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Analysis Of Fly Ash Resistivity Impact In Electrostatic Precipitator Performance

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Abstract: Fly ash particles, which are produced from coal fired thermal power stations in the form of suspension in the flue gas from combustion units, contribute to an increased suspended particulate matter (SPM) in surrounding environment. To reduce emission levels of SPM, various devices, such as cyclone separator, bag filter and/or electrostatic precipitator (ESP) are employed. On the other hand, ESP is most popularly used at thermal power stations to reduce SPM levels. Fundamental principle of operation of an ESP is that flue gas is forced to pass through an electrical field, wherein SPM get electrically charged. Charged particles are then deflected across the field and collected on a grounded plate. ESP process involves i) Charging of particles flowing between electrodes; ii) Migration and collection of particles on oppositely charged plates; iii) Dislodging particles off the plates and into hoppers; and (iv) Removal of material from hoppers. Frequency and intensity of rapping is important, for it is necessary to minimize rapping re-entrainment and maximize collection efficiency. Rapping should facilitate dislodgement of deposited particulate media from collector surface in an agglomerated form, large enough to fall through the gas flow into receiving hoppers, rather than exploding the layer from collection surface, which may result in severe particle re-entrainment. Performance of ESPs is affected by the characteristics of coal burnt and the properties of ash procured. Poor performance has been associated with low sulphur coals, but establishing a relationship is strenuous.

This study correlates resistivity with various constituents that affect it and also the effect of resistivity on precipitator performance as resistivity is the first of many parameters used as a guide for precipitator performance and migration velocity quantification.

***Index Terms* -** Electrode charging, Corona, ESP, Particulate Matter, Environment.

I. Introduction

Particulate matter adversely affects human health and the environment. Coal-fired power plants, biomass power plants, waste plants, cement kilns, steel factories, glass kilns, coal gasification structures, and other modes of consumption in the energy industry were identified as the main sources of pollutant emissions. The characteristics of dust, gas temperature, and gas composition differ for each industry (e.g., fly ash particles produced in the power industry, ore particles in the metallurgical industry, and high aluminum/silicon particles in cement plants and glass kilns). Electrostatic precipitators (ESPs) are widely used in collecting fly ash because of their low cost and technical advantages, such as low-pressure drop, stability, and adaptability features. Of the major particulate collection devices deployed today in industries, Electrostatic precipitators (ESPs) are one of the more frequently used. They can handle large gas volumes with a wide range of inlet temperatures, pressures, dust volumes, and acid gas conditions. They can collect a wide range of particle sizes, and they can collect particles in dry and wet states. For many industries applications, the collection efficiency can go as high as 99%.

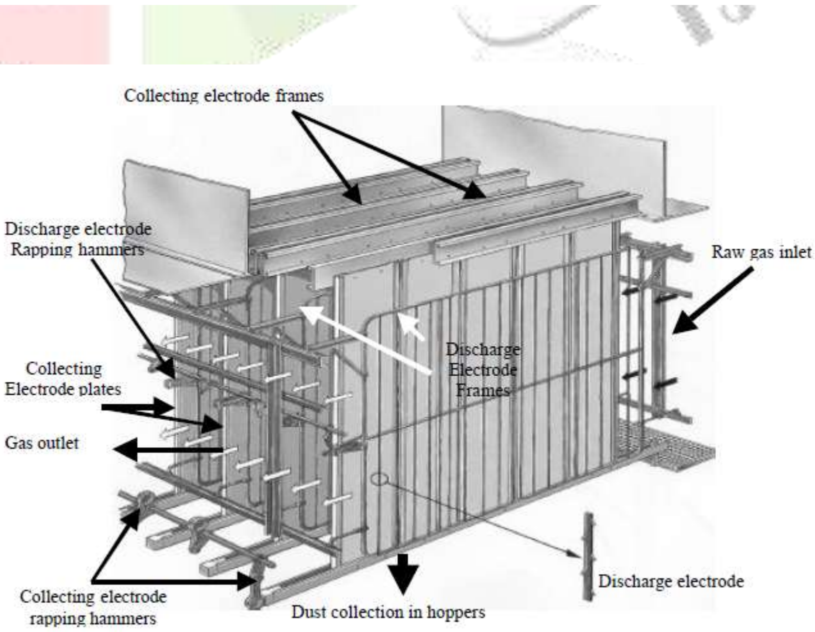
Fly ash resistivity is an important parameter in ESP design and operation. Particle migration, as well as anti-corona and dust removal on collecting plates, affects fly ash resistivity. Accordingly, these factors considerably affect ESP efficiency in principle and practical use. To achieve the required collection efficiency of fly ash and to avoid major capital investment, a better understanding of the mechanisms involved in the collection process and the effect of operating conditions of the ESP is crucial. Research on electrostatic precipitation, to date, has addressed many different areas but more effort is needed in improving understanding of dust collection efficiency, particularly when dealing with high-carbon or high-resistivity fly ash.

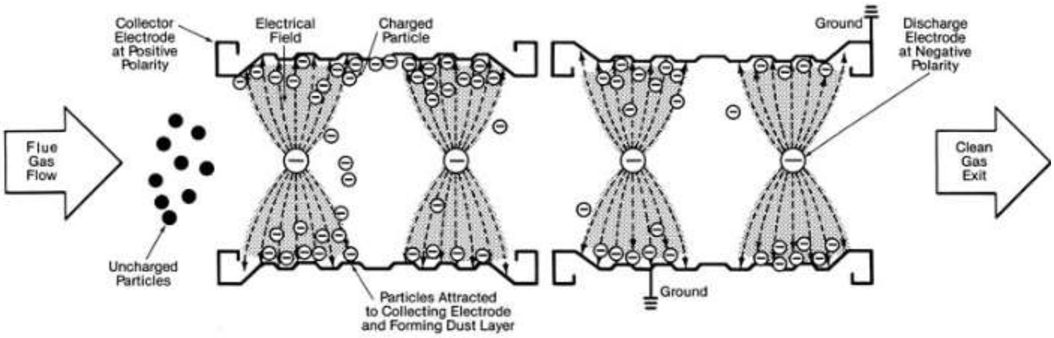
WORKING PRINCIPLE OF AN ESP:

A dry electrostatic precipitator (ESP) electrically charges the ash particles and imparts a strong electric field in the flue gas to collect and remove them. An ESP is comprised of a series of parallel, vertical metallic plates (collecting electrodes) forming lanes through which the flue gas passes. Centred between the collecting electrodes are discharge electrodes which provide the particle charging and electric field. This figure shows a plan view of a typical ESP section which indicates the process arrangement. A transformer-rectifier (T-R) set along with an automatic voltage controller (AVC) supply the high-voltage and unidirectional current to the discharge electrodes. Several T-R sets are normally required to power a precipitator. The collecting electrodes are typically electrically grounded and connected to the positive polarity of the high-voltage power supply. The discharge electrodes are suspended in the flue gas stream and are connected to the output (negative polarity) of a high-voltage power source. An electric field is established between the discharge and collecting electrodes, and the discharge electrodes will exhibit an active glow, or corona. As the flue gas passes through the electric field, the particulate takes on a negative charge.

The negatively charged particles are attracted toward the grounded collecting electrodes and migrate across the gas flow. Some particles are difficult to charge, requiring a longer residence time. Other particles are charged easily and driven toward the plates, but also may lose the charge easily after contacting the grounded CE, requiring recharging and recollection. Resistivity is an inverse measure of a particle’s ability to accept and hold a charge. Lower resistivity indicates improved ability to accept a charge and be collected in an ESP.

Gas velocity between the plates is also an important factor in the collection process since lower velocities permit more time for the charged particles to move to the CEs and reduce the likelihood of migrating back into the gas stream (re-entrainment). A series of CE and DE sections is generally necessary to achieve overall particulate collection requirements. The ash particles form an ash layer as they accumulate on the collection plates. The particles remain on the collection surface due to the forces from the electric field as well as the cohesive forces between particles. These forces also tend to make the individual particles agglomerate, or cling together.





WHERE RESISTIVITY PLAYS ITS ROLE:

Resistivity a key factor in the efficient and stable operation of electrostatic precipitators. Previous studies have shown that the most suitable range in measuring fly ash resistivity is at $10^4 - 5 \times 10^{10}$ ohm-cm. However, for low resistivity (i.e., below 10^4 ohm-cm), serious back mixing is common; for high fly ash resistivity (i.e., above 10^{11} ohm-cm), back corona and secondary blowing of fly ash occurs. Fly ash resistivity can also be affected by temperature and humidity of gases, chemical composition of ashes, and the sulphur content of burning coal. The main components of the fly ash generally were Fe (0.8–5.0%), K + Na + Li (0.3–5.1%), Ca + Mg (0.5–4.0%), and Al + Si (10–34%), respectively. Fe, K, and Na were highly sensitive to fly ash resistivity. Resistivity decreased with the increase in Fe, K, Na, and Li contents; by contrast, resistivity increased with Ca and Mg contents. The effects of Si and Al on fly ash resistivity were weak. Resistivity initially increased first and then decreased with the increase in temperature. The resistivity diagrams generated specifically for this study suggest that typical fly ash samples from different industries can be estimated using chemical composition and temperature data. The resistivity diagrams generated specifically for this paper suggest that typical fly ash samples from different industries can be estimated using chemical composition and temperature data.

Electrical resistivity of ash deposited on collector electrodes shall lies within the appropriate range of values usually 104-1010 ohm-cm. However, for uniform gas flow across ESP, good velocity inside ESP and proper power supply to maintain adequate current density, there are certain other conditions to be met. If resistivity of collected fly ash is too low, only a small voltage drop will occur across dust layer, resulting in low electrical holding force of dust layer and this causing re-entrainment loss. On the other hand, if resistivity of dust layer is too high, either of the following phenomenon’s may happen: i) Resistance through collected layer of ash will lower corona current that can be produced with the normal operating voltage and as a consequence, electric field ingas stream and resulting migration velocity of negatively charged fly ash particles towards collector electrodes will be markedly reduced; and ii) Resistance through collected layer of ash may be sufficient to cause electrical breakdown with formation of positive gaseous ions viz. back-corona or reverse ionization. Higher resistivity, therefore, leads to poor performance of ESPs, and back corona can cause also re-entrainment by local layer explosion. Fly ash electrical resistivity is determined by surface and volume conduction mechanisms; the former being prominent at low temperatures while the latter dominates at high temperatures. Surface conductivity is dependent on interaction between flue gas and ash particles. During this interaction, electrical conduction on the surface of ash particles is produced due to the movement of ions in molecular coatings on particles.

RESISTIVITY DIAGRAM FROM ESTABLISHED MODELS

An ash resistivity models developed by a reputed firm under research grant, developed various functions and predicted models. The ultimate analysis of coal originated from South Africa for a thermal power plant, SO3 conversion, flue gas temperature range likely will operate are basic data besides the ash sampling results. The constituents like K, Al, Si influence resistivity are part of the model analysis. It is imperative that electrical resistivity methods measure the ability of electrical current to flow through the subsurface. In the presented diagram the analysis of coal and ash analysis samples are as below.

% by Weight	As received Ultimate Coal Analysis
C	63.85
H2	2.70
O2	7.65
N2	1.35
S	0.45
H2O	10.00
ASH	14.00
SUM	100.00

Table 1: Ultimate Analysis of Coal

% by Weight	Ash Components
Li2O	0.00
Na2O	0.47
K2O	0.47
MgO	1.50
CaO	7.51
Fe2O3	4.13
Al2O3	29.39
SiO2	49.48
TiO2	1.78
P2O5	1.03
SO3	4.23
Sum	100.00

Table 2: Fly ash sample test results

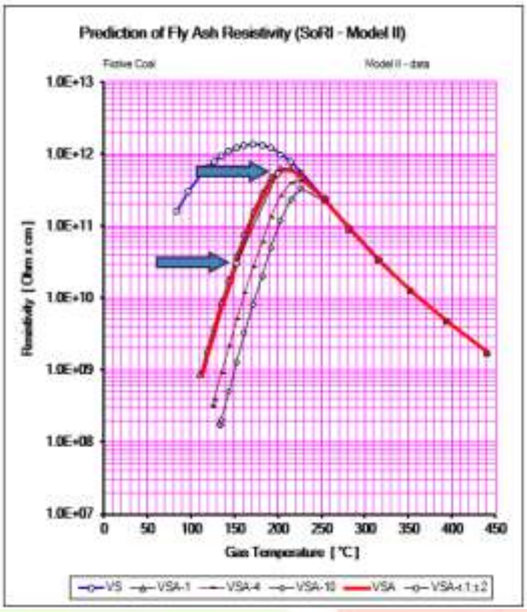


Table 3: Predictive model of Fly Ash Resistivity, Gas Temperature Vs Resistivity (ohm-cm)

From the calculations, the acid dew point temperature is 112 Deg C (at SO3 1.17 PPMv) and at gas temperature range from 153 Deg C to 200 Deg C the ash Resistivity derived as 3.11x 1010 to 5.411x 1011 ohm-cm. The inference from this diagram is that the ash resistivity range is as predicted between this these temperatures hence the operation of ESP. This resistivity range which is increasing with increase in temperature reflects the ESP operation to limit the temperature for ionization performance. Had the temperature further increased that the resistivity though would decrease but the re-entrainment of ash into stream will be observed that deteriorates collection efficiency. The deposition of the ash on collecting plates and unable to dislodge during rapping creates a lot of resistivity and underperform the ESP. Images showing here are from an ESP with spring type discharge electrode and 400 gas passages collecting electrodes

Images: During Internals inspection of an ESP with upstream scrubbing system using Bicar as reagent.

CONCLUSION:

Resistivity is the first of many parameters used as a guide for ESP performance and migration velocity quantification. The factors that influence electrical resistivity are coal, sulphur, flue gas moisture, flue gas temperature, and ash chemistry etc. Methods have been developed to overcome poor performance of ESPs due to high resistivity by introducing Pulse Energisation and adopting Flue Gas Conditioning technique. Of late, the former technique is being predominantly used, considering low investment and low maintenance compared to gas conditioning technique.

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