has been encouraging EPA to set work practice standards for this source instead.

It may thus be understood that even with best design, engineering & manufacturing capability and carrying out progressive improvements/ modifications to fall in line with the standards promulgated time to time from 1970s, USA coke oven operators and EPA are now facing difficulties with respect to the new standards (that too with only PLD, PLL, PLO & s/c) though the new standards are not very stringent compared to earlier baseline regulations.

Another important point to note that USA, the technology titan of the globe, in their wisdom have so far refrained themselves from developing standards for pushing, quenching, stack and BOP emissions.

SCENARIO OF COKE OVEN BATTERIES IN INDIA

Most of the batteries in India are of old design. No major design improvements could be brought in earlier as there were only two designers in India viz. Otto India and MECON. These designers had collected drawings of old designed batteries of Germans and Russians and thereafter made some modifications for adjustment with the site conditions. The basic requirements for reducing emission from charging, doors, oven top area were not addressed properly except incorporation of "on-main" charging with HPLA (high pressure liquor aspiration system) at a later date. The design of HPLA system did not cover all the requirements. As a result not much improvement with respect to control of emissions could be achieved.

In India, before the 1997 notification, there were only the following limits for coke ovens emissions (as per Environment Protection Rules 1986).[5]

• Carbon monoxide emissions from coke ovens	: 3 kg / tonne of coke
• Particulate matter emissions	: 50 mg/Nm^3

In March 1995, CPCB first assigned MECON to take up the preparation of report intending to :

i) develop national standards for control of emissions in coke oven plant in integrated steel plants.

ii) describe clean technology for coke making after assessment of pollution potential from each source in coke ovens and latest developments that have taken place in developed countries.

MECON's report [6] did not clarify the status of Indian coke oven batteries as existed in 1995-96 with respect to PLD, PLL, PLO and s/c and emissions from other sources. This was a new concept in India. People were not very sure of the definition of this standard. However, MOEF notified the emission standards in October 1997 for PLD, PLL, PLO, charging, stack, pushing, quenching and BOP.

In the standards, it was written that units set up after publication of the notification should be treated as new units. At a later date, one official of CPCB had written that the rebuilt batteries should also be treated as new batteries.

A shadow exercise was carried out in 1998 by SAIL to find out where do plants stand with respect to PLD, PLL, PLO and s/c and stack emissions. There were huge gaps in comparison with the standards notified in 1997. [8]

In SAIL, many new techniques/ technologies were incorporated earlier to reduce coal consumption for steel making. Some of these are:[7]

At Coke Ovens

- Imported coal in blend
- High capacity (7m tall) battery

- PBCC (Partial Briquetting of Coal Charge) Technology
- Group-wise Crushing Technology
- Selective Crushing Technology
- Modernisation of Coal Preparation Plant

At Blast Furnaces

- High hot blast temperature
- High level of automation
- High top pressure
- Bell less top charging
- Rotor charging unit
- Increased sinter percent in the burden
- Coal dust injection technology

The reduction in requirement of coal has reduced the requirement of number of pushings from coke oven. This has resulted in less pollution in coke ovens. In addition, other measures had also been taken in the nineties in some coke oven batteries either during first installation or during rebuilding for improvement of the performance as well as for reduction of emissions. These are :[7]

- Introduction of ceramic welding technology for repair of oven walls
- Introduction of dry gunniting technology for repair of oven walls
- Introduction of High Pressure Liquor Aspiration (HPLA) system for 'on-main' charging of coal
- Water sealed AP caps
- Hydro jet door cleaners at end benches
- Provision of Gas Transfer Units (GTU) in the oven top
- Provision of magnetic lid lifting system
- Pusher cars with leveller muff, door and door frame cleaners
- Charging cars with screw feeders having telescopic chute for positive sealing
- Guide cars with door and door frame cleaners
- Provision of gas mixing station
- Computerised combustion control systems
- Gooseneck and AP cleaners in charging cars
- Modified doors with spring loaded knife edge
- Oven top vacuum cleaner
- Water jet gooseneck cleaner
- Charging hole lid compatible magnetic lid lifter
- Mechanised lid lifting facility
- Hydraulic controller for regulation of askania

- Quenching tower with grit arrestor and auxiliary spray system
- Spillage coke conveyor on the service platform
- Conversion to double collecting main from single collecting main and vice-versa
- Steam aspiration system for on-main charging.
- Provision of additional capacity of decanter compatible with HPLA and double collecting mains
- Conversion to three charging holes from five charging holes

It may be mentioned here that these facilities could only be incorporated either during installation or during rebuilding of batteries. These had, no doubt, improved performance of batteries with respect to quality of coke, environmental status etc. However, barring a few cases, there were design and erection deficiencies in these facilities. As a result of this, full potential of these facilities could not be realised. Some of the reasons for design and erection deficiencies were due to :

- Inadequate knowledge of the Indian technology suppliers
- Basic engineering was done on the basis of inadequately envisaged input parameters since no field studies were conducted to get actual data.
- Detailed engineering was done assuming certain site parameters which, during erection, were found inaccurate. As a result of this, site modifications were carried out and these resulted in mismatches creeping into the system.
- As per the practice, local parties had to be chosen for supply of items and erection of the system. This resulted in poor quality of material as well as poor workmanship. Further, inadequate training for the operation and maintenance personnel was also another constraint.

In view of these constraints, efforts were made to involve foreign designers in some cases. The following constraints are being experienced for getting complete involvement of foreign designers:

- Cost of foreign engineering is very high
- Availability of foreigners as per time schedule of the project is doubtful.
- Adaptability of foreign design to Indian standards and Indian practice of manufacturing, erection and commissioning of equipment / facility is poor.

In view of these constraints, Indian parties are not very much inclined to get the total system designed by the foreign designers. Instead they try to carry out the design themselves by using incomplete inputs without really understanding the various intricacies fully. Further, even when the equipment is manufactured by Indian suppliers under foreign collaboration, the quality of material and workmanship is often compromised resulting in poor performance inspite of adequacy of design of equipment.

This has led to various inadequacies / failures in the new facilities which were installed from time to time.

It can thus be concluded that proper infrastructural facilities for design and manufacture of coke oven equipment have not been established. Not much research work was also carried out. Many aspects have not been understood by Indian designers, manufacturers and operators and, therefore, the equipment/facilities remained as it was in earlier days. Only recently some improvements have been carried out but without developing the total concept. As a result of this, focus on environmental aspects remained within the stipulated norms of 3 kg carbon monoxide emissions per tonne of coke and particulate emission of 50 mg/Nm^3. Designers/ manufactures/ operators/ regulatory authority did not invest much for further development.

CONCLUSIONS

Keeping in view the evolution of emission standards in USA and India, the following suggestions were put forward by Consultants, Designers, Suppliers & Operators together to MOEF for amendment:

- Standards may be amended to include three categories i.e. (i) new battery, (ii) rebuilt battery & (iii) existing operating battery.
- It would be proper to put only the following norms in place initially for five years (October 2001 to September 2006)

Table 1 : Suggested Norms

Norm	Unit	New battery	Rebuilt battery	Operating battery
PLD	%	5	10	20
PLL	%	1	3	5
PLO	%	4	6	10
Charging emission	Sec/Charge	16	50	180
Stack Emission				
SO_2	mg/Nm^3	800	800	800
NO_x	mg/Nm^3	500	500	500
SPM	mg/Nm^3	75	75	100

- To constitute a committee with representatives from Regulatory Authority, Operator, Designer and Supplier to monitor and to evaluate the emission status during implementation of new norms from October 2001 to September 2006 and suggest further course of action. The committee will also make efforts to formulate norms for pushing and quenching operations.

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[7] *"Control of pollution in SAIL Coke Oven Batteries" prepared by CET in April 1999 for CPCB.*

[8] *"Measurement of emissions from SAIL Coke Oven Batteries" prepared by RDCIS in April 1999 for CPCB.*