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Overview of The Advantages of Using Electrostatic Precipitators (ESP) and Filter-Bag Dust Collectors for Air Pollution Control

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ABSTRACT

The role of cement industry is more that increases CO2, particulate matter considerably. In the control of pollution, the Electro Static Precipitator and air filter play a major role. Especially, now that environmental pollution is becoming more and more serious. Nowadays, based on the current situation, the targeted and applicability of the Electro Static Precipitator and air filter material are the future direction of development; Low resistance and high efficient air filter material are the focus of our future research. In addition, the development of eco-friendly filter material which solved the pollution of itself, making filter material into a completely environmentally friendly product. A study of current-voltage characteristics (CVC) of an Electrostatic Precipitator (ESP) for the protection of the environment was carried out. Electrostatic Precipitator is an air pollution control device used to separate solid particulate matter from a contaminated air stream. The Benue Cement Company (BCC) PLC at Gboko was used as a case study to ascertain the need of ESPs in cement producing industries. The ESP under study is comprised of three electrostatic fields as seen in table 2 which represent the currents (mA) and their corresponding voltages. Using figs. 2, 3 and 4 of the CVC test, the average distribution of current in the electric fields gave a mean regression line of 0.976; which satisfies the requirement that the equipment has been built to handle the job of flue gas cleaning effectively for overall particulate collection efficiency. It is interesting to note that the environment under study during factory production was found to be free from these harmful air pollutants while the ESP was operating. However, the incessant complaints launched by the inhabitants of the area against the industry on pollution of the neighborhood immediately ceased following the installation of the ESP.

Keywords: Environment, Electrostatic Precipitator, Gravity, Settlers, Centrifugal Separators, Filter Bag-Dust Collector, Current-Voltage Characteristic Test

Aims Research Journal Reference Format:
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1. INTRODUCTION

Cement production, in any country, plays a major role in the growth of the nation. The cement industry in its various processes emits Suspended Particulate Matter (SPM) and oxides of nitrogen besides carbon dioxide, which is produced during calcinations process. Particulate matter is the main pollutant emitted from cement industries Srujan shivaram.M (2014). Most cement plants have made considerable efforts in controlling the stack emissions using most efficient control systems like bag filter and ESP, and these plants generally meet the environmental regulations for stack emissions. Sources of particulate matter can be man-made or natural. They have impacts on climate and precipitation that adversely affect human health. The size of the particle is a main factor, affect the respiratory tract when inhaled. Larger particles are generally filtered in the nose and throat via cilia and mucus, can settle in the bronchi and lungs and cause health problems. Because of their small size, particles on the order of ~10 micrometers or less (PM10) can penetrate the deepest part of the lungs such as the bronchioles or alveoli.

The major health effects caused by the particulate matters are lung cancer, cardiovascular disease, respiratory diseases, premature delivery, birth defects, and premature death. It has been suggested that particulate matter can cause similar brain damage as that found in Alzheimer patients. The particulate matter emission also results in reduced visibility. Particular matter can also cause severe climatic changes Abhishek P S, Dr. P N Ramachandran (2015).
Particulate matter is one of the industrial air pollution problems which militate against our environment, and therefore needs to be controlled with every effort. This emission problem is not particular to a few industries, but pervasive across a wide variety of industries. Many industrialized nations have enacted laws to restrict the emission of these particulate matters to a certain limit, thus the use of various control devices are in use both internationally and locally to protect the environment (Beachler, Joseph and Peterson, 1983). Electrostatic precipitator is topping (in terms of efficiency which is 99% and above) amongst the various dust controlling devices, besides it has the capabilities of handling high volume/hot flue gases unlike bag house and other control devices.

2. REVIEW OF LITERATURE

2.1 Bag House

Bag house uses filtration to separate dust particulates from dusty gases. They are one of the most efficient and cost effective types of dust collectors available and can achieve a collection efficiency of more than 99% for very fine particulates. Dust-laden gases enter the bag house and pass through fabric bags that act as filters. The bags can be of woven or felted cotton, synthetic, or glass fibre material in either a tube or envelope shape. To ensure the filter bags have a long usage life they are commonly coated with a filter enhancer, that is precoat. This not only traps fine particulates but also provides protection for the bag itself from moisture, and oily or sticky particulates which can bind the filter media C.S.Rao (1991).

Without a pre-coat the filter bag allows fine particulates to bleed through the bag filter system, especially during start-up, as the bag can only do part of the filtration leaving the finer parts to the filter enhancer dust cake. A. Working of Pulse Jet Bag House This type of bag house cleaning (also known as pressure-jet cleaning) is the most common. A high pressure blast of air is used to remove dust from the bag. The blast enters the top of the bag tube, temporarily ceasing the flow of dirty air. The shock of air causes a wave of expansion to travel down the fabric C.S.Rao (1991). The flexing of the bag shatters and discharges the dust cake. The dust collection observed on the fabric was done by the following four mechanisms: Inertial collection, Interception action, Brownian movement of particles and electrostatic forces.

All these actions result in formation of the dust cake on the filter medium. The air burst is about 0.1 second and it takes about 0.5 seconds for the shock wave to travel down the length of the bag. Due to its rapid release, the blast of air does not interfere with contaminated gas flow.

Electrostatic Precipitator (ESP) is an air pollution control device used to separate solid particulate matter from a contaminated air stream (Nag, 2001). Gravity settlers and centrifugal separators are devices that cannot function effectively in an industrial operation for particles below 0.5mm in diameter. External forces greater than gravity or centrifugal forces should be used for this range (Hall, 1975). ESP uses electrostatic force to drive particles to the wall of collecting electrodes. It imparts electrostatic charges and then puts them in an electrostatic field that drives them to a collecting plate. That is, the principle of dust collection with electrostatic precipitators is based on the utilization of the effect of gas ionization in strong electric field, which is formed by discharge electrodes and by collecting electrodes with a sufficiently high electrical voltage between the two electrodes. The discharge electrodes begin to emit electrons, resulting in charging the gas molecules surrounding the electrodes in the ESP.

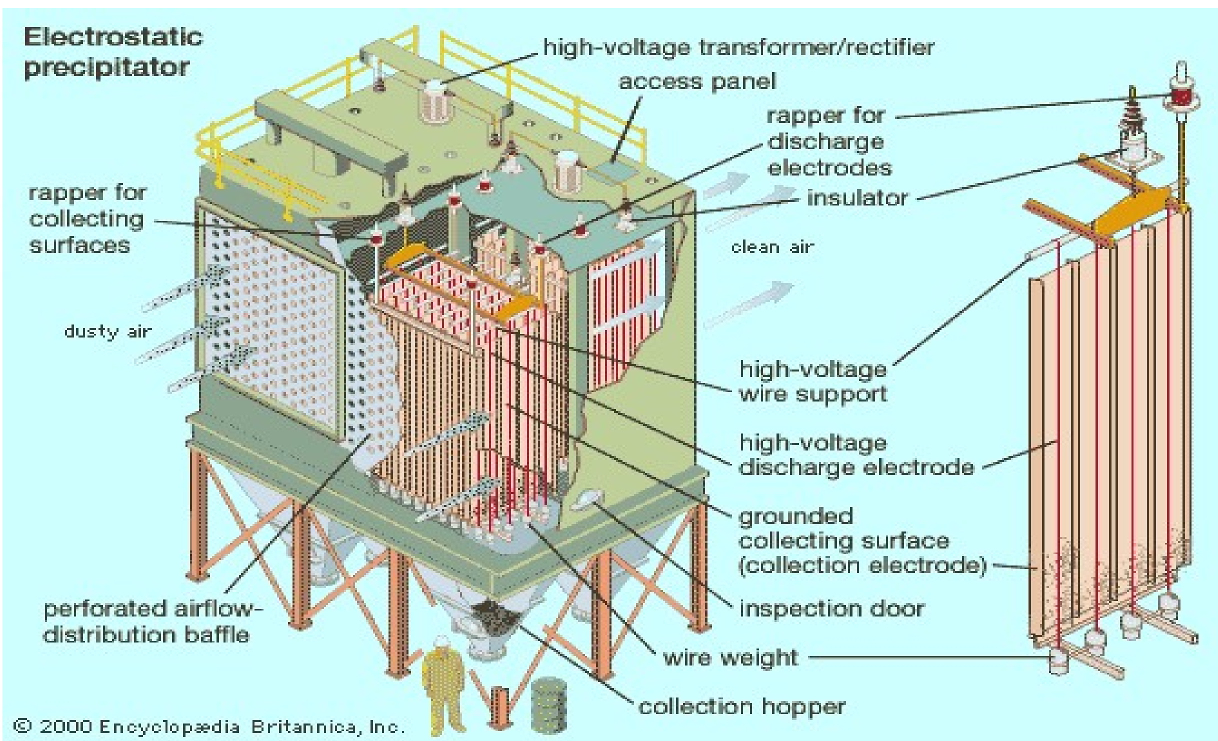

Fig 1: Schematic Diagram of ElectroStatic Precipitator (source:Encyclopaedia Britainnica, 2000).

The negative ions now migrate to the grounded positive or collecting electrode. If the gas is dust-laden, the negative ions impose their charges onto the dust particles. The negatively charged dusts are attracted by the positive electrodes, being here precipitated and neutralized.

By rapping or vibrating, the collected dust is removed from the collecting electrode, dropping into a dust bin (hopper). However, a small part of the dust particle will also be charged positively and precipitated on the discharge electrode; therefore, for proper cleaning the discharge electrode must also be rapped.bThere are three major unit variables in the operation of electrostatic precipitator; these variables are the factors that are dependent on the optimum performance of the Electrostatic Precipitators.

These variables are;

1 System Variable: system variables of the ESP are the parameters which depend on the design of the ESP. these parameters include types of materials used in the construction of discharge and collection electrodes, the power and rating of the rectified- transformer (RT), aspect ratio (AR) of the ESP, Sectionilization of the electric field, specific collection area(SCA) and so on.

2 Material Variables: these include the constituent's parameters of the flue gas handled by the ESP. In any cement industry, the material is the cement dust mixed with combustion products (clinker dust). So, the parameters in this case are the density of the flue gas, the texture of the dust and humidity of the dust (Mastropietro and Dhargalker, 1991).

3 Operating variables: these include the parameters which are associated with the operation of the system. These parameters can be affected positively or negatively by the skills and attitude of the operators of the ESP. They include: corona power, flue gas temperature, induced drought fan power and differential pressure of the system (Osuchukwu, 2010).

2.2 Resistivity

Resistivity which is a characteristic of a particle in an electric field is a measure of a particle's resistance to transferring charge (both accepting and giving up charges). Resistivity is a function of a particle's chemical compositions as well as flue gas operating conditions, such as temperature and moisture. Particles can have high, moderate (normal) or low resistivity (Kart, 1976). In an ESP, where a particle charging and discharging are key functions, resistivity is an important factor that significantly affects collecting efficiency. While resistivity is an important phenomenon in the inter-electrode region where most particle charging takes place, it has a particularly important effect on the dust layer which is at the collection electrode where discharging occurs (US, E.P.A. 1985).

Particles that exhibit high electrical resistivity are more difficult to charge. But once charged, they do not readily give up their acquired charges on arrival at the collection electrode. On the other hand, particles with low resistivity easily become charged and readily release their charges to the ground collection plate. Both extremes in resistivity impede the efficient functioning of the ESP (White, 1982). Electrostatic precipitators work best under normal electrical resistivity conditions. Resistivity is the electrical resistance of a dust sample, 1.0cm^2 in cross sectional area, 1.0cm thick and is recorded in ohms-centimeter. Table 1 gives value ranges for low, normal and high resistivity

Table 1: Low, Normal and High Resistivity

RESISTIVITY	Low, Normal and High Resistivity
Low	Between 10^4 and 10^7 ohm.cm
Normal	Between 10^7 and 10^{10} ohm.cm
High	Between 10^{10} and 10^{14} ohm.cm

Source: US EPA, (1985).

2.3 Dust Layer Resistivity

A potential electric field (voltage drop) is formed across the dust layer as negatively charged particles arrive at the dust layer surface and leak their electrical metal surface of the electrically grounded collection plate, voltage is zero. Whereas at the outer surface of the layer, where new particles and ions are arriving, the electrostatic voltage caused by the ions can be quite high. The strength of this electric field depends on the resistivity and thickness of the dust layer. In high resistivity dust layers, the dust is not sufficiently conductive, so electrical charges have difficulty, moving through the dust layer (Copper and Alley, 1994). Consequently, electrical charges accumulate on and beneath the dust surface, creating a strong electric field. Voltage can be greater than 10,000 volts. Dust particles with high resistivity are held too strongly to the plate making them difficult to remove and causing rapping problem. In low resistivity the dust layers, the corona current is readily passed to the grounded electrode.

Therefore, a relatively weak electric field, of several thousand volts is maintained across the dust layer collected. Particles with low resistivity do not adhere strongly enough to the collection plate. They are easily dislodged and become re-entrained in the gas stream. ESP performs best in normal resistivity. Particles with normal resistivity do not rapidly lose their charge on arrival at the collection plate. These particles slowly leak their charge to the grounded plate and are retained on the collection plates by intermolecular adhesive and cohesive forces. This allows a particulate layer to be built up and then dislodged from the plates by rapping. Within the range of normal dust resistivity, fly ash is collected more easily than dust having low or high resistivity.

3. MATERIALS & METHOD

3.1 Materials

The materials and equipment used to generate data for the current voltage characteristic examination of the electrostatic precipitator in order to ascertain the degree of performance and functionality of ESP in the job of flue gas cleaning are as follows:

(a) High voltage rectified transformer
(b) Barometer
(c) Thermometer
(d) Existing ESP
(e) Voltmeter
(f) Ammeter.

3.2 Method

This test was carried out by subjecting the ESP to an idle running mode. Idle mode of the ESP is when the system is energized by the high voltage rectified transformer without a dust laden air stream. The transformer rectifier type of this ESP was RICO-W3X80KV/115A/600 mA. The experiment was carried out under 32^0 C temperature and barometric pressure of 741 bars. The collection area of the ESP under study was $2223m^2$. Then the vicinity of the ESP was barricaded to prevent people from getting near to the equipment in order to forestall electrocution. At the electrical panel (comprised mostly of the materials mentioned before this section) situated at the central control room, minimum and maximum voltages were keyed in starting from 37 volts and 40 volts respectively. This in effect, gave rise to the corresponding current in milli-amperes and the average voltage in the ESP. This was applied in ascending order of magnitude until a substantial data that could describe the behavior of current against voltage in the ESP was obtained.

4. RESULTS

The results of the current voltage characteristic test conducted for the three fields of the electrostatic precipitator to determine the current density of the equipment are presented in tables 2. The CVC curves with model regression equation (y = mx + c) for the three fields are shown in figs. 2, 3 and 4.

Table 2: The current voltage characteristic test to determine the current density of the ESP equipment

ESP Field 1				ESP Field 2				ESP Field 3			
Collection Area of ESP = $2223M^2$				Collection Area of ESP = $2223M^2$				Collection Area of ESP = $2223M^2$			
Current(mA)	Average Voltage(V1	Min Voltage(v1	v1m ax	mA	v2a vg	v2m in	v2m ax	ma	v3a vg	v3m in	V3m ax
20	38.5	37	40	20	37.	36.5	39	20	38.	37.5	40
30	39.5	38	41	30	39	37.5	40.5	30	40	38.5	41.5
45	41	39	43.5	45	40.	38.5	43	45	41.	39.5	44
65	43	40.5	46.5	65	42.	40	45.5	65	43.	40.5	46.5
90	44.5	41	48.5	90	44	40.5	47.5	90	45	41.5	49
155	48.5	42.5	54.5	15	47.	42	53	15	48.	43	54.5
220	51.5	44	59.5	22	50.	43.5	58.5	22	51.	44	59.5
290	54.5	45.5	64	29	53.	45	62.5	29	54	45	64
445	60	49.5	72	44	59	48.5	70.5	44	59.	48.5	71.5
460	61	50	72.5	44	59.	49.5	71	47	61	50	73

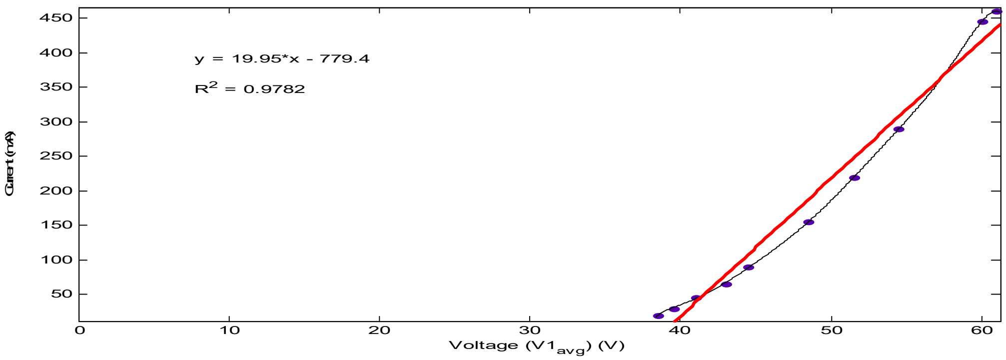

Fig. 2: current –voltage characteristic test of ESP field 1.

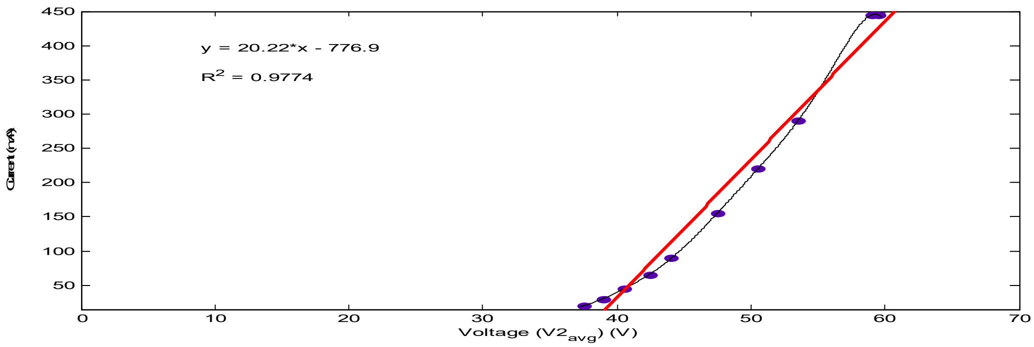

Fig. 3: current –voltage characteristic (CVC) test of ESP field 2

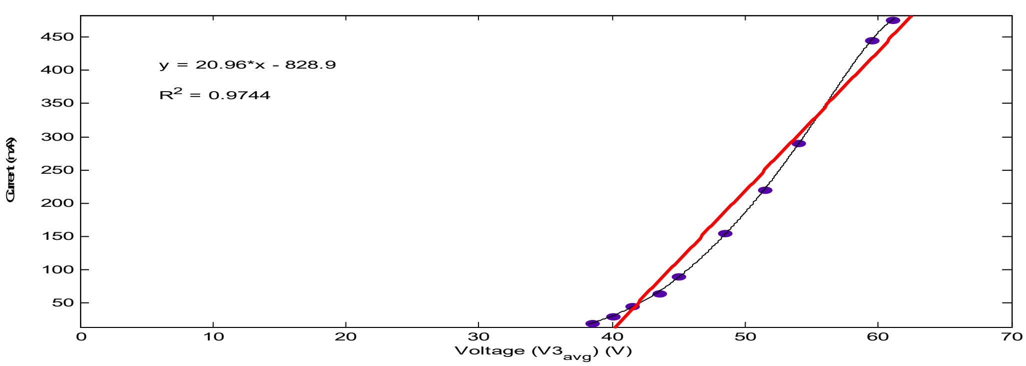

Fig. 4: current –voltage characteristic (CVC) test of ESP field 3.

5. DISCUSSION

Table 2 contains three fields, each with a minimum voltage, maximum voltage, average voltage and their corresponding currents in (mA). Each field has a graph of current against voltage to show the movement of current in the entire area of the electric field. The CVC for ESP field 1, 2 and 3 are shown in figs. 2, 3 and 4. Looking critically at the three graphs, one observes that the regression line (line of best fit) of 0.978, 0.977 and 0.974 respectively are close to unity depicting a gentle slope through the threshold voltage (40V). While the average distribution of current in the electric field of the ESP gave the mean regression line of 0.976 which confirms that the ESP equipment has been built to efficiently handle the job of flue gas cleaning, recovery of otherwise wasted raw materials, general conservation of energy in the ESP UNIT and indeed the sole responsibility for the protection of our dear environment.

6. CONCLUSION

The use of CVC test has confirmed that the ESP is an important machine to be employed for air pollution control. This is seen in the mean regression value of the three sections of the ESP which stood at 0.976. This value is an indication that the ESP functioned optimally. Very important is the environmental protection it offers by cleaning contaminated gas stream. Basically, the reaction of the inhabitants of the area where the industry is sited proved the effectiveness of the use of an ESP for particulate matter air pollution control. Before the installation of the ESP, there were continuous agitations and protests launched by the inhabitants of the area against the management of the industry on account of the uncontrolled emission of hazardous dust particles in the area. However, the installation of the ESP at the cement production plant changed the situation. The protesters immediately stopped their agitation and peace was restored since the recurring air pollution problems were reduced to the barest minimum. Hence, the effectiveness of the ESP under the CVC test satisfies the objectives for which the research was conducted.

While in an Investigation of Dust Adsorbing Ability of Bag Filter using Nano Technology carried out by Aravind Kumar B, Dr Jeyasubramanian K, and Senthil Murugan S (2017) from the Department of Mechanical Engineering, Mepco Schlenk Engineering College, Sivakasi, India. The found out that Natural fibres like jute and coconut coir fabric filters were successfully designed and fabricated. The modern process of cement production generates a huge quantity of gases and particulates. An increasing filter area causes the decrease in air to cloth ratio even when the rate of airflow remains same. The air permeability of natural fibres such as jute and coconut coir was efficient as like in synthetic fibres. The Nanocoated jute has the higher bursting strength and tensile strength comparatively than coconut coir. The acid/alkali environments are affected the uncoated and Nanocoated natural fibres. The efficiency of Nanocoated jute fibre is higher than coconut coir.One of the main advantage of using natural fibres as a filtering medium is that it can be easily decomposed but the decomposition is difficult in the case of synthetic fibre.

7. RECOMMENDATIONS

What follows are a number of reccomendations based on findings from the research;

a. Decreasing the actual gas flow in ESP will have a positive effect on the dust collection. The reduction of the intake air leakage and motor-control-system (frequency converters) of fans will allow for a better control of the gas flow.
b. Installation of spare carbon monoxide (CO) analyzer: when the CO analyzer is taken out for maintenance, ESP should be switched off to prevent explosion which can occur due to high concentration of CO.
c. Production of clinker should be done in such a manner that high quality clinker is obtained which in essence reduces the moisture content in the flue gas. This moisture content which is related to electrical conductivity of cement particles affects the efficiency of the ESP.
d. Always make sure the high voltage energization system is operating properly.

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