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Removal of Fine Particles in Industrial Emission Through Electrostatic Precipitator

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Abstract: An electrostatic precipitator (ESP) is an air cleaner device that removes fine particles, like dust and smoke, from a flue gas using the force of an induced electrostatic charge minimally impeding the flow of gases through the device. The Electrostatic Precipitator has become known for its efficiency and reliability but there are some advantages and disadvantages. An electrostatic precipitator is a large industrial emission and air pollution control unit.

Keywords: Electrostatic precipitator, Electrodes, Air pollution, Flue gas.

I. INTRODUCTION

Electrostatics precipitator can be designed for high volumetric gas flow rates, variable temperatures and pressures, and variable particulate loading. Precipitators have been placed in a number of locations at different power plants, including downstream of the economizer (hot side), downstream of the air pre heater (cold side), or after a wet scrubber (which requires a wet ESP). With a properly designed electrostatic precipitator, 99% collection efficiency is possible with medium and high ash coals [3].

Dust collection systems play an integral role in ensuring that certain industrial manufacturing processes, such as those conducted at steel and paper mills do not release harmful amounts of industrial dust. To do so, dust collection systems must contain dust or remove it from an air stream. However, dust particles can range in size from barely visible to substantial, solid particles. Because dust can range in both size and form, different dust collector systems can be used alone or in conjunction to prevent the dangerous circulation of dust during a manufacturing process.

Collectors such as inert separators, centrifugal collectors, and fabric collectors can be used to eliminate dust from an air stream, while wet scrubbers offer an equally efficient alternative that depends on the introduction of water. Electrostatic precipitators, highly efficient dust collector systems, can function with or without water and are applicable to a wide array of highly dust productive operations. [2]. Precipitators are used in these industries: Power / electric, cement, chemicals, metals, paper mill, etc.

II. INVENTION

The first use of corona discharge to remove particles from an aerosol was by Hohlfeld in 1824. However, it was not commercialized until almost a century later. In 1907 Frederick Gardner Cottrell, a professor of chemistry at the University of California, Berkeley, applied for a patent on a device for charging particles and then collecting them through electrostatic attraction—the first electrostatic precipitator.

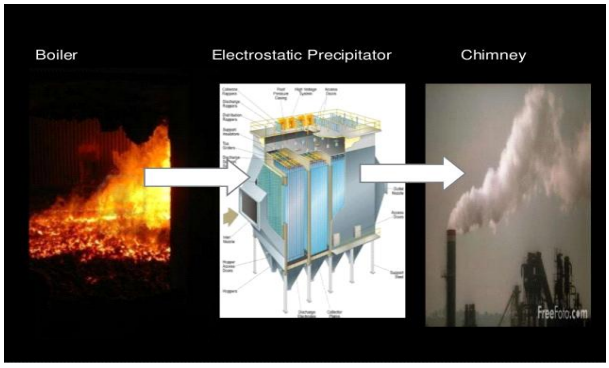

Fig 1.1 Basic introduction

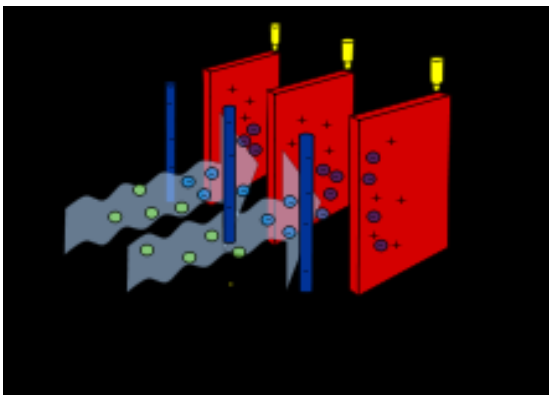

Fig 1.2 Conceptual diagram of an electrostatic precipitator

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Cottrell first applied the device to the collection of sulphuric acid mist and lead oxide fumes emitted from various acid-making and smelting activities. Wine-producing vineyards in northern California were being adversely affected by the lead emissions.

At the time of Cottrell's invention, the theoretical basis for operation was not understood. The operational theory was developed later in Germany, with the work of Walter Deutsch and the formation of the Lurgi Company [1].

III. CONSTRUCTION OF ELECTROSTATICS PRECIPITATOR

In electrostatic precipitator the main components used are electrodes, 440V 50Hz, AC supply, High voltage transformer, Rectifier, Insulators, Hopper, Rappers, and Collecting Plates.

1. Rectifier: Rectifier is used to convert ac supply into dc supply.
2. Transformer: Transformer is used to step up or step down voltage as per design of electrostatic precipitator.
3. Hopper: Hopper is used to store dust particles and ash content coming out from the electrostatic precipitator.
4. Control Cabinet: Control cabinet is used to interconnect the ac supply and transformer through cables.
5. Electrodes: Based on DC current flow terminals electrodes can be divided as below:
6. Discharge electrode: Electrodes wire which carries negatively charged high voltage (between 20 to 80KV) act as discharge or emitting electrodes.
7. Collector electrodes: Electrode plate/wire which carries positively charged high voltage act as collecting electrodes [5].

IV. WORKING

Electrostatic smoke precipitators work by forcing dirty flue gas (the gas escaping from a smokestack) past two electrodes (electrical terminals), which take the form of metal wires, bars, or plates inside a pipe or smokestack. The first electrode is charged to a very high negative voltage. As the dirt particles move past it, they pick up a negative charge. Higher up the pipe (or further along, if it's a horizontal pipe), there's a second electrode consisting of metal plates charged to a high positive voltage.

Since unlike charges attract the negatively charged soot particles are attracted to the positively charged plates and stick there. From time to time, the collecting plates have to be shaken to empty away the soot; that can be done either manually (by someone brushing them clean) or automatically (by some kind of automated shaking or brushing mechanism in a process called rapping) [6].

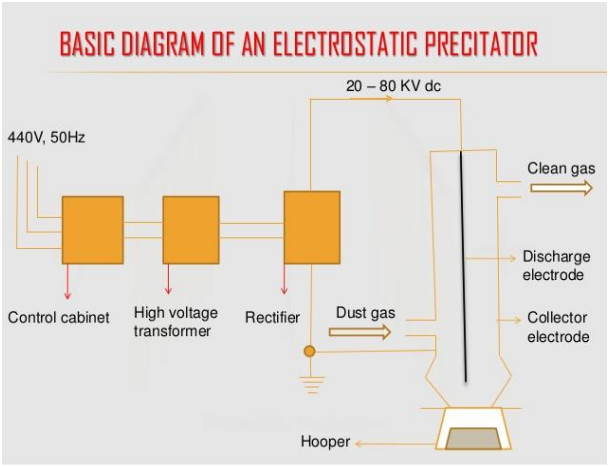

Fig 1.3 Basic diagram of an electrostatic precipitator

V. TYPES OF ELECTROSTATICS PRECIPITATOR

A. Dry type electrostatics precipitator

When the dust is a dry solid, such as dust or fumes, and it is collected on a collecting plate in the dry state, the precipitator is referred to as “dry type”. Dry type Electrostatic precipitator can collect dust over a wide range of exhaust gas temperatures, ranging from room temperature to several hundred degrees C. Also, the collected dust or fumes are dry and easy to handle. The dust or fumes collected on the collecting plate of the dry type electrostatic precipitator is dislodged from the collecting plate and taken out from a hopper. Dust is normally removed from the plate through mechanical vibrations created by rapping the collecting plate. Our moving-electrode system uses a rotating brush to scrape off the collected dust.

B. Fixed-electrode type and moving electrode type

Dry type Electrostatic precipitator can be a fixed-electrode type or a moving-electrode type, depending on the method for removing the collected dust.

In the fixed-electrode type, a collecting plate rapping device is used to remove the dust collected on the collecting plate when the dust has accumulated to a certain thickness. Therefore, a thin dust layer always remains on the collecting plate surface with the fixed-electrode type. Also, when rapping, some of the dust entrains the gas flow and is carried away (rapping re-entrainment).

In our moving-electrode type, the collecting plates are divided into short strip elements that are joined by chains, and the collecting plates are moved slowly. The dust collected on the collecting plate elements is completely scraped off by rotating brushes provided in the hoppers.

The moving-electrode type has the following features.

1. The surface of the collecting plates is clean and there is no back corona. Therefore, fine, high-resistivity dust can be efficiently collected.

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2. The brushes in the hopper scrape off the collected dust, and there is no reduction of performance due to rapping re-entrainment.
3. Because the equipment always has high collection efficiency, it can be made compact.[7]

VI. FACTORS AFFECTING THE PERFORMANCE OF ELECTROSTATICS PRECIPITATOR

A. Dust collection efficiency and electrical resistivity of dust

The dust collection efficiency of Electrostatic precipitator is affected by the electrical resistivity of the dust collected. In the normal resistivity area, the dust collection efficiency is high, so dust collection is stable. Most of the aerosols handled by Electrostatic precipitator are in this electrical resistivity area. Particles in the low-resistivity area lose their charge as soon as they arrive at the collecting plate, so they are re-entrained in the dust collection area, and the dust collection efficiency is greatly reduced. The dust collection efficiency in the high-resistivity area reduces as the electrical resistivity of the dust increases. Also, partial discharge occurs within the dust layer collected on the collecting plates, and as a result flashovers frequently occur, the applied voltage is reduced, and the discharge current is reduced. If the electrical resistivity of the dust is further increased, the discharge current increases abnormally, and the applied voltage is reduced (back corona phenomenon).

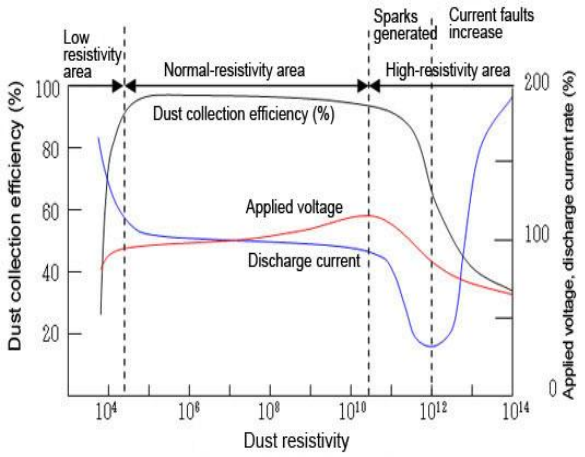

Fig. 1. Resistivity	Fig. 2. Range of measurement
Fig. 3. Low	Fig. 4. below 10^4 ohm-cm
Fig. 5. Normal	Fig. 6. between 10^4 a 10^{10} ohm-cm
Fig. 7. High	Fig. 8. above 2×10^{10} ohm-cm

Fig. 1.4 Relationship between electrical resistivity and dust collection efficiency

The moving-electrode type electrostatic precipitator we developed is suitable for high-performance collection of high-resistivity dust. Therefore, an important factor when planning Electrostatic precipitator is the electrical resistivity of the dust to be collected.

B. Dust collection efficiency and particle size distribution

The dust collection efficiency of Electrostatic precipitator is affected by the particle size of the aerosol (dust, mist) to be collected. The theoretical migration velocity at which a particle diameter of several µm moves towards the collecting plate is almost directly proportional to the particle diameter. When dust collection is performed on an aerosol with different size particles using an electrostatic precipitator, the collection efficiency is high for the large particles, and low for the small particles. To obtain the same dust collection efficiency for an aerosol with small particle size, the electrostatic precipitator must be larger (to increase the treating time it takes for the process gas to pass through) than that of large-size particles. Therefore, the particle size distribution of the aerosol to be collected is an important factor when planning an electrostatic precipitator.

C. Dust collection efficiency and aerosol concentration

The dust collection efficiency of an electrostatic precipitator is greatly affected by the concentration in the gas of the aerosol (dust, mist) to be collected. For the same required value of aerosol concentration at the outlet of the electrostatic precipitator, the higher the aerosol concentration at the inlet, the longer the treatment time of the gas in the electrostatic precipitator, and the larger the device. Also, if the inlet aerosol concentration is high and the content of fine particles smaller than several µm is high, in order to create a charge cloud of charged fine particles between the discharge wires and the collecting plates, the corona discharge from the discharge wires is reduced, also reducing the dust collection efficiency (space charging effect).The aerosol concentration at the electrostatic precipitator inlet and the required outlet concentration are important factors when planning an electrostatic precipitator [7].

VII. ADVANTAGES OF ELECTROSTATICS PRECIPITATOR

1. This is also most effective for high dust loaded gas (as high as 100 grams per cu. Meter)
2. This is more effective to remove very small particles like smoke, mist and fly ash. Its range of dust removal is sufficiently large (0.01 micron to 1.00 micron). The small dust particles below 10 microns cannot be removed with the help of mechanical separators and wet scrubbers cannot be used if sufficient water is now available. Under these circumstances, this type is very effective.

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3. The dust is collected in dry form and can be removed either dry or wet.
4. It provides ease of operation.
5. The draught loss of this system is the least of all forms (1 cm of water) [4].

VIII. DISADVANTAGES OF ELECTROSTATICS PRECIPITATOR

1. The efficiency of the collector is not maintained if the gas velocity exceeds that for which the plant is designed. The dust carried with the gases increases with an increase of gas velocity.
2. Because of closeness of the charged plates and high potential used, it is necessary to protect the entire collector from sparking by providing a fine mesh before the ionizing chamber. This is necessary because even a smallest piece of paper might cause sparking when it would be carried across adjacent plates or wires.
3. The direct current is not available with the modern plants, therefore considerable electrical equipment is necessary to convert low voltage (400 V) A.C to high voltage (60000 V) D.C. This increases the capital cost of the equipment as high as 40 to 60 cents per 1000 kg of rated installed steam generating capacity.
4. The space required is larger than the wet system [4].

IX. CONCLUSION

Electrostatic precipitators have been a reliable technology since the early 1900's. They were originally developed to stop serious smoke and air issues and have definitely helped the environment. Today electrostatic precipitators are found mainly on large power plant, cement plants, incinerators, and various boiler applications.

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BIOGRAPHY

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