ESP for Soda Recovery Boilers in the Pulp & Paper Industry

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Introduction

In the Pulp & Paper industry, the recovery boiler (RB) is part of the Kraft pulping process where the so-called black liquor containing lignin from the processed wood is combusted to recover cooking chemicals. The flue gas from these boilers is treated in the electrostatic precipitator (ESP) for dust collection and sometimes subsequently in wet scrubbers.

The RB is a vital machine in the process, therefore must be in stable operation at all times. This includes the availability of the ESPs for dust collection from an operational point of view and naturally to protect the environment. The gas flow rate depends on the size of the RB and can be from 200,000 to 1,600,000 Nm³/h, and for availability purposes, the flue gas is cleaned by several ESP chambers in parallel.

The design features in ESPs for RBs have been developed and refined over the years. We will describe some of the advances made.

There are also many options to enhance the performance of existing ESPs for RBs. We will describe some of them highlighting the advantages of each solution.

Trends

Several operational parameters of the new or upgraded RBs have changed over the last 10-15 years. The dry solids content in the combusted black liquor has increased (from ~70 to >80%) which led to a higher ESP inlet dust concentration and lower moisture in the flue gas to the ESP.

In addition, the RB design exit temperature has increased – e.g. from 170°C to 220°C. Individual heat exchangers (flue gas cooler) are sometimes installed after each ESP chamber to get the best heat-economy and to reduce the stack’s flue gas temperature to e.g. 140°C [1].

Like in all other industries, the dust emission limit itself is driven down by legislation. China introduced the latest requirement of <10 mg/Nm³ for RB ESP stacks.

Factors Affecting ESP Performance

The particulate released from the RB combustion process is very fine (D₅₀~1µm) and as a result the dust concentration has been increasing over the recent years in new RB systems. The ESP operation faces the risk of corona quenching, reducing the power input and making it difficult to obtain a low dust emission.

Dust from RBs also show a tendency to form build-ups on gas distribution screens, collecting plates, high voltage electrodes and any horizontal or even steeply inclined inner surfaces. The stickiness of the dust depends on the chemical composition and the pH-value. Usually, a pH>9 of the dust is an indication, but not a guarantee, that shows less tendency of adhering to inner ESP surfaces.

One of the most characteristic features of RB ESPs is the flat bottom scraper commonly used for dust removal. This device either drags the collected dust from ESP outlet to inlet – or across perpendicular to the gas flow – from a flat surface, so dust build-up is continuously eliminated in the hopper area.

Not only in the ESP, but also in the RB itself, does this type of material raise challenges that will not be discussed in detail here. However, the frequent soot blowing sequences throughout the boiler heat transfer surfaces leads to changing ESP inlet conditions. Such as variations in dust concentration and moisture depending on which operating part is affected.

Without soot blowing, the flue gas itself has a high moisture content which is useful for maintaining high flashover voltage.

Optimizing ESP Performance

Combining the trends and critical factors above, it is clear that the operation of ESPs for RB is a very challenging task. It requires several unique features that are typically not relevant for other applications where ESPs are used today.

Fig 1 – Particle size of RB dust [2]
Dust collection

As the operating parameters for RB ESPs are unique, great care should be taken in designing and operating the dust collection process. Factors that will increase the operating voltage of RB ESPs are the very fine dust, which increases inlet concentration and high moisture in the flue gas. This calls for a combination of narrow plate spacing (300 mm is standard in most cases) and aggressive discharge electrodes, i.e. electrodes with a low corona onset voltage. This allows ESPs with a moderate voltage, while maintaining a high current density that keeps the dust on the collecting plates. It is most relevant for the inlet fields, e.g. first and second field. Dust emissions depend on the specific power input at the ESPs outlet fields (Watt per m² of collecting surface). Electrodes with higher corona onset voltage may be used to ensure an even higher power input.

![Discharge electrodes with low and high corona onset voltage](image)

**Fig 2** Discharge electrodes with low and high corona onset voltage

ESPs for RBs constructed with two or more chambers in parallel, individual isolation dampers and ID-fans are available in case of mechanical or electrical failures. The individual field size in a chamber can be up to 4,400 m² because gas volumes to process can be as high as 500,000 Nm³/h per chamber. Typically, the required design current density is >0.5-0.8 mA/m² or ~2,000-3,500 mA.

For RB ESPs, three types of power supplies can be used – 1-phase, 3-phase [3] and high-frequency power supplies (SMPS). As RB dust has a low resistivity and fine particle size, at least for the inlet fields, a flat electrical curve shape gives the best performance. This is possible with 3-phase power supplies and SMPS. The advantages of 3-phase power supplies are a wide range of rated voltages, high rated current e.g. 4,500 mA and are very simple and reliable. SMPS models available are less variable and the current typically is <2,000 mA.

Therefore, 3-phase power supplies offer a flexible choice to RB ESPs with large field sizes(m²). Indeed, a large field may be split in two or more bus-sections to reduce the collecting energized by the same high voltage supply. But this is not always the most cost-effective solution.

It is essential that a fast controller unit manage the power supplies, given that process conditions can vary and in stability e.g. from soot blowing can challenge the ESP electrical operation. Most importantly is a fast voltage recovery after sparking:
- to minimize the time the field is not energized and being able to operate at a high sparking rate; and
- to ensure operation as close as possible to the maximum voltage – the flashover voltage.

Because the availability of ESPs for RB is so critical(meaning low dust emission and no mechanical problems), it is vital for troubleshooting purposes that the ESP controller, like the PIACS DC4, is equipped with functions and tools assisting this process locally in the electrical room. This controller has a built-in trend function, oscilloscope, logs for alarms and various events.

![PIACS DC4 – a fast reacting ESP controller with user-friendly display functions](image)

**Fig 3** PIACS DC4 – a fast reacting ESP controller with user-friendly display functions

**Keeping the internals clean**

To keep RB ESPs in operation, it is important to keep the internals free of excessive dust accumulations to ensure that dust is collected by the electrical field, and mechanically on the gas distribution screens (GDS). Then, it is removed steadily by the rapping systems and dust transport system in the hopper.

Due to the often very sticky nature of RB dust, all the internals (GDS, collecting plates and electrodes) must be designed for efficient rapping while ensuring long life without mechanical failure. Also, carefully consider how to properly use the entire collecting area by gas distribution devices and means of eliminating hopper sweepage (sneakage), because it can cause undesired dust accumulations reducing ESP availability.

**Upgrade solutions for existing ESPs**

ESPs for new, green-field RBs, are designed from the beginning using all the latest technology for optimal performance. Many RBs around the world face these requirements of ESP upgrading – either because of increased boiler capacity, reduced emission requirements from local authorities or both.

Upgrading RB ESPs can be done in many ways depending on the actual circumstances by one of the following or a combination:

1. Increased collecting area - extra chamber(s) in parallel
2. Increased collecting area – the extension of existing chambers by field(s) in series
3. New more efficient high voltage electrodes
4. Complete new internals (collecting plates and electrodes)
5. New high voltage equipment and controller increasing the power input

The right choice is a combination of cost and downtime required to implement the solution. Below are some case stories describing ESP upgrades made by FLSmidth.

Case A – New ESP internals during a 12 day stop
A recovery boiler in Norway had a three field Fläkt concrete casing ESP that needed an upgrade to stay below 50 mg/Nm$^3$. The new internal parts were 0.5 m taller than the original ESP. They were pre-assembled next to the operating ESP over the course of about a month. When the RB stopped, the roof was cut off, removed, and the new internals and roof were lifted in – all within a 12-day outage. The advantage of this solution is more time for careful pre-assembly, alignment and short boiler downtime.

Case B – New high voltage electrodes and 3-phase power supplies
An RB in Sweden had a two-chamber Fläkt ESP, each with two series of fields operating at 150 mg/Nm$^3$, which needed to reduce emissions below 100 mg/Nm$^3$. FLSmidth's rigid Fibulax electrodes replaced the existing spiral wire electrodes, and the 3-phase power supplies replaced the single-phase power supplies. When the ESP started operations, the dust emission was far below the requirement. The work inside the ESP was limited to the exchange of high voltage electrodes and frames as well as adjustment of rapping system.

Case C – Upgrading an ESP again
An RB in Sweden has one FLSmidth ESP from 1997 with three chambers and three electrical fields per chamber. In 1998 the high voltage electrodes of the outlet fields were modified/upgraded to prevent re-entrainment issues, and the emission dropped below 5 mg/Nm$^3$ [4], well below the guarantee of 20 mg/Nm$^3$. The gas velocity at the time was 0.63 m/s and the ESP operated at 175°C.
The RB capacity has been increased twice (from 3300 to 4400, and later on from 4400 to 4700 tDS/day) since initial start-up. The ESP today operate at 0.87 m/s (38% higher than original design) and 210°C. Two of the chambers have been upgraded in 2016/2017, equipped with the latest FLSmidth high-voltage electrodes, 3phase power supplies, and the dust concentration after these is <10 mg/Nm$^3$. The last chamber will be upgraded in 2018. This is an example of ESP technology continuously improving over the years. It is increasing the cleaning capacity at moderate cost levels compared to building new chambers in operating ESPs (+ducts/fan etc.).

**Case D – new FLSmidth ESP**

A recovery boiler in Austria has a two-chamber FLSmidth ESP, each with three fields from 2013 equipped with Fibulax electrodes, and 3-phase power supplies.

**Conclusion**

Operating parameters for recovery boiler (RB) ESPs have changed over the last 10-15 years, becoming more challenging. At the same time, many countries are reducing the required dust emissions. This has called for new developments in ESP design to accommodate for these changes. In FLSmidth we have developed and installed many of these features such as 3phase power supplies, specialized discharge electrodes, fast reacting high voltage controller and efficient rapping of the internals.

All these things together have enabled FLSmidth in some cases to upgrade existing ESPs with or without replacing ESP internals with a very short stop of the RB, achieving lower dust emissions. In other cases, all the design features are included from the beginning, either in new ESPs or additional chambers built in parallel with the existing ones.

Looking ahead, we believe the development for RBs will continue and constant improvement in ESP designs and features will be required.

**References**