Report

Improvements in the Operation of the Electrostatic Precipitator

Boral Cement Works, Berrima NSW

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Executive Summary

The Boral Berrima Cement Works has had in place an electrostatic precipitator as part of the kiln 6 process since its commissioning in 1978. The equipment is located, in the cement manufacturing process, downstream of the raw mill 6 and upstream of the vent stack.

The electrostatic precipitator, as outline in principles of operation, primary purpose is to remove fine dust particles from emissions to the air. To avoid catastrophic failure due to an explosion, ESPs are designed to automatically deactivate (trip) when carbon monoxide levels are elevated.

In usual and steady conditions the cement manufacturing process generates very small levels of carbon monoxide which, at these levels, does not pose a health nor safety risk. In certain conditions, disturbances in the manufacturing process can lead to higher levels of carbon monoxide which, due to its combustible nature, may pose a risk to the integrity of the electrostatic precipitator. Such conditions are automatically detected early before any risk can materialise and the electrostatic precipitator is deactivated for a short period of time.

During the initial SWDF Proof of Performance Trials, an ESP trip occurred on 20 September 2018 during a high RDF trial. During subsequent stack emission monitoring the ESP has tripped two out of the six rounds of air emission monitoring. In the EPA's letter dated 17 September 2021 the EPA requested that Boral is to demonstrate that the ESP is operating efficiently and consistently. It was recommended that this be undertaken by reviewing either CEMs or ESP data.

Prior to the receipt of the request from the EPA via the DPIE, Boral had already undertaken a review of the ESP trip frequency and implemented processes and procedures in May 2021.

This report discusses the main root causes for automated electrostatic precipitator trips and the mitigation actions put in place by Boral Cement. The report details a significant improvement in the number of automated deactivation (trips) compared to the previous period, a direct result of the effectiveness of the mitigation actions.

Electrostatic Precipitator – Principles of Operation

An electrostatic precipitator is a device that removes fine particles (dust) from a flowing gas using the force of an induced electrostatic charge, minimally impeding the flow of gases through the unit. A typical unit is depicted in Figure 1.

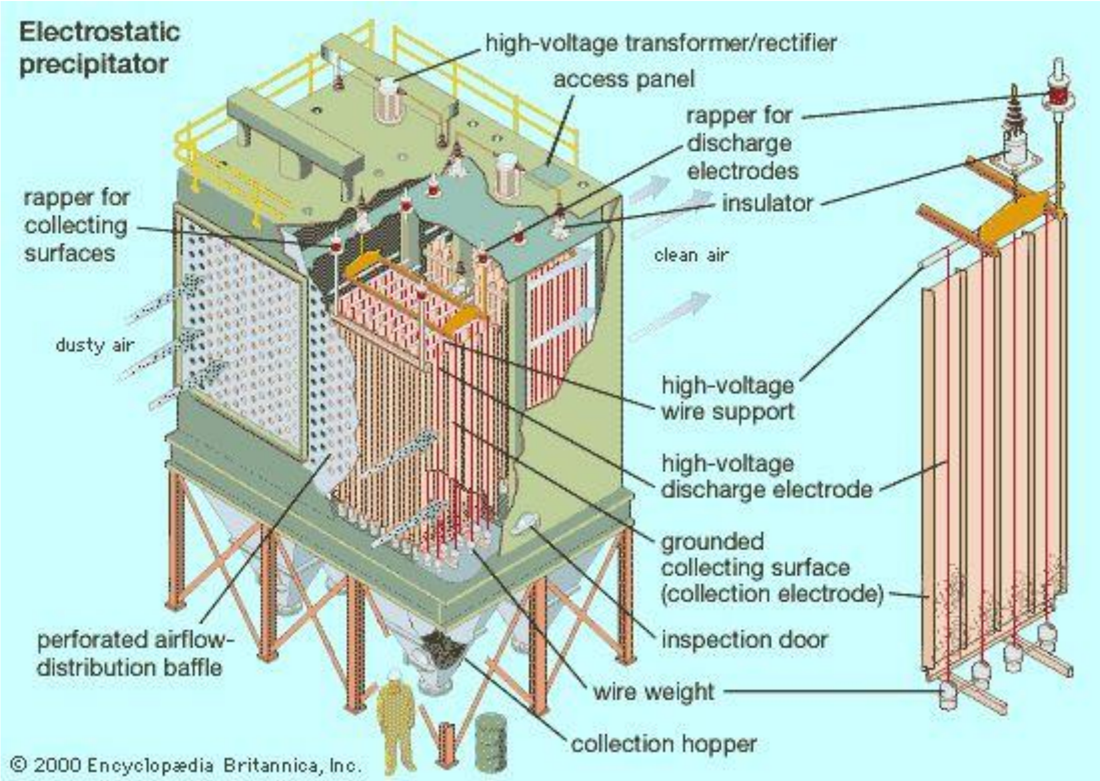

Figure 1 Typical electrostatic precipitator

A typical electrostatic precipitator contains a row of thin vertical wires (discharge electrode) followed by a stack of large flat metal plates (collection electrodes) oriented vertically, with the plates typically spaced a few centimetres apart. The dust laden gas flows horizontally through the spaces between the discharge and collection electrodes. A negative voltage of several thousand volts (30 to 40 kV) is applied between the wire and the plate. An electric corona discharge ionizes the air around the electrodes, which then ionizes the dust particles in the gas. The ionized particles, due to the electrostatic force, are diverted towards the collection electrodes where they build up. At regular intervals, collected solids are removed in collection hoppers by shaking/vibrating the collection electrodes.

At the Boral Berrima Cement Works kiln 6, the electrostatic precipitator is located, in the cement manufacturing process, downstream of the raw mill 6 and upstream of the vent stack. Hot gases from the kiln enter raw mill 6 and dry and convey the fine raw meal (mix of limestone and shale) milled in the raw mill. These solids, vital for the production process, are then recovered in the electrostatic precipitator and fed in the kiln while the cleaned gases are vented to atmosphere. The ESP has been part of the kiln 6 process since commissioning in 1978.

Primary Causes of Electrostatic Precipitator Upsets

The Cement manufacturing process has at its core the chemical transformation of lime, silica and other additives into cementitious compounds. This transformation is enabled by very high temperatures achieved in the rotating kiln: about 1450ºC, through the combustion of fuels: coal and other solid fuels, with atmospheric air.

Under ideal operating conditions, the combustion of carbonaceous fuels would be complete with all the carbon reacting with oxygen to release energy, in the form of heat, forming carbon dioxide. The ideal combustion assumes enough oxygen is made available for the complete combustion and the solid carbonaceous particles are perfectly mixed/distributed within the air stream to achieve a high temperature flame.

Under normal operating conditions, although the cement manufacturing process is conducted with an excess of oxygen, in respect to the requirement for complete combustion of the carbonaceous fuels due to the large scale of operation, the mixing of fuel particles in air deviates from the that ideal scenario. This leads to a small portion of the fuel to incompletely burn generating carbon monoxide (CO).

Alongside the fuel-air mixing, the temperature of the combusting mixture plays an important role in the complete combustion or, on the other hand, in the incomplete combustion and carbon monoxide generation.

In the cement manufacturing process, the combustion of fuels is conducted over a wide range of temperature levels: from thousands of Celsius degrees with the presence of flame, in the kiln, to below 1000ºC without flame in the pre-calcinater. In the pre-calcinater, the raw material – limestone is chemically transformed to lime with the release of carbon dioxide. The chemical transformation is endothermic, as in requires thermal energy (heat) to be completed. Imperfect mixing of the limestone with the combusting mixture of fuel and air leads to localised cooling, lower temperature combustion than in the whole mass of reaction and a slight generation of carbon monoxide.

Under normal operating conditions, the cement manufacturing process generates very small levels of carbon monoxide: 250 – 300 ppm.

Unlike carbon dioxide, which is inert, carbon monoxide is a flammable gas. It is easily ignited when mixed with air. In the presence of a spark caused by an electrical discharge, an explosion is possible, especially if the mixture of CO and air is found in a confined space, e.g. the electrostatic precipitator.

To prevent such a catastrophic event, the electrostatic precipitators are automatically controlled to disconnect the electrical power (trip) when a spike (a sudden increase) in the concentration of carbon monoxide is detected in the system. In such a case the discharge electrodes are deactivated along with the dust recovery of the electrostatic precipitator.

At the Boral Berrima Cement Works kiln 6, the electrostatic precipitator is automatically deactivated (tripped) when the level of carbon monoxide detected in the flue gas exceeds 1.25% volumetric.

Analysis of Electrostatic Precipitator Upsets

A detailed analysis of operations during November and December 2020 (first two columns in Figure 2) was undertaken in February 2021, which revealed different causes for the automated deactivations of electrostatic precipitator.

Figure 3 details that the main causes of ESP trips during November being Kiln Start up/shut down, Alternative Fuel operation, coal operation and false alarms. In response to the identified issues the Plant Management team implemented specific measures to address the particular root causes as described following section in February 2021 and March 2021 during the annual kiln shut down.

The measures proved highly effective resulting in a significant improvement in the total number of occurrences from May 2021, as shown in Figure 2.

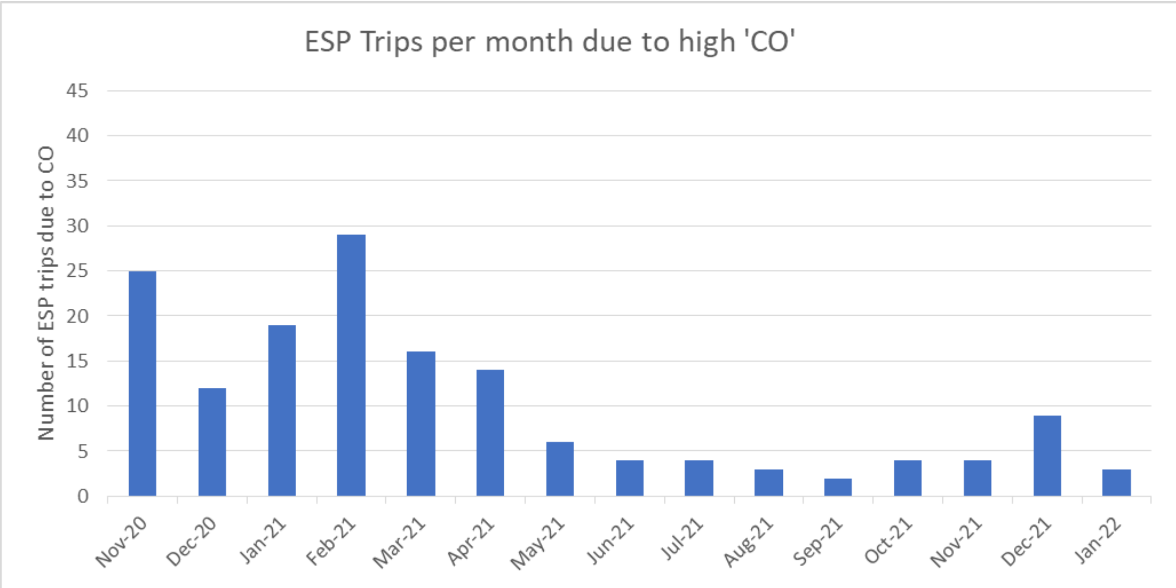

Figure 2 Recent history of electrostatic precipitator deactivations at Boral Cement – Berrima Works

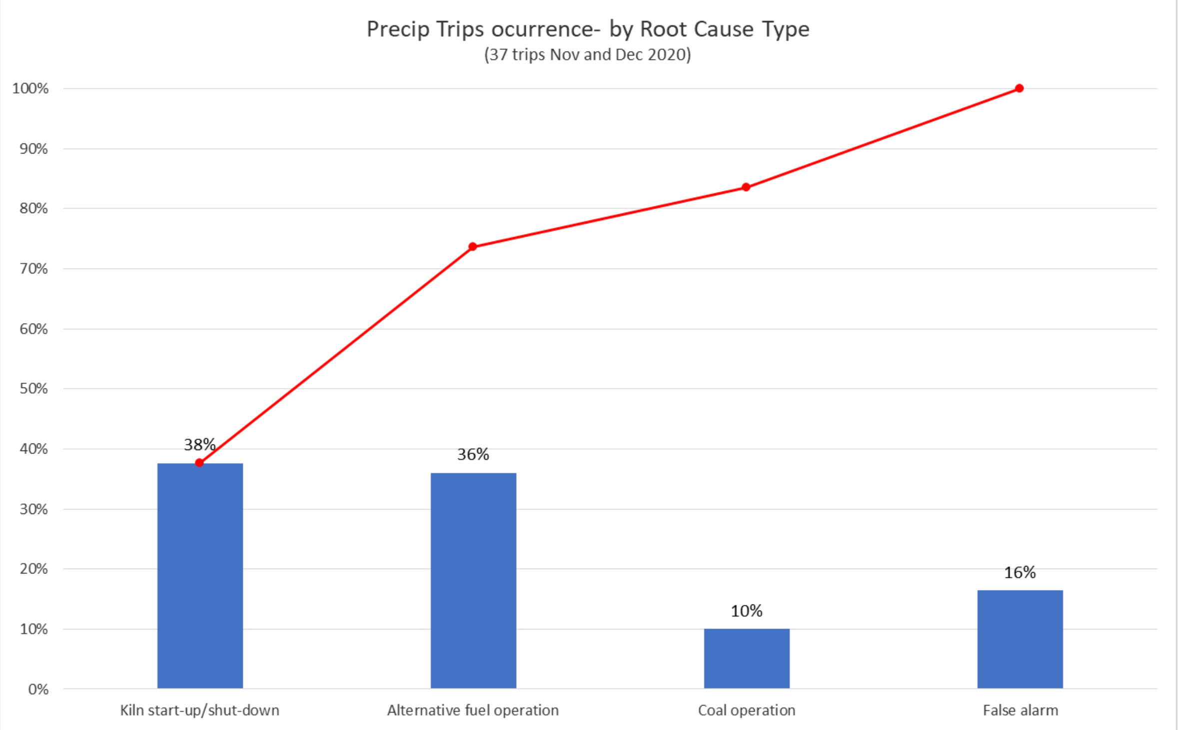

Figure 3 Distribution of root causes among historical occurrences (Nov 2020 to Dec 2020)

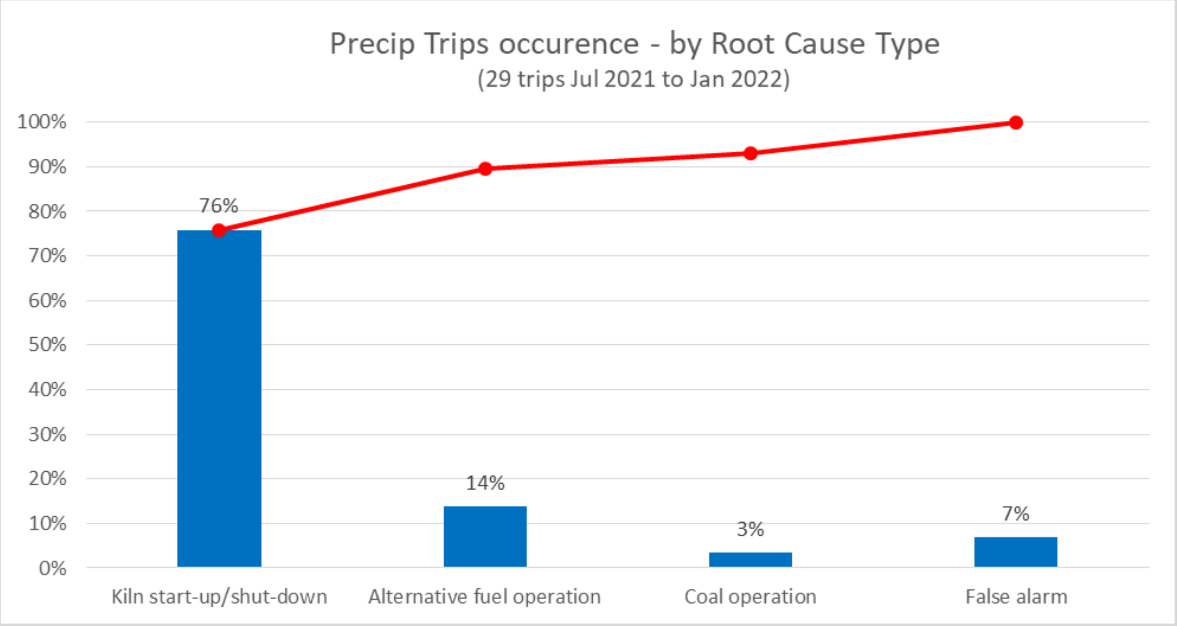

Figure 4 Distribution of root causes during the reporting period: Jul 2021 to Jan 2022

Figure 4 shows a significant improvement in the distribution of root causes of the ESP trips during the reporting period: July 2021 to January 2022, with kiln start-up/shut-down representing the main root cause.

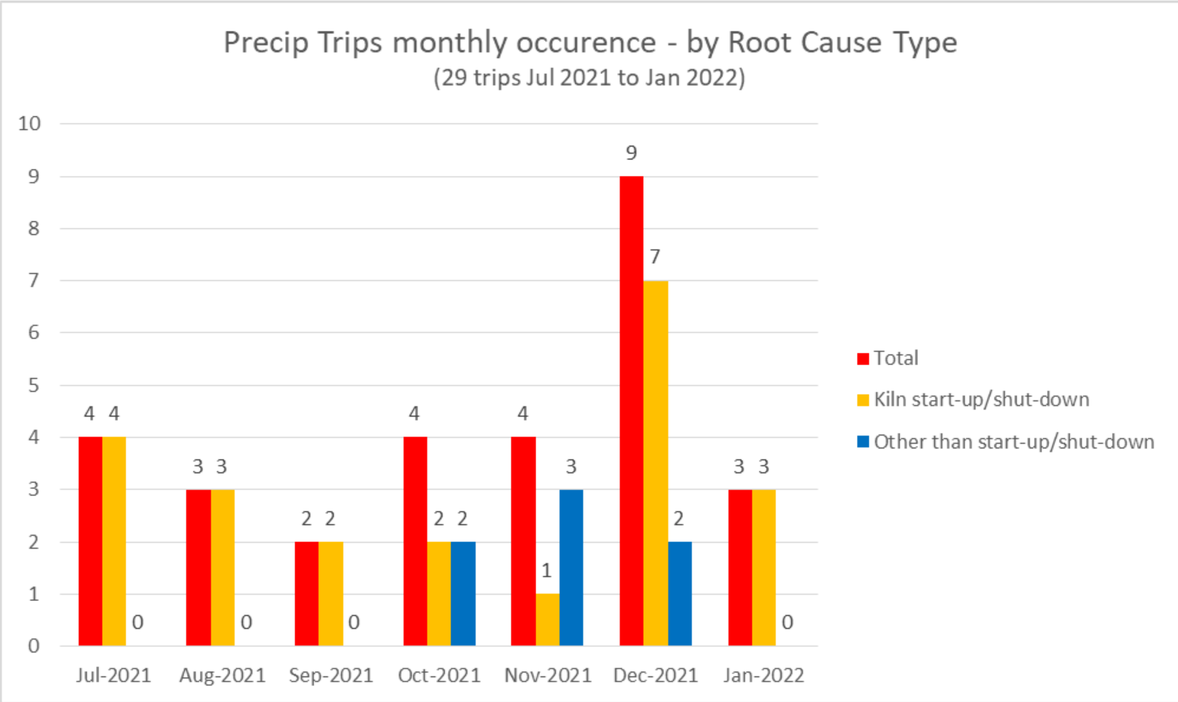

Figure 5 Proportion of root causes during the reporting period: Jul 2021 to Jan 2022

This trend is consistent through each month of the reporting period, as shown in Figure 5.

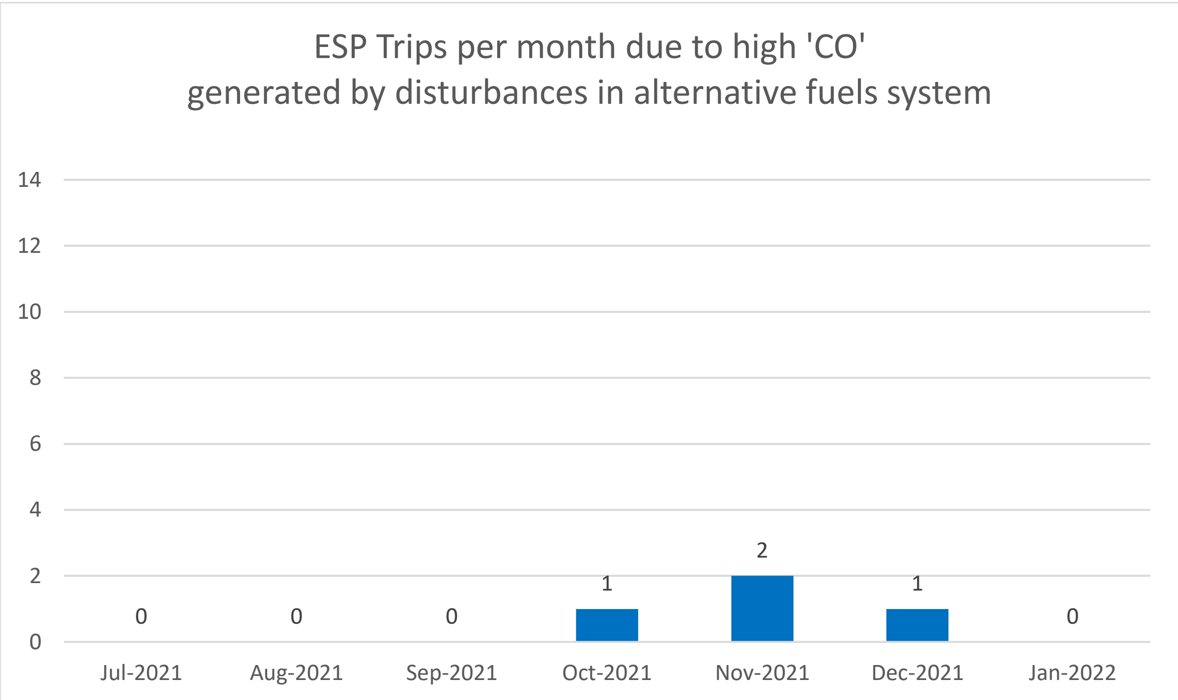

Figure 6: Number of ESP trips per months attributed to the alternative fuels system.

Major Causes of CO Spikes and Mitigating Actions

Automated deactivation of the electrostatic precipitator (ESP trip) is the direct consequence of a sudden increase in the measured/reported concentration of carbon monoxide in the flue gas generated by the cement manufacturing process. The major causes of these events are briefly discussed below.

Unstable Conditions during Kiln Start-up and Shut-down

Normal operation of the cement manufacturing process features constant operating parameters, e.g.: constant or very small disturbances in raw material feed rates, fuel injection rates, temperatures and pressure. During this steady state, the generated level of carbon monoxide is very small (ppm level) which does not present any risk to the operation of the electrostatic precipitator.

Unlike the steady state, the kiln start-up represents a transition phase between no-production and normal operation which inherently features a high degree of instability in the operating parameters. Raw material feed rates are progressively increased to the nominal values. The fuel injection rate is increased alongside the flow rate of air needed for combustion. All the operating parameters need to be tightly controlled and each one adjusted in respect to all others in order to achieve a safe and quick transition to the nominal production capacity. A similar context is valid for the shut-down.

Inherently, these transition phases are vulnerable to creating the undesired conditions for generating spikes in carbon monoxide concentration, leading to electrostatic precipitator trip. Any disturbance in the air flow rate or the ratio air/fuel could create the conditions for incomplete combustion due to insufficient air or due to poor mixing of fuel in the air stream. Furthermore, any disturbance in the feed rates of the raw materials could lead to localised cooling of the combusting mixture, generating an increase in the level of carbon monoxide.

Kiln start-up and shut down are very delicate operations, a true art which gets to be mastered by the plant operators through years and years of hands-on experience. At an organisation level, specific operating procedures are in place to ensure a safe, smooth, and quick transition to normal operation, mitigating the risk of carbon monoxide spikes and electrostatic precipitator deactivations.

During start-up conditions solid waste derived fuels are not used, only diesel/fuel oil and coal is used as the source of fuel for kiln operation. As per Operating Condition O4 Processes and management, standards of concentration prescribed by this licence do not apply to or in relation to any plant during start-up periods and shutdown periods for kiln 6, having said that Boral are still required to prevent and minimise air pollution reporting.

To reduce ESP trips during Start-up and Shut down conditions Boral Cement Berrima initiated a program to review the start-up procedures and refresh operator training.

Disturbances in Alternative Fuel Feeding System

In 2018 the Cement Works introduced alternative fuels in order to reduce the share of coal used to generate the required thermal energy for cement manufacturing.

The new system injected combustible materials in the pre-calcinater where the combustion is conducted at lower temperatures, between 850 and 1000ºC. In this section of the process the risk of localised cooling, and thus of generating higher levels of carbon monoxide, is higher.

An analysis of historical occurrences of electrostatic precipitator deactivations revealed a direct link between operating issues related to the alternative fuels feeding systems (e.g.: disturbances in the feeding rate leading to improper mixing and localised cooling) and spikes in carbon monoxide.

The management team of Boral Cement – Berrima Works drafted specific plans to mitigate the occurrence of such events and the Maintenance and Operations teams implemented modifications to the feeding system during the March 2021 kiln 6 shut, such as: changing the injection point of alternative fuels; revamping the expansion joints on the screw conveyors and revamping the paddles in the screw conveyors feed bin to tighten the control of the feed rate; new Standard Operating Procedures for starting, stopping and ramping up the injection rate.

These actions greatly improved the track record of electrostatic precipitator deactivations.

Spurious Upsets of Coal Feeding System

Complete combustion of the carbonaceous fuels requires the right amount of oxygen/air. Insufficient oxygen, in respect to the amount of fuel, or excess of fuel, in respect to the available oxygen leads to incomplete combustion and an increase in the level of carbon monoxide which in turn may lead to deactivation of the electrostatic precipitator.

Analysis of historical occurrences of electrostatic precipitator deactivations revealed a direct link between operating issues related to the coal injection pump, on one hand, and primary air-blowers reliability, on the other hand, and spikes in carbon monoxide.

In response to this root cause, the Engineering team of Boral Cement – Berrima Works put in place active measures to streamline the operation of the air-blowers greatly reducing the occurrences of electrostatic precipitator deactivations.

Other Causes

False alarms are found among other causes for electrostatic precipitator deactivations. Spurious high levels of carbon monoxide are falsely detected by malfunctioning or un-reliable detectors. The maintenance team swiftly replaces malfunctioning detectors and the Operations team implemented a program for regular on-line calibration of the detectors.

Conclusion

As a result of the analysis and implementation of actions for the main causes of ESP trips, the Berrima Cement Works has significantly reduced the number of events from an average of 20 per month to less than 5 and mostly during Start-up or Shut down conditions. Boral will continue to monitor the performance of the ESP to ensure trips are kept to a minimum.