Pushing ESP boundaries

With the strengthening of emissions legislation, marginally performing electrostatic precipitators (ESPs) may have difficulty to achieve the emission reductions called for. However, the conversion of a tumbling hammer ESP into a top-rapped design will help to achieve more challenging emission limits.

■ *by **John A Knapik**, Babcock & Wilcox, USA*

In its simplest form, the ability of an electrostatic precipitator (ESP) to collect dust is directly related to its relative size, or specific collecting area (SCA), and the amount of useful power density (Watt/m^2) that is applied to the collecting surface area. The SCA is a number derived by dividing the ESP's collecting surface area by the gas volume the ESP is treating. The power at which an ESP operates is a function of its original design, electrical clearances and the resistivity of the dust it collects. Highly-resistive dust limits power to the ESP and, in turn, lowers the ESP's ability to collect dust.

Two fundamental designs are commonly found in cement and industrial ESPs – top-rapped and tumbling hammer. A top-rapped design offers some distinct advantages over a tumbling hammer design for improving ESP performance and maintainability, including:

- an increased number of electrical fields for higher collection efficiency
- increased SCA within the same ESP casing for higher collection efficiency
- reduced maintenance and associated costs
- reduced particulate matter emission spikes.

ESP dust resistivity

The most important property of the collected ESP dust is its resistivity, or the resistance to current flow. The two critical factors affecting resistivity are the temperature and moisture content of the gas stream. Higher moisture content, in most cases, reduces dust resistivity. Resistivity also depends on particle size, chemistry, kiln gas moisture content and the temperature of the dust-laden gas stream. Dust from a long wet-process kiln has the lowest resistivity and is easy to precipitate, as is dust on a raw mill. Resistance continues to increase from long dry-process kilns to preheater kilns to a

The conversion of a tumbling hammer ESP into a top-rapped design will enable cement plants to meet stricter emission limits

clinker grate cooler ESP, as the amount of water-soluble alkalies decreases.

When dust resistivity remains in an acceptable range, the ESP will perform well. The conversion from a tumbling hammer ESP to a top-rapped design does not change resistivity, but it can significantly increase the ESP's SCA and collecting power density to improve collection efficiency.

More electrical fields

An ESP's electrical field is an arrangement of bus sections in the direction of gas flow that is energised by one or more power supplies situated laterally, transverse to gas flow. Each field is in effect an independent ESP preceded and/or followed by another ESP, and handles flue gas of the same volume flow and temperature as those fields preceding and following. However, the dust concentration changes and is reduced by the amount collected by the preceding field.

Dust concentration affects the electrical characteristics of the field. As more dust is

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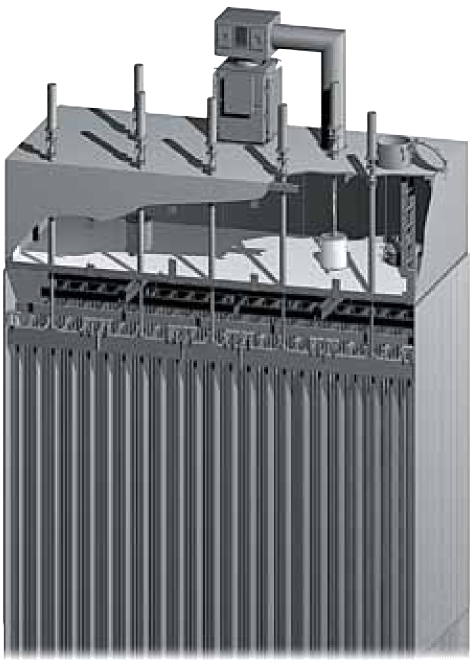
removed in each field, the ESP operating current and power to that field successively increases. It is recommended to have more separately-energised fields in the direction of gas flow, which is also useful in the event any one field fails because of a broken high-voltage (HV) electrode, tracked insulator, hopper over-filling or failure of the power supply itself. The more electrical fields an ESP has, the less the impact an out-of-service field has on ESP collection efficiency.

A top-rapping conversion provides benefits that improve ESP performance, reliability and collection efficiency



Higher ESP current density in the rebuilt field

As previously-mentioned, the greater an ESP's power, the greater its collection efficiency. For example, if the power density of an ESP with an SCA of 60_{300mm} is raised from $5.6W/m^2$ to $11.2W/m^2$, the ESP's efficiency will increase significantly, from 99 to 99.5 per cent.

The ESP power component is made up of the kilovolts applied to the field and the resulting ESP current (mA). ESP designers use expectancies for certain ranges of current density (nanoamps/cm^2) for each succeeding field, based on theory and years of experience in each process application. In top-rapped designs that number usually ascends from 10-20nanoamps/cm^2 in the inlet field to 70-90nanoamps/cm^2 in the outlet. Tumbling hammer designs rely less on ESP power and more on ESP area to achieve collection efficiency. Many use the same density (35nanoamps/cm^2) for every field of the ESP.

In most cases, converting a tumbling hammer field to a top-rapped field will usually increase power to the field by 50-100 per cent, if two fields are created and an additional power supply is added. The enhancement factor is further increased if the original power supplies were 1ϕ transformer rectifiers (TR) and are replaced with low-kV ripple, 3ϕ TR sets.

Increased SCA within the same ESP casing

Tumbling hammer ESP designs often require a significant distance of untreated space between fields to accommodate the suspension of the HV system and the location of the tumbling hammer system. This space can be greater than 1.2m, whereas the top-rapped ESP designers often leave a space of 0.45m to serve solely as a maintenance/inspection walkway. When a tumbling hammer ESP field is converted to a top-rapped design, part of that vacant space can be taken up with more collecting plate panels, up to 0.8m. In some cases that can be an additional 20 per cent in SCA, resulting in a significant improvement in ESP efficiency, even without considering the potential gains expected from the increased power input resident.

Reduced maintenance by eliminating the tumbling hammer system

With a series of hammers sequenced by a rotating shaft, tumbling hammer ESPs are inherently high-maintenance, which can result in high costs. Tumbling hammer rapping control is achieved by motor operating time and shaft speed.

Tumbling hammer systems have inherent weaknesses as a result of having multiple moving parts within the dust-laden gas stream. Problems such as rotating shaft seizure, bearing and coupling wear, misaligned hammers and undersized gear motors can result in the loss of an entire ESP field of rappers, requiring the whole ESP system be taken out of service for maintenance.

The advantage of electromagnetic, gravity return impact rappers in a top-rapped system is their flexibility in the rapping program and a reduced need for maintenance. The typical electromagnetic rapper should last at least 10 years and if a failure occurs it can be corrected without having to shut down an entire ESP.

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Reduced PM spikes by eliminating the tumbling hammer system

A benefit of the tumbling hammer's cleaning system is the brute force of one hammer per collecting plate, assuring maximum collecting plate cleaning. Unfortunately, those hammers are sequenced by toggling the motor on and off. If the motor is left on to complete one revolution in an outlet field of the ESP, a massive PM spike would be created from all the hammers striking in one short period of time. To alleviate this problem, the motor is usually toggled on for seconds at a time and then off sequentially until one revolution of the shaft has occurred.

With a top-rapped ESP design, a rapper control sequences the rappers individually, with the ability to programme the force of each rapper's impacts, how many times it impacts at each sequencing and the time between raps. This flexibility in sequencing is invaluable in fine-tuning an ESP cleaning programme, especially with highly-conductive dust, and which easily re-entrains into the gas stream. The ability to provide multiple impacts when it initiates a rapper also has a positive effect on cleaning. The first impact helps to break the bond of the dust to the collecting plate and the second impact serves to encourage that dust falls into the hopper.

Conclusion

The conversion of a tumbling hammer ESP to a top-rapped design will result in certain capital expenditures for new ESP internals and new power supplies. However, it does not require any changes to the duct work and dust transportation system. It can take a marginally performing ESP over the edge to achieve more challenging PM emission limits, within the same ESP box. This is accomplished by the increased number of electric fields and by the larger SCA. Since the inception of this technology, Babcock & Wilcox has rebuilt over 50 tumbling hammer ESPs. ■