Experimental Study on Impact of Ammonia Dosing on the Resistivity of Fly Ash

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Abstract

Performance of Electrostatic precipitators (ESP) depends on the characteristics of the coal used and the fly ash generated. Fly ash resistivity is one of the vital parameters which significantly influence the performance and hence the sizing of ESP. Indian coal is generally characterized with high ash content and high ash resistivity. High resistivity of fly ash results in reduced ESP efficiency and thus forces for an over sized ESP. So it is of prime importance to reduce the ash resistivity to enhance ESP efficiency. Also, knowledge of ash resistivity is required at design stage for sizing of the ESP. In this paper we are discussing our experimental study on ash resistivity measurement, influence of ammonia conditioning on ash resistivity and optimum ammonia conditioning using resistivity measuring equipment with ash samples collected from various Indian power plants.

Introduction

The electrostatic precipitation process encompasses number of disciplines including electrostatics, coal and ash chemistry, fluid dynamics, aerosol technology, and high voltage electrical design. Many parameters influence the performance of the precipitator viz. gas flow, gas temperature, inlet dust concentration, gas composition, dust composition, gas moisture content, electrical property such as ash resistivity, voltage waveform and the precipitator mechanical design features like geometry of discharge electrode, collecting electrode, electrode spacing and rapping mechanism. However, ash resistivity is one of the vital parameters which significantly influence the performance and hence the sizing of ESP.

The electrical resistivity of the fly ash depends on the chemical composition of the coal used. Indian coals are characterised with high ash content and low sulphur and low sodium content. Ash resistivity of Indian coals are typically at a very higher range of 10^{11} to 10^{14} Ωcm. Efficiency of the ESP is influenced by the electrical resistivity of dust layer on collecting plate in the following ways: (1) high electrical resistivity of the dust limits the corona current flowing and thus limits particle charging and electric field magnitude. (2) the adhesive forces of the dust particles on the collecting electrodes increases as the value of resistivity increase. So more rapping force is required to dislodge the dust from collecting plate. This will result in large re-entrainment of the dust. (3) for high resistive dust, electrical breakdown of gases in the interstitial spaces of dust layer can occur at very low current densities. This can result in either a spark propagating to emitting electrode or a steady state breakdown usually referred as back-corona in ESP parlance. So, understanding and controlling of ash resistivity is of utmost importance in improving ESP efficiency.

The conduction of corona current or charges through the dust layer is mainly by two mechanisms namely – surface conduction and volume conduction. The surface conduction process depends upon the chemical composition of the ash, the flue gas temperature, gas moisture and the sulphur trioxide present in the flue gas. In volume conduction, transfer of electric charge takes place through the bulk of the dust materials by means of electron carriers within the materials. This depends upon the thermal excitation of the electrons in the molecular structure of the materials. Typically, in power plants, inlet gas temperature to ESP is around 150 ^{0}C, and hence surface conduction is prevalent. **FIG -1** shows the effect of surface and volume conduction on resistivity of fly ash**.** The electrical resistivity of fly ash particle layer varies with temperature and it is on an upward trend up to a temperature and beyond that, the resistivity drops. The threshold temperature at which the transition takes place depends mainly on the moisture content. The initial increase in resistivity is attributable to reduction in surface conduction and is a function of gas composition, the surface area of the particles and moisture**.** The threshold value varies with precipitator application. All the power plant precipitators in India are working in the range of temperature close to the threshold value.

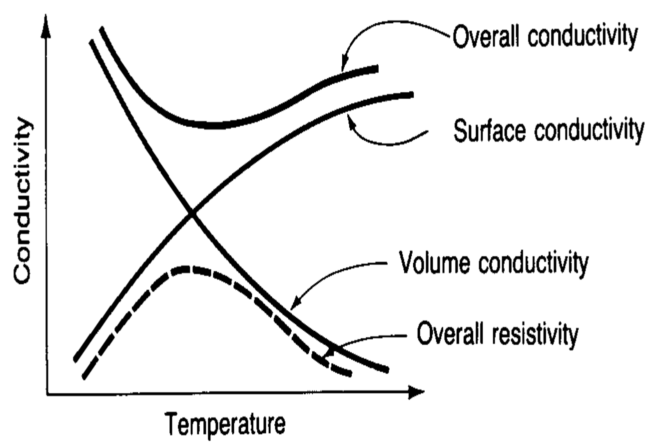

FIG -1

Some of the practical means of overcoming problems of high resistivity fly ash in ESPs are (1) using hot zone ESP (ESP before air preheater), (2) intermittent charging, (3) adding chemical agents to the flue gas. Injecting conditioning agents of SO_3 or NH_3 or SO_3 +NH_3 modify the fly ash properties such as resistivity, agglomeration and cohesivity. Spraying of water into flue gas can increase the surface conductivity of the ash.

In our experiment we are using ammonia (NH_3) as the additive. We intend to study the effect of ammonia on resistivity of fly ash and ultimately on the collection efficiency of ESP. We also intend to find out the optimum dosing amount.

Experimental Setup

Our experimental setup is a special resistivity measurement apparatus with provision for ammonia injection at ppm level. It consists of conditioning chamber (1), an air pump (2), boiler (3), oil tank (5) and ammonia injection system (6) as shown in Fig.2. The air pump is connected to the system through rotameter and the air flow rate can be monitored. Boiler is filled with de-mineralized water and 500W heater is used to heat the water and steam generated flows into the conditioning chamber. Circulation inside the chamber is maintained by a recirculation fan. Air temperature inside the conditioning chamber is measured.

Resistivity Cell: The resistivity cell consists of parallel plate electrode. The bottom electrode is made of stainless steel and a thin layer of carbon is pressed into a shallow recess in the steel covering the active area dust layer. The top electrode is a disc made of porous carbon. The fly ash sample to be tested will be placed in the bottom electrode. Two sets of resistivity cell are placed in the test rack. The test rack is kept in the conditioning chamber. Picoammeter(4) is used for measuring the current which is connected to the electrode.

Dew point control system: The dew point temperature in the resistivity measurement system is controlled using an oil bath & a photoelectric sensor. The temperature of the oil in the oil bath is maintained using the heating coil & temperature control system.

A small outlet tube is at the end of the conditioning chamber through which the steam from the conditioning chamber passes out and impinges on the reflective surface. If the chamber has taken enough moisture, the steam impinges on the reflective surface produces water vapors and steam generator is switched-off thereby controlling the moisture content in the system. By controlling the dew point temperature, the percentage of moisture in the chamber is controlled.

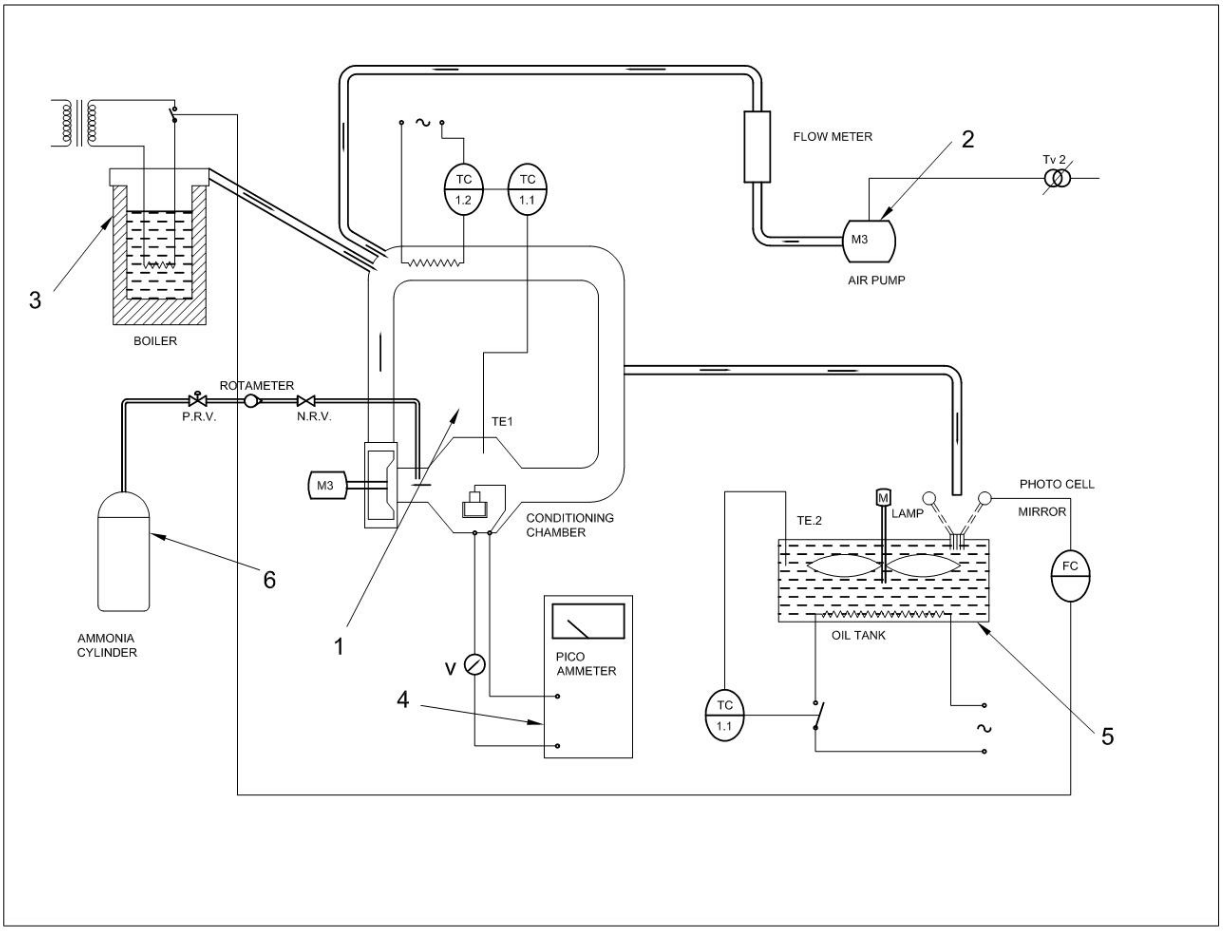

Fig.2. Schematic of Resistivity Measurement Equipment with ammonia conditioning system

Principle of operation

The resistivity cell rack is placed in the conditioning chamber and connected to the picoammeter. The control panel consists of temperature & humidity control system which will control the air heater, and boiler heater respectively along with the DC power supply. The recirculation fan motor and RTD sensor for oil bath are also connected to the control panel. The sensor is controlled by the relays in the main control panel. Air flow rate inside the equipment during the operation is 4L/min. Steam produced in the steam boiler will flow into the conditioning chamber, where the dew point is maintained at 40 ^{o}C (set value in the control panel). The indicator in the control panel is used to adjust the frequency values of the emitting light density, depending upon our required interval of cut off when there is steam impinging on the reflective surface. A small amount of air from conditioning chamber is taken by a pipe line which leads to a reflecting surface on the oil bath which is maintained at 40 ^{o}C. As the air impinges on the surface and if the dew point is equal to the surface temperature, the steam will condense. This is sensed by a photocell arrangement and the steam generator will be put off. The flow of air is affected by the air pump which pumps the required amount of air to affect air flow through the pipe line. The temperature at which the resistivity value to be measured is set in the control panel.

Injection of Ammonia in the resistivity measurement system and analysis

NH_3 cylinder contains 1% ammonia in nitrogen. Gas pressure regulator is used to regulate the NH_3 pressure and it is maintained at 1psi. The flow rate for NH_3 gas is controlled by a rotameter. Then the gas is allowed to pass through the non-return valve. By this method ammonia gas is injected into the conditioning chamber. Air flow rate inside the equipment during the operation is controlled through another rotameter. Ammonia gas flow and air flow is controlled such that to maintain injection from few ppm to few tens of ppm of ammonia.

Testing procedure

The fly ash sample is filled in the resistivity cell and above which top electrode is placed and the cell rack is placed inside the conditioning chamber. The air pump and recirculation fans are started. The temperature and dew point temperature controls in the control panel are switched on. The temperature of the conditioning chamber is set at 60°C and Dew point temperature at the outlet point is set at required level in the control panel. When the set temperature and Dew point temperature level is reached, the D.C. voltage supply is applied across the resistivity cell and the current is measured using the Picoammeter. The resistivity of the samples were calculated**.** The procedure was continued for range of values temperatures from 60°C to 240°C. The entire procedure is repeated for testing the same sample with ammonia injection with required ppm level. The resistivity of the fly ash samples with ammonia injection are calculated for all temperature values.

Analysis & Results

The fly ash samples from Vijayawada, North Chennai, Badarpur, Jamnagar, Ukai, Kothagudem Chandrapur, Santaldih & Mejia were collected. Each fly ash sample was tested from 60°C till 240°C with required dew point temperature without ammonia dosing. Based on the current measured, the resistivity is calculated. Graphs are plotted as Temperature (^{o}C) versus Resistivity (Ω-cm). Same procedure was followed for all ten fly ash. The fly ash samples were also tested with ammonia injection in the resistivity measurement equipment between the temperatures (60°C - 240°C). Dew point temperature was maintained at required temperature. Measurements were made on ascending mode & descending mode of temperatures with a constant flow of ammonia gas into the conditioning chamber. The following observations are made:

(i) Significant changes in the resistivity were observed during ascending mode and descending mode when the tests were carried out with ammonia injection compared to the samples tested without ammonia injection.

(ii) The reduction in the resistivity of the fly ash samples tested is more prominent in the temperature range 120°C - 180°C.

(iii) The difference in resistivity without ammonia dosing and with ammonia dosing conditions is less during higher temperatures.

Sl No.	Temp in° C	Voltage in V	Current in Cup A(in A)	Current in Cup B(in A)	Resistvity in cup A	Resistvity in cup B
1	60	486.2	1.73E-04	3.40E-05	1.41E+08	7.15E+08
2	90	485.9	2.20E-07	1.90E-07	1.10E+11	1.28E+11
3	120	488.5	2.09E-08	3.00E-08	1.17E+12	8.14E+11
4	150	487.6	5.40E-09	2.38E-08	4.51E+12	1.02E+12
5	180	489.2	2.50E-10	8.00E-11	9.78E+13	3.06E+14
6	210	487.2	3.10E-08	2.70E-08	7.86E+11	9.02E+11
7	240	489.9	1.03E-07	6.20E-08	2.38E+11	3.95E+11

Tab.1.Badarpur sample tested without Ammonia

Sl No.	Temp in ° C	Voltage in V	Current in Cup A(in A)	Current in Cup B(in A)	Resistivity in cup A	Resistivity in cup B
1	60	488.1	3.32E-04	4.21E-04	7.35E+07	5.79E+07
2	90	487.3	2.10E-05	2.60E-05	1.16E+09	9.37E+08
3	120	490.3	3.48E-06	2.56E-06	7.04E+09	9.57E+09
4	150	488.1	4.50E-07	5.90E-07	5.42E+10	4.13E+10
5	180	488.8	9.50E-08	1.01E-07	2.57E+11	2.41E+11
6	210	490.5	1.26E-07	1.42E-07	1.94E+11	1.72E+11
7	240	489.6	1.72E-07	1.61E-07	1.42E+11	1.52E+11

Tab2.Badarpur sample tested with Ammonia

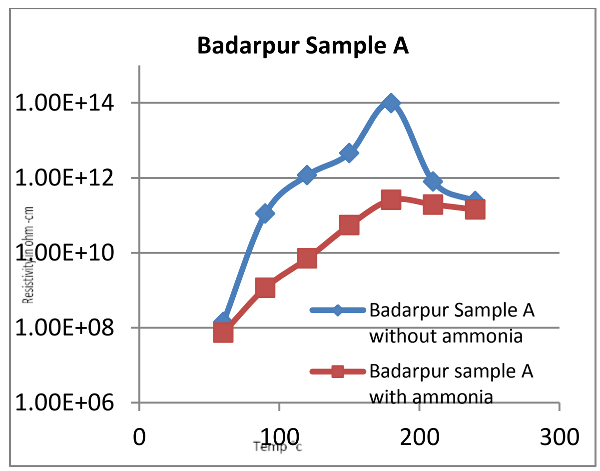

Fig.3 Temperature vs Resistivity plot of Badarpur

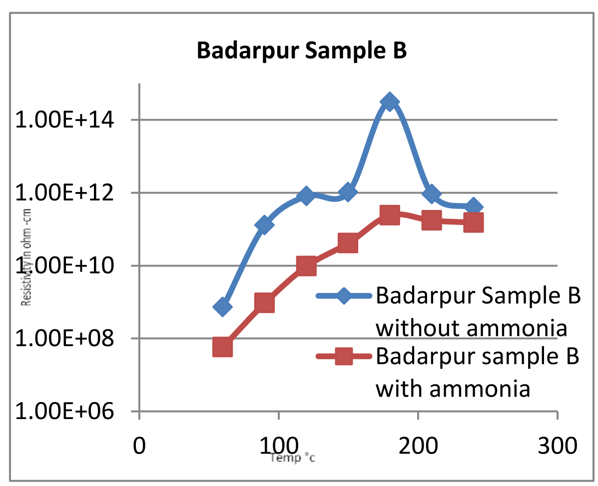

Fig.4 Temp. vs Resistivity plot of Badarpur

Conclusion

Ten fly ash samples have been tested without ammonia injection and with ammonia injection. It was observed that there is a considerable reduction in the resistivity of fly ash in the temperature range between 120^oC and 180^oC. It was also observed that the resistivity has not shown any further reduction beyond critical amount of ammonia dosage.

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