

Lecture 5

Particulate emission control by electrostatic precipitation

ELECTROSTATIC PRECIPITATORS

The electrostatic precipitator is one of the most widely used collection devices for particulates. An electrostatic precipitator (ESP) is a particulate collection device that removes particles from a flowing gaseous stream (such as air) using the force of an induced electrostatic charge.

ESP can be operated at high temperature and pressures, and its power requirement is low. For these reasons the electrostatic precipitation is often the preferred method of collection where high efficiency is required with small particles.

ESP are highly efficient filtration devices that minimally impede the flow of gases through the device, and can easily remove fine particulate matter such as dust and smoke from the air stream [1].

In the electrostatic precipitation process the basic force which acts to separate the particles from the gas is electrostatic attraction. The particles are given an electrical charge by forcing them to pass through a corona, a region in which gaseous ions flow. The electrical field that forces the charged particles to the walls comes from electrodes maintained at high voltage in the center of the flow lane [2].

Control of emissions from the industrial sources has served the threefold purpose of

1. Recovery of the for economic reason
2. Removal of abrasive dusts to reduce wear of fan component
3. Removal of objectionable matter from gases being discharged into the atmosphere

APPLICATION OF ELECTROSTATIC PRECIPITATORS:

- Pulp and paper mills, Non-ferrous metal industry, Chemical industry, Public buildings and areas
- Cement recovery furnace, steel plant for cleaning Blast furnace gas.
- Removing tars from coke oven, sulphuric acid (Pyrite raw material) , phosphoric acid plant
- Petroleum industry for recovery of catalyst, carbon black, thermal power plant.

Table 2.5.1. Advantages and Disadvantages of ESP.

Advantages	Disadvantages
High collection efficiency.	High initial cost.
Low maintenance and operating costs.	More space requirement.
Handles large volume of high temperature gas.	Possible explosion hazards.
Negligible treatment time.	Production of poisonous gas.
Easy cleaning.	

REQUIREMENT OF ELECTROSTATIC PRECIPITATION PROCESS

- Source of high voltage
- Discharge and collecting electrode
- Inlet and outlet for gas
- A means for disposal of collected material
- Cleaning system, Outer casing.

STEPS IN ELECTROSTATIC PRECIPITATION

- Generation of Electric field high voltage Direct current 20-80kv.
- Generation of electric charges
- Transfer of electric charge to a dust particle.
- Movement of the charge dust particle in an electric field to the collection electrodes.
- Adhesion of the charge dust particle to the surface of the collection electrode.
- Dislodging of dust layer from collection electrode
- Collection of dust layer in a hopper
- Removal of the dust from the hopper.

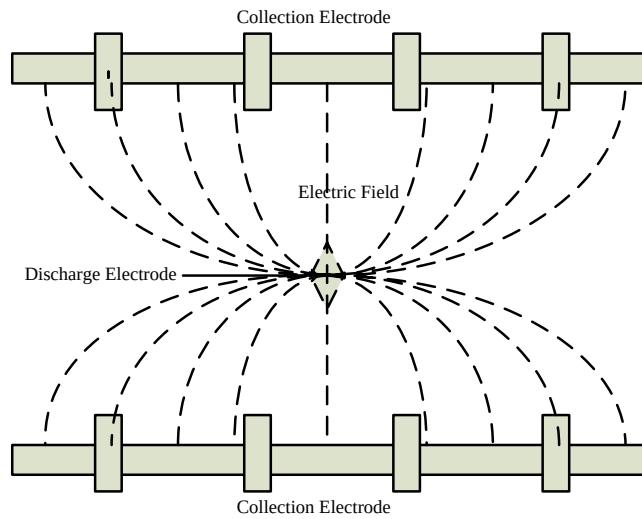


Fig: Electrical Field Generation

Figure 2.5.1. Electrical field generation

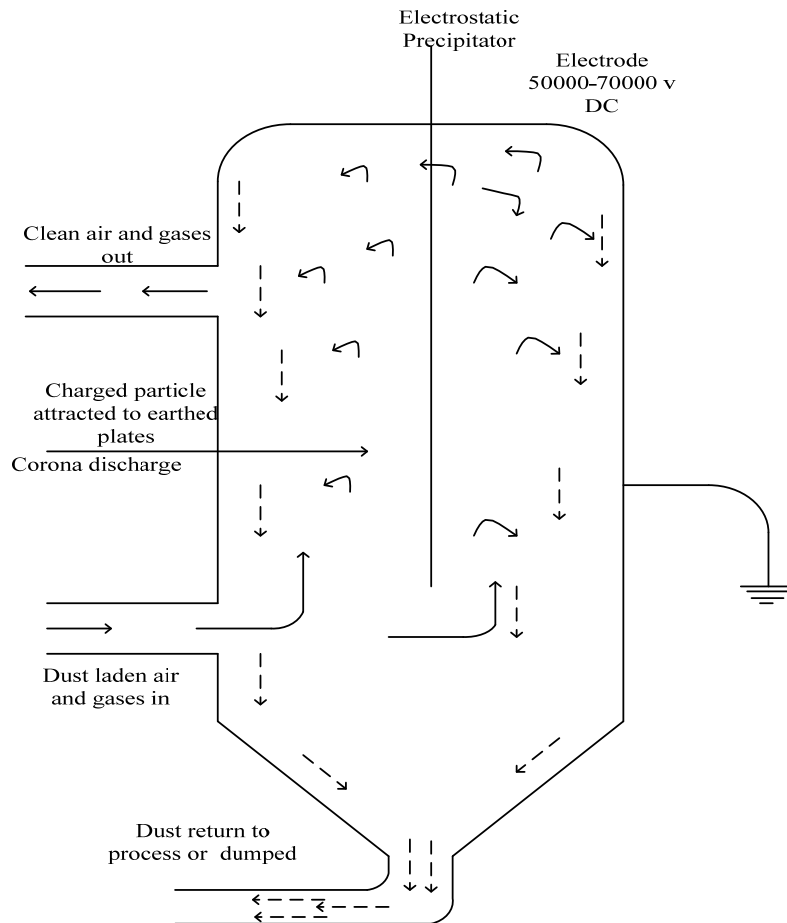


Figure 2.5.2. Movement of dust and air in ESP

PRINCIPLE OF ESP

Principle of ESP has four distinct phases as follows:

(I) Ionization or corona generation: When the potential difference between the wire and electrode increases, a voltage is reached where an electrical breakdown of the gas occurs near the wire. This electrical break down or ion discharge is known as corona formation and thereby gas is transformed from insulating to conducting state.

Two types of corona discharge can be generated which are:

(a) Negative corona: In negative corona, discharge electrode is of negative polarity and the process of electron generation occurs at narrow region

(b) Positive corona: When positive voltage is applied to discharge electrodes in the same way as negative corona, large number of free electron and positive ions are generated. Or large number of positive ions produced move towards collecting electrode and thus transfer charge to dust particles upon collision.

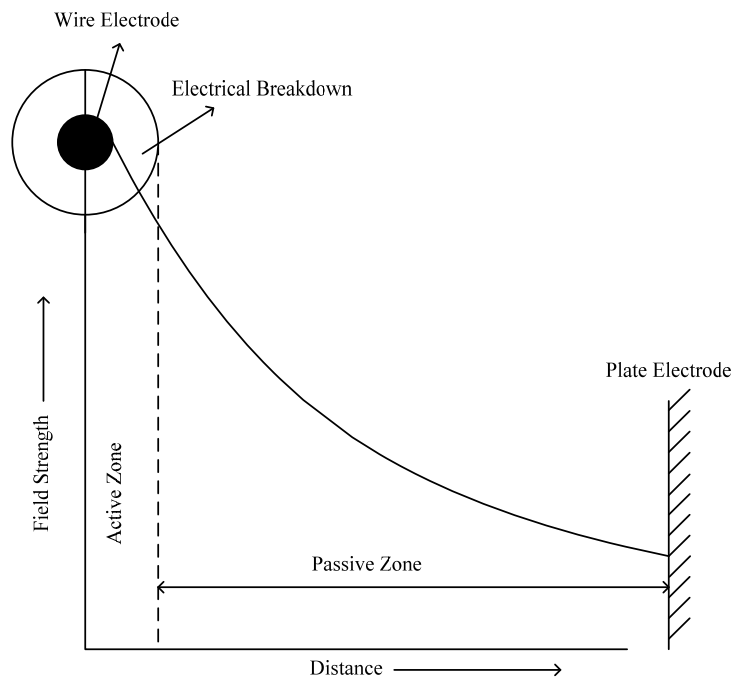


Figure 2.5.3. Variation of field strength between wire and plate electrodes

Negative coronas are more commonly used in industrial application, while for cleaning air in inhabited space positive coronas are used. Due to ozone generation in negative corona its application for air cleaning in inhabited area is avoided.

(II) Charging of Particles: Particle charging takes place in region between the boundary of corona glow and the collection electrode, where particles are subjected to the rain of negative ions from the corona process. Mainly two mechanisms are responsible for particle charging. Each mechanism becomes significant according to particle size ranges. For particles having diameter greater than $1\mu\text{m}$, field charging is dominant force; and for particle size less than $0.2\mu\text{m}$ diffusion charging predominates.

(III) Migration and precipitation of particle:

(IV) Removal of deposited dust: Once collected, particle can be removed by coalescing and draining, in the case of liquid aerosols and by periodic impact or rapping, in case of solid material. In case of solid material, a sufficiently thick layer of dust must be collected so that it falls into the hopper or bin in coherent masses to prevent excessive re-entrainment of the material into the gas system [2].

TYPES OF ELECTROSTATIC PRECIPITATORS

ESPs are configured in several ways. Some of these configurations have been developed for special control action, and others have evolved for economic reasons.

[A] SINGLE STAGE PRECIPITATORS

Plate-Wire Precipitators

- In a plate-wire ESP, gas flows between parallel plates of sheet metal and high-voltage electrodes.
- These electrodes are long wires weighted and hanging between the plates or are supported there by mast-like structures (rigid frames).
- Within each flow path, gas flow must pass each wire in sequence as flows through the unit.
- Plate-wire ESPs are used in a wide variety of industrial applications, including coal-fired boilers, cement kilns, solid waste incinerators, paper mill recovery boilers, petroleum refining catalytic cracking units, sinter plants, basic oxygen furnaces, open hearth furnaces, electric arc furnaces, coke oven batteries, and glass furnaces [2, 3].

Flat Plate Precipitators

- A significant number of smaller precipitators [100,000 to 200,000 actual cubic feet per minute (acfm)] use flat plates instead of wires for the high-voltage electrodes.
- A flat plate ESP operates with little or no corona current flowing through the collected dust, except directly under the corona needles or wires [3].
- Flat plate ESPs seem to have wide application for high-resistivity particles with small (1 to 2 μm) mass median diameters
- Fly ash has been successfully collected with this type of ESP, but low-flow velocity appears to be critical for avoiding high rapping losses.

Tubular Precipitators

- The original ESPs were tubular like the smokestacks they were placed on, with the high-voltage electrode running along the axis of the tube.
- Tubular precipitators have typical applications in sulfuric acid plants, coke oven by-product gas cleaning (tar removal), and, recently, iron and steel sinter plants [2].

Wet Precipitators

- Any of the precipitator configurations discussed above may be operated with wet walls instead of dry.
- The water flow may be applied intermittently or continuously to wash the collected particles into a sump for disposal.
- The advantage of the wet wall precipitator is that it has no problems with rapping re-entrainment or with back coronas.
- The disadvantage is the increased complexity of the wash and the fact that the collected slurry must be handled more carefully than a dry product, adding to the expense of disposal [4].

TWO-STAGE PRECIPITATORS

- The previously described precipitators are all parallel in nature, i.e., the discharge and collecting electrodes are side by side.
- Two-stage precipitators are considered to be separate and distinct types of devices compared to large, high-gas-volume, single-stage ESPs.

- The two-stage precipitator invented by Penney is a series device with the discharge electrode, or ionizer, preceding the collector electrodes.
- Advantages of this configuration include more time for particle charging, less propensity for back corona, and economical construction for small sizes [3].

OPERATIONAL ISSUES

- Pre-Scrubbing
- Wash-down sprays and wires
- Wet/dry Interface
- Current Suspension
- Sparking
- Mist Elimination

REFERENCES

- [1] De Yuso, A. M., Izquierdo, M. T., Valenciano, R., Rubio, B. Toluene and n-hexane adsorption and recovery behavior on activated carbons derived from almond shell wastes. Fuel Processing Technology, 2013, 110 1–7.
- [2] Theodore, L. ‘Electrostatic Precipitators’ in “Air Pollution Control Equipment Calculations”, Wiley, 2008.
- [3] <http://www.epa.gov/ttn/catc/dir1/cs6ch3.pdf>.
- [4] <http://icespx.com/>