Optimizing Electrical Precipitators with Multiclone Technology for Particulate Emission Control in Alumina Calcination

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Abstract

Net Zero Emission is on the agenda for many companies over the next generation. Legislation is supporting this goal by tightening emission norms. For particulate emissions, either electrostatic precipitators or bag filters are typically used. More than 13 000 electrostatic precipitators have been installed by Lurgi and its successors worldwide. Several units have also been installed in alumina calcination. However, this application requires special attention, as the particle load to the electrostatic precipitator is extremely high.

With a typical service life of about 20 years for the internal components of electrostatic precipitators, many units are now due for refurbishment - presenting an opportunity to implement improvements. One such improvement is the combination of electrostatic precipitators with multiclones to further reduce particulate emissions. Cyclones, which have no moving parts and feature a simple design, can operate under high temperatures and pressures. However, they involve complex, three-dimensional, highly turbulent two-phase gas flows.

Environmental regulations often allow exceptions during start-up or process disturbances in metallurgical operations. In such cases, applying multiclones enables effective particle separation from the gas stream, even when the electrostatic precipitator is safely de-energized. As a result, the combination of multiclones and electrostatic precipitators has achieved dust emission levels well below current regulatory limits.

All enhancements in particle separation come at the cost of increased pressure drop. Operational constraints, such as design temperature limits, must also be carefully considered.

While other emissions can also be addressed – and some industrial applications already exist – this article focuses solely on the reduction of particulate emissions.

Keywords: Net Zero Emission, Multiclone, Electrical precipitator, Bag filter, Metallurgical process.

1. Net Zero Emission and Development of Particle Emission Limits

The development of particulate matter (PM) limits worldwide is closely linked to the growing awareness of the harmful health effects of particulate matter. These limits vary depending on the region, legal framework, and objectives (e.g., health protection, environmental protection).

In general, the particulate emission limits follow the available technologies and best practices. Below just to illustrate the development we focus on the German standard of TA Luft:

1. TA Luft 1964 (first version):
- Very general, with hardly any specific limit values for particles.

- Focus rather on "avoiding significant nuisance."

2. TA Luft 1986:
- First specific limit values for total dust.
- Frequent values of 50–100 mg/m^3 for industrial processes.
- Introduction of requirements for separation technologies (e.g., electrostatic precipitators, fabric filters).

3. TA Luft 2002:
- Significantly tightened.
- General limit value for dust reduced to 20 mg/m^3 (for many processes).
- Introduction of differentiated values depending on the type of substance and plant type.

4. TA Luft 2021 (current):
- Further reduction of many values to 10 mg/m^3 or less.
- Introduction of fine dust considerations, e.g. E.g., for PM10/PM2.5 in permit procedures.
- Greater consideration of best available technologies (EU standard) [4]

Particle emission limit standards are different with respect to the country but in general it can be observed that the particle emission limits are decreasing.

Net zero particle emission means that a system, activity, or company as a whole causes no net emissions of particles (i.e., small solid or liquid pollutants in the air). This does not necessarily mean emitting no particles at all, but rather that all emitted particles are offset or avoided through measures so that, on balance, there is no negative impact on the environment.
To achieve net-zero particle emissions, the following three strategies can be used:

a) Avoid emissions
- Use of electrically powered systems instead of diesel- or gas-powered machines
- Use of cleaner raw materials with lower particle emissions
- Process optimization, e.g., lower temperatures or closed systems

b) Reduce emissions
- High-performance filter systems (e.g., fabric filters, electrostatic precipitators)
- Exhaust gas cleaning systems (e.g., cyclones, wet scrubbers)
- Dust binding agents in storage areas and access roads

c) Offset emissions
- Installation of air purifiers around facilities (e.g., "City Trees" or photocatalysts)
- Reforestation near sites for natural air purification
- Investment in CO_2/particle offset projects.

This article will focus on the reduction of emissions via exhaust gas cleaning systems.

2. Exhaust gas Cleaning Systems

To remove particles from exhaust gas streams, cyclones, electrostatic precipitators, bag filters, ceramic filters or scrubbers can be used. The pressure drop for ceramic filters and scrubbers are usually too high for alumina calciner application while the separation efficiency from cyclones cannot reach the ambient emission limits.

Alumina calcination plants with their high exhaust volume stream typically operate electrostatic precipitators or bag filters.

original design functionality of the electrostatic precipitator, especially regarding the gas flow dynamics. While the working principle for electrostatic precipitators has been known for more than 100 years, its execution and details hold plenty possibilities for deviation from optimal performance, which can lead to increased particulate emissions.

6. References

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