Lowering NO\textsubscript{x} in India

India’s cement industry has grown steadily in recent years and production capacity has reached just under 380Mta. Alongside this expansion has been an increasing need to curtail emissions, including NO\textsubscript{x}, from cement plants. This article considers some of the challenges and solutions available.

by S Bhattacharya, PK Ghosh and S Chatterjee, Ercom Engineers Pvt Ltd, India

Under constant pressure to reduce costs and environmental impact, the Indian cement industry has adopted state-of-the-art technology to improve its energy efficiency and lower its carbon footprint. Particulate emissions have been curtailed by optimisation of raw materials and process conditions, as well as by installing efficient pollution control equipment. Specific energy consumption in the best-performing Indian plants is also in line with the best in the world.

Recently India’s norms for gaseous emissions from cement plants have been revised and the Ministry of Environment and Forests (MOEF) has amended the Environment (Protection) Rules of 1986. The limit for NO\textsubscript{x} emissions for new plants is set at 600mg/Nm\textsuperscript{3} at 10 per cent O\textsubscript{2} (800mg/Nm\textsuperscript{3} for older plants) and for SO\textsubscript{2} emissions at 100mg/Nm\textsuperscript{3} at 10 per cent O\textsubscript{2}, dry basis. This has led to the need for cement producers to assess to what extent their current operations meet these more stringent requirements and if necessary, carry out the appropriate modifications to their plant.

NO\textsubscript{x} formation

NO\textsubscript{x} in kiln flames is generally generated by heat (thermal NO\textsubscript{x}) or fuel (coal, oil and pet coke).

Thermal NO\textsubscript{x} is formed by the combination of atmospheric nitrogen and oxygen at very high temperatures, typically 1800-2000° C near the burner. The reaction takes place between oxygen radicals, nitrogen radicals and molecular nitrogen. Apart from temperature, the in-flame oxygen concentration and the residence time in the high-temperature zones influence the final thermal NO\textsubscript{x} emissions.

Fuel NO\textsubscript{x} is formed due to the presence of nitrogen bound as an organic compound in the structure of fuel (other than gas). During burning, this organic nitrogen becomes converted into a range of cyanide and amine species, some of which are subsequently oxidised to NO\textsubscript{x}, depending on the local oxygen availability. This mechanism is less dependent on temperature.

Typical NO\textsubscript{x} emission values in older technologies can be as high as 1800-2000mg/Nm\textsuperscript{3}, while average emission values are around 1200mg/Nm\textsuperscript{3} (based on 10 per cent O\textsubscript{2}).

NO\textsubscript{x} emissions are dependent on certain process-related factors such as feed mix composition, kiln fuel type, increased thermal efficiency, burner type and amount of excess air.

The burnout and reduction zones in a typical preheater precalciner (PH/PC) system are shown in Figure 1.

NO\textsubscript{x} control mechanisms

To control NO\textsubscript{x} emissions the following retrofitting options can be incorporated in
existing PH/PC dry-process cement kilns.

**Installing low-NO, burners (LNB) in the kiln**

Two distinct combustion zones are created using LN Bs. Flame turbulence as well as air and fuel mixing are suppressed during the first stage of combustion. A fuel-rich, oxygen-lean, high-temperature combustion zone is first created by reducing the amount of primary air in the primary combustion zone and delaying the combustion of all of the fuel. Thermal NO, formation is suppressed in the primary combustion zone because less oxygen is available.

A secondary, oxygen-rich combustion zone follows, where fuel combustion is completed, but at lower temperatures to avoid NO, formation. This method can secure 10-15 per cent NO, reduction depending on the existing level of emissions.

**Combustion zone control**

Continuous monitoring of CO and O2 emissions in the exhaust gases of kilns provides an indication of the amount of excess air: present.

Maintaining the combustion zone temperature at a minimum acceptable value for the given excess air level minimises process energy requirements and NO, emissions.

**Staged combustion in calciner with tertiary air split**

Staged combustion in calciner (SCC) works by staging the introduction of fuel, combustion air and feed material in a manner to minimise NO, formation and reduce NO, to nitrogen. NO, formed in the kiln's combustion zone is chemically reduced by maintaining a reducing atmosphere at the kiln feed end by firing fuel in this region (see Figure 2). The reducing atmosphere is maintained in the calciner by controlling combustion air such that the calcining fuel is first burned under reducing conditions to reduce NO, and then under oxidising conditions to complete the combustion reaction. However, the overall process parameters during kiln operation under such reducing conditions must be carefully watched to limit CO emissions, especially where an ESP is being used instead of a baghouse.

Controlling raw meal introduction allows control of the calciner temperature. Through these mechanisms, both fuel NO, and thermal NO, are regulated. The combustion chamber allows for improved management of the introduction of tertiary air in the calciner region, which helps to promote the proper reducing environment for NO, control.

Engineered to the existing design of the kiln, this method can secure up to 25-30 per cent NO, reduction.

**Selective non-catalytic reduction**

The selective non-catalytic reduction (SNCR) process is the injection of ammonia in the form of ammonia water or urea in the flue gas at a suitable temperature. An aqueous ammonia solution is the reagent that has been most often used for cement kilns and experience indicates that an ammonia solution is most effective for PH/PC cement kiln applications. Other reagent alternatives include anhydrous ammonia (injected as a gas), urea solutions and ammonium sulphate solutions. This reagent is called a reductant.

SNCR system performance depends on:

- residence time available in optimum temperature range
- degree of mixing between injected reagent and combustion gases
- uncontrolled NO, concentration level and oxygen level
- molar ratio of injected reagent to uncontrolled NO,

The SNCR system can be easily installed as retrofit in an existing pyroprocessing system with the following main additions:
**Table 1: typical aqueous ammonia consumption**

<table>
<thead>
<tr>
<th></th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production (tpd)</td>
<td>2800</td>
<td>4200</td>
<td>9000</td>
<td>10,000</td>
</tr>
<tr>
<td>NO(_x) at preheater outlet, 10% O(_2), dry (mg/Nm(^3))</td>
<td>2000</td>
<td>1200</td>
<td>1800</td>
<td>1347</td>
</tr>
<tr>
<td>NO(_x) emission required at 10% O(_2), dry (mg/Nm(^3))</td>
<td>600</td>
<td>700</td>
<td>600</td>
<td>700</td>
</tr>
<tr>
<td>Gas volume at actual O(_2), wet (Nm(^3)/h)</td>
<td>200,000</td>
<td>270,000</td>
<td>550,000</td>
<td>580,000</td>
</tr>
<tr>
<td>NO(_x) reduction required (%)</td>
<td>70</td>
<td>42</td>
<td>67</td>
<td>48</td>
</tr>
<tr>
<td>Ammonia slip (mg/Nm(^3))</td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Ammonia slip (kg/h)</td>
<td>1600</td>
<td>522</td>
<td>2500</td>
<td>2230</td>
</tr>
<tr>
<td>Aq ammonia consumption (l/h)</td>
<td>1764</td>
<td>575</td>
<td>2756</td>
<td>2459</td>
</tr>
<tr>
<td>Aq ammonia consumption (m(^3)/day)</td>
<td>42.3</td>
<td>14</td>
<td>66.2</td>
<td>59</td>
</tr>
</tbody>
</table>

**Practical considerations**

The Indian cement industry is currently assessing its existing systems to formulate a practical and sustainable approach to reducing NO\(_x\) emissions. The typical requirements for ammonia reagent (25 per cent ammonia in water) for SNCR systems are given in Table 1. While the data presented is for different locations and different SNCR vendors, it provides an indication of aqueous ammonia volumes required to be handled and consumed for the SNCR process.

It is imperative that stakeholders of the cement industry, such as manufacturers, OEMS, technical consultants, industry associations and regulatory bodies, collaborate and share their experiences to work out a sustainable solution. Consultants and OEMs with global experience can also help to find the most suitable technology and address the issue of ammonia availability.

**Conclusion**

India’s cement industry has carried out a critical analysis of the NO\(_x\) emissions from its plants, taking into account the increasing use of alternative fuels. In all cases primary measures, such as staged combustion and burner improvements, are expected to be carried out to help minimise process-specific NO\(_x\) emissions and meet limits set out in recent legislation. Only then should secondary measures such as SNCR be adopted to minimise the operational cost.