THE ELECTROSTATIC PRECIPITATOR WILL MEET STANDARDS

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Abstract

The emission standards on particulates in flue gases are often in the 10 - 20 mg/m³ NTP range today due to an increasing concern about fine inhalable particles and toxic compounds. The demand in a few years time may be 1 - 2 mg/m³ NTP for many applications. The electrostatic precipitator (ESP) is very often the preferred filtering device due to its low maintenance and operating costs.

Can the ESP meet these requirements or must alternatives such as fabric filters be specified? There are already many moderately sized ESPs working with these low emission levels today. This paper gives examples of very low emissions obtained from operating plants and discusses measures to be taken in order to meet the future demands.

Introduction

The ElectroStatic Precipitator (ESP) is generally acknowledged as an efficient particulate collector with low maintenance and operating costs. So far stipulated emission guarantees have been achieved for all major applications and the ESP technology is well established and understood. This is not to say that the ESP could always meet the collecting efficiency in all plants. Lack of process knowledge, low quality equipment, poorly erected and commissioned ESPs and non existing maintenance have through the years forced the ESP supplier to correct and to improve the equipment in order to get the ESPs in compliance. With the increased knowledge among suppliers ESPs are more marginally sized -- actual performance data come close to guaranteed emissions. The Fabric Filter (FF) is today in many cases a viable alternative as it generally operates with low emissions. Furthermore, new fabrics and longer life time of the bags and reduced pressure drop have shifted the market from ESPs to FFs in many cases.

The low measured emissions from the FFs compared to the ESPs were achieved regardless of the required collecting efficiency. This is an inherent feature of the FF provided that bags are intact, no leakage occurs, etc. The difference in historical emissions between the two filters has in many cases resulted in statements like "FFs are the best available control technology". This is not necessarily the truth.

If we look back on past emission requirements it was not long ago guarantees in the range of several hundreds mg/m³ NTP were common. The ESP is a device which in principle can be sized to any desired efficiency. With the help of Deutsch' equation or its successors an ESP size can be selected for any given efficiency. The actual ESP was not made larger than required in order to give the demanded emission. Contrary to the ESP an FF cannot in principle be sized for a high emission. The penetration through the filter media is always kept very low by the dust cake on the bag. Even clean bags give low emissions compared to ESP sized to lenient standards.

Newer legislation is more stringent and ESPs had to be enlarged or made more efficient to meet the new standards. Wider spacing, well tuned electrode geometries, modern high voltage equipment with pulsing properties and sophisticated management systems are among the new technologies, which have made it possible to build ESPs for lower emissions at reasonable costs. In fact, its robustness, reliability and insensitivity for disturbances is still many customer's preference.

Today's emission demands are very often in the 10 - 20 mg/m³ NTP (10 mg/m³ NTP = 0.0044 gr/scf) range and numerous ESPs have been sized for such levels for quite some time. The background for these low emissions varies from case to case but is often due to local regulations or due to toxic compounds in the particulates.

The historic development is illustrated in figure 1. The curves are constructed from weighted averages of guarantees and measured results from a large number of plants. Different processes, and countries, have different requirements and a weighting is required to reveal the common trend.

Fig. 1.

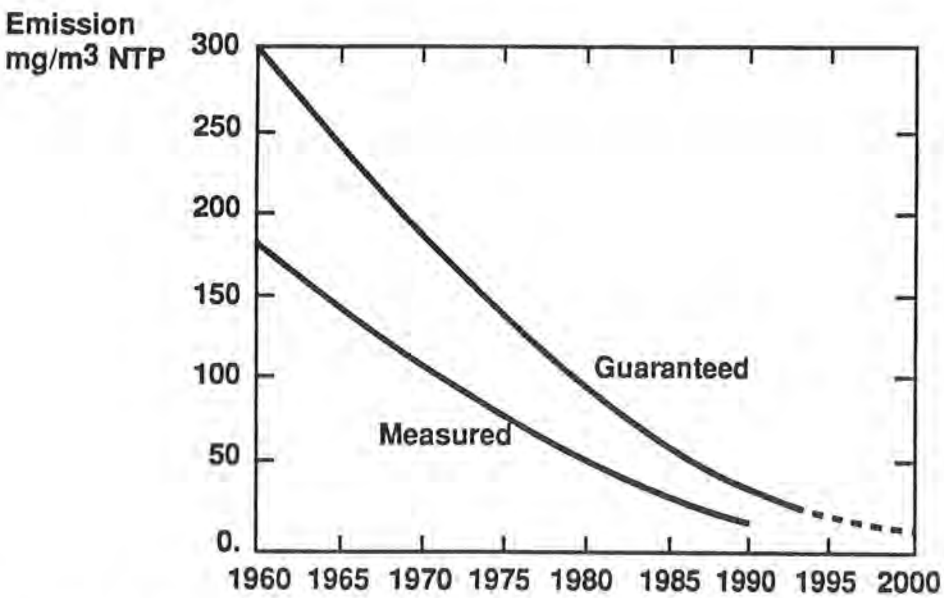

Fig. 1. Guaranteed and achieved emissions after ESPs since 1960. Weighted averages from several countries and applications.

We see that the requirements have changed through the years. Most important, the achieved results have also improved at the same rate. There is no indication in our experience so far that zero emission is not the true asymptotic value.

With today's awareness of environmental problems we will see emission standards much lower in the future than the present ones. Can ESPs live up to tomorrow's demands -- say 1 - 2 mg/m³ NTP -- in competition with other technologies? From technical viewpoint the answer is definitely yes for a great number of applications. It can even be concluded that ESPs may be able to give lower emissions than standard fabric filters. The following is a survey of operating commercial ESPs for various applications, where very low emissions have been achieved. All measurements referred to have been done according to EPA-5 or EPA-17 procedures or alike. The ultimate choice between an ESP and an FF will be determined by economics, reliability and maintenance considerations.

Pulverized Coal Fired Boiler (PC)

PCs represent the most common application for ESPs. The fly ashes generated from these have from an ESP viewpoint widely spread properties depending on ash composition and burning conditions. This can easily result in variations of relative migration velocities from 1 to 5. The more difficult fly ashes are normally characterized by high resistivities and fluffy, non-agglomerating dust particles. An unfavourable flue gas temperature can worsen the situation as the resistivity often peaks at around 150°C.

At quite a few occasions ESP operating problems have been encountered after PCs. Not only high resistivities appear but also corona quenching is taking place. This is due to space charge phenomena caused by many fine particles. High firing temperatures in the boilers generate submicron particles which may be difficult to precipitate. Can moderately sized ESPs give emissions below, let us say, 10 mg/m^3 NTP?

Table 1 shows results from five different plants operating under various conditions. The results between the plants are not directly comparable as there are differences in coal and ash composition (resistivity $< 10^{12}$ ohm cm), flue gas temperature, ESP gas velocity, etc. Inlet dust concentrations varied from 5 to 30 g/m^3 NTP. Each result presented is the average of at least three separate measurements. Also the results from plants A, B and C are no chance performances. They represent measurements done during different test campaigns while D and E are taken during one campaign each. As can be seen specific collecting areas (SCA) of less than 100 $m^2/m^3/s$ (= 508 ft^2/kacfm) can result in reproducible emissions of less than 10 mg/m^3 NTP.

According to the results obtained in plant C, at SCA 97 and 119, the emission at SCA 166 would be expected to reach about 1 mg/m^3 NTP. However, at these low emissions sneakage becomes a matter of consideration. Sneakage is when a constant small part of the gasflow is not being treated between the electrodes. This is even more clearly demonstrated in a following section.

Can high emission from a high resistivity case also be reduced to these low emissions? It is more difficult due to the changed agglomeration properties of these particles. One way of overcoming this is to condition the flue gas. Commonly accepted methods are either NH_3 or SO_3 injection or a combination thereof. The use of SO_3/NH_3 will also increase the cohesiveness of the dust and consequently reentrainment is greatly reduced. Careless injection such as overdosing of SO_3 easily results in acid conditions and a visible SO_3 plume. However, advanced control methods using microprocessors can today identify the correct injection rates.

Table 1.

Average emissions after ESPs installed after PC-boilers.

Plant	SCA $m^2/m^3/s$	Emission mg/m^3 NTP
A	54	4.1
B	94	5.9
C	97	8.5
	119	5.3
	166	3.4
D	88	9.0
E	98	5.0

Circulating Fluidized Bed Combustion (CFBC)

Figure 2 represents emission levels after coal fired CFBCs. The use of ESPs became common 10 years ago and in the beginning sizing criteria were uncertain. Therefore experience gained from pulverized coal fired units was applied with caution. For expected difficult fly ashes the ESPs were built with large SCA margins. The data from plant F in figure 2 show that the actual ESP size was much too large. Not until the SCA was reduced to less than 50 % by switching off bus sections any appreciable emission above 1 mg/m^3 NTP was measured. Looking at results from plant G the same trend could be seen but on a slightly higher level at high SCAs. At plant H only measurements at high SCAs could be performed. We are led to believe that also this plant gives a constant emission at high SCAs like plants F and G. When we apply standard ESP theory on the results from plant F at low SCAs we expect results better than 1 mg/m^3 NTP at high SCAs. Our conclusion is that the constant emission, higher than expected at high SCAs, is due to sneakage.

Possibly rapping loss is part of the answer. The small but clear differences at large SCAs between the three plants can then be interpreted as differences in gas flow and rapping adjustments.

Clearly these small emissions may be aggravated by differences in gas distribution, reentrainment from high gas velocities, dust discharge arrangement, etc. Extremely low emissions can be achieved with proper attention to such "boundary" effects. Not only expert knowledge of the ESP technology is required but also intimate insight in the firing process.

Fig. 2.

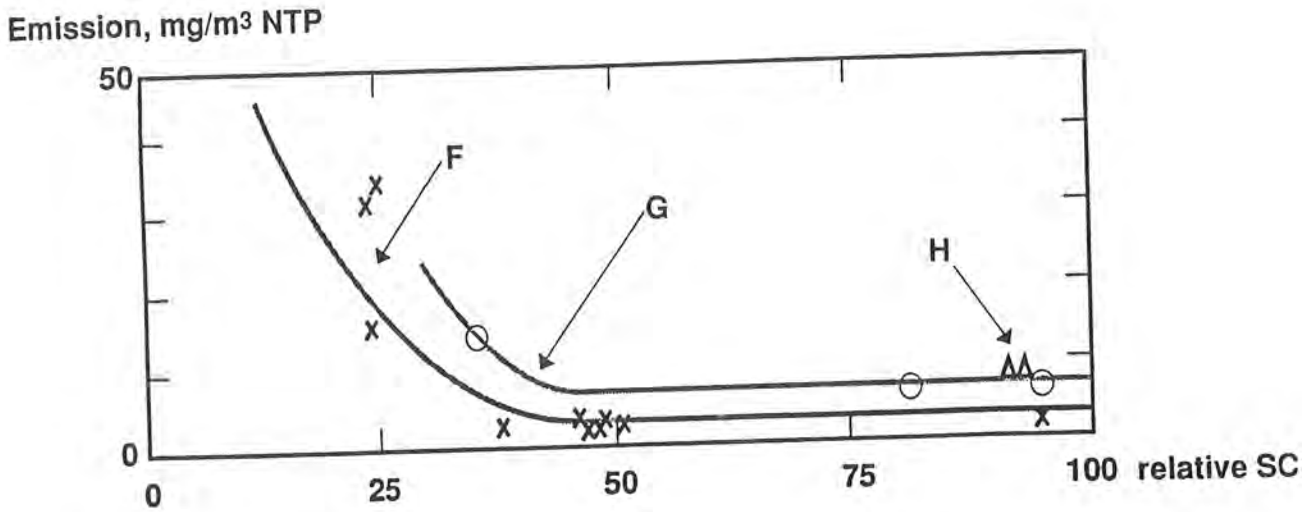

Fig. 2. Achieved emissions from ESPs after Circulating Fluidized Bed Combustion. Coal firing.

CFBC's are often used for biomass fuel such as wood, waste and peat. Figure 3 illustrates measurements from various plants. Among the low emissions there are quite a few with high content of unburnt. With low gas velocities there is no significant emission.

Fig. 3.

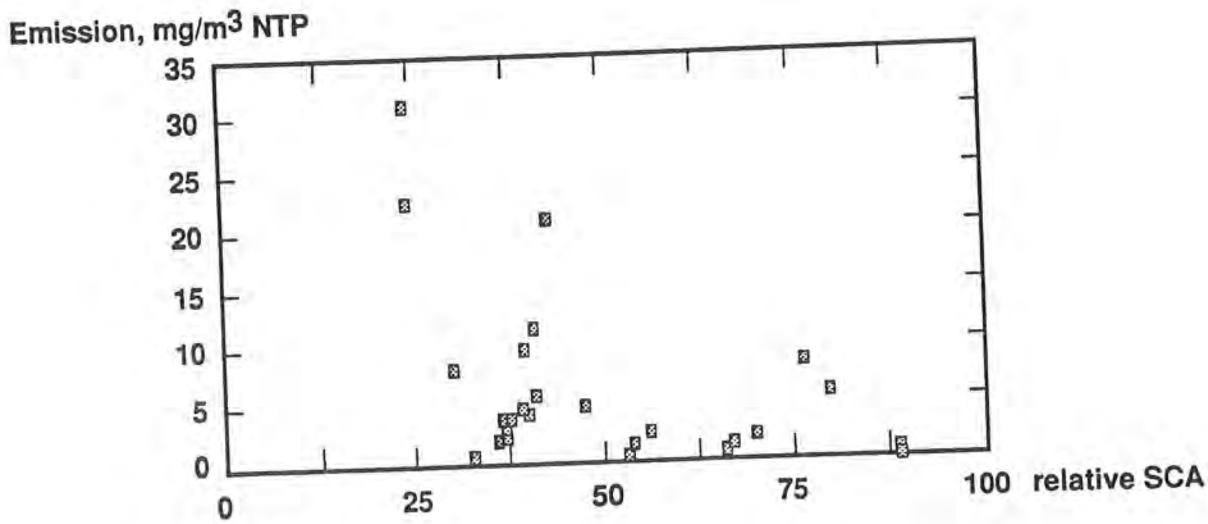

Fig. 3. Achieved emissions from ESPs after Circulating Fluidized Bed Combustion. Biomass fuel.

Soda Recovery Boilers

Can submicron particles be precipitated efficiently? Test results from a US plant where ESPs are installed after the soda recovery boiler show emissions consistently below 6 mg/m^3 NTP. The plant has two moderately sized 3-field ESPs (SCA around 90 $m^2/m^3/s$ at test conditions). Operating temperatures are around 160°C and inlet dust load is in the neighbourhood of 15 g/m^3 NTP. The average particle size is around 0.3 - 0.5 μm and there are hardly any particles above 1 μm. High current densities are obtained in all fields.

The achieved emissions correspond to collecting efficiencies of 99.95 + % and the practical limitation is rather sneakage and rapping losses.

The design of an ESP for this application is critical from many viewpoints. An example is shown in figure 4. The nature of the dust makes it prone to reentrainment at high gas velocities. The spread of results at high velocities is higher than for most other applications.

Fig. 4.

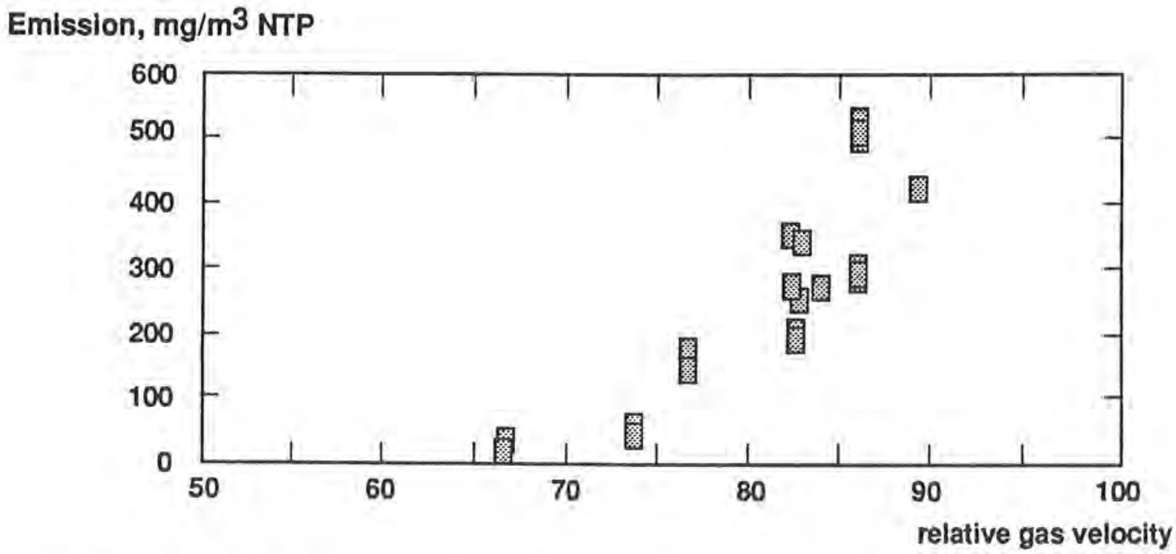

Fig. 4. Example of the increase in emission in an ESP after a soda recovery boiler as a function of gas velocity.

Clinker Cooler

The dust from the clinker coolers in cement plants is normally considered as high resistivity dust and therefore ESPs should according to some, not be used. In most cases the dust is easily collected, however, and this is illustrated in Table 2 where results from five coolers in Korea are shown. In this context it is interesting to see the effect of Semipulse -- blocking of half waves of the mains (1, 2) -- in order to achieve an intermittent corona current. The emission results with and without Semipulse are the same within normal operational spread. These low emissions were maintained while a big power saving could be recorded. The kW figures represent the total power consumed by the T/R-sets. Thus, low emissions do not necessarily imply high power usage.

Table 2.

Emissions and T/R power consumptions after clinker cooler ESPs.

ESP		Without pulsing		With Semipulse	
No.	Inlet conc. g/m³ NTP	Emission mg/m³ NTP	T/R-power kW	Emission mg/m³ NTP	T/R-power kW
1	1.6	9	45	15	8.5
2	3.5	4	77	1 - 7	11 - 18
3	7.2	5	130	< 3	22
4	7.1	8	136	2 - 5	22 - 74
5	21.4	11	171	15 - 20	22 - 60

Oil-fired Boiler

ESPs after oil-fired boilers are not mandatory all over the world. The reason is the low ash content in the oil resulting in dust loads less than 100 mg/m³ NTP. However due to toxic constituents in the oil emission regulations have been enforced in many countries. In Japan, Taiwan, Italy and Sweden, for example, ESPs have been used to a great extent. Table 3 shows results obtained in a Japanese plant before and after extension of the ESPs. Originally two parallel ESPs were installed giving emissions around 10 - 20 mg/m³ NTP. The customer requested new guarantees of 3 mg/m³ NTP. The adopted solution was a new third casing in parallel with the previous ones and with "off flow rapping" applied. This means that when the last bus section in a casing is being rapped that casing is isolated so that no gas enters. In this way there are virtually no rapping puffs. However the elimination of this part of the emission is off-set by a higher "base"-emission from the other two casings due to higher gas velocities. Therefore the average emission is not necessarily reduced compared to standard rapping procedures. A proper evaluation of the merits of off flow rapping and knowledge of the rapping losses are imperative to achieve the desired low emissions. The outlet emission given in the table, < 1 mg/m³ NTP, is the average of several individual measurements.

Table 3.

Emission before and after extension of the ESP after an oil-fired boiler.

No. of casings	SCA $m^2/m^3/s$	Emission mg/m^3 NTP	
2	41	10 - 20	normal rapping
3	136	0.1	off flow rapping
3	78	0.2	"-
3	66	0.4	"-
3	54	0.4 - 0.8	"-

Wet ESPs (WESPs)

For some applications the obvious choice is the WESP. The insensitivity to high resistivities and absence of reentrainment makes it excellent for achieving low emission in the 1 mg/m^3 NTP range. A good example of fine particulate collection is after paint booth applications. Overspray of paint is first efficiently collected by a venturi. Recirculation of air makes it necessary to remove all paint particles. WESPs have been applied and are in operation since several years. Table 4 shows results from two different plants, where the emission guarantees were 0.37 and 0.5 mg/m^3 NTP respectively. Each plant has been tested under three different conditions - varying type of paint, mist concentration and SCAs. Note, that guarantees down to 0.37 mg/m^3 NTP have been met. The WESPs are installed to protect a downstream "police filter", e.g. an active carbon filter, before the air is re-injected into the spray booth.

Table 4.

WESP emissions after paint booth applications.

	Emission, mg/m^3 NTP	
Case	Design	Measured
1	0.37	0.17
2	0.37	0.06
3	0.37	0.05
4	0.50	0.19
5	0.50	0.12
6	0.50	0.07

Others

In a recent paper, (3), it has been demonstrated that emission of a few mg/m^3 NTP can be achieved after spray dryers in spite of fear of reentrainment due to low resistivities of the dust. However, the high moisture content in the flue gas gives sufficient cohesiveness in the dust layer to avoid any serious reentrainment. Another interesting application is waste incineration. In a great number of ESPs emission levels below 5 mg/m^3 NTP have been observed. A closer investigation shows that also here a prerequisite for steady low emission is a low gas velocity.

Discussion and conclusions

Low emissions from ESPs have been demonstrated in a great number of cases. The experience gained through the years can focus on a number of parameters which have to be taken care of to secure future success. The following is a summary of the factors which have been discussed in this paper.

- sneakage - must be kept to a minimum for low emission applications.
- gas velocity - low velocities will avoid reentrainment.
- conditioning - may correct the resistivity and may generate the right cohesiveness of the particles.
- off flow rapping - will eliminate rapping puffs and losses.
- in all applications where a wet dust discharge is acceptable the WESP is the natural choice to achieve extremely low emissions.

As shown by all the examples there are a number of applications where ESPs can compete with FFs in terms of low emissions. Future standards can be met. Whether the ultimate choice is an ESP or FF must be based on economical evaluations where investment, operating and maintenance costs as well as availability is taken into consideration.

References

1. K. Porle, S. Maartmann, M-O. Bergström and K. Bradburn. "Modern Electrode Geometries and Voltage Waveforms Minimize the Required SCAs". Eight Symposium on the Transfer and Utilization of Particulate Control Technology, San Diego, California, March 1990.

2. K. Porle. "on Back Corona in Precipitators and Suppressing it Using Different Energization Methods". Third International Conference on Electrostatic Precipitators, Albano, Italy, October 1987.

3. K. Porle, L. Lindau, K. Bradburn and H. Wheeler. "ESP Operation Following Spray Dryers with Low Resistivity Particulates". Ninth EPRI Particulate Control Symposium, Williamsburg, Virginia, October 1991.