3.7 ELECTROSTATIC PRECIPITATORS

This electrical equipment was first introduced by Dr.F.G. Cottel in 1906 and was first economically used in 1937 for removal of dust and ash particles with the exhaust gases of thermal power plants

- The electrostatic precipitators are extensively used in removal of fly ash from electric utility boiler emissions.
- The use of this collector is growing rapidly because of the new strict air quality codes.
- An electrostatic precipitator can be designed to run at any desired efficiency for use as a primary collector or as a supplementary unit to a cyclone collector.

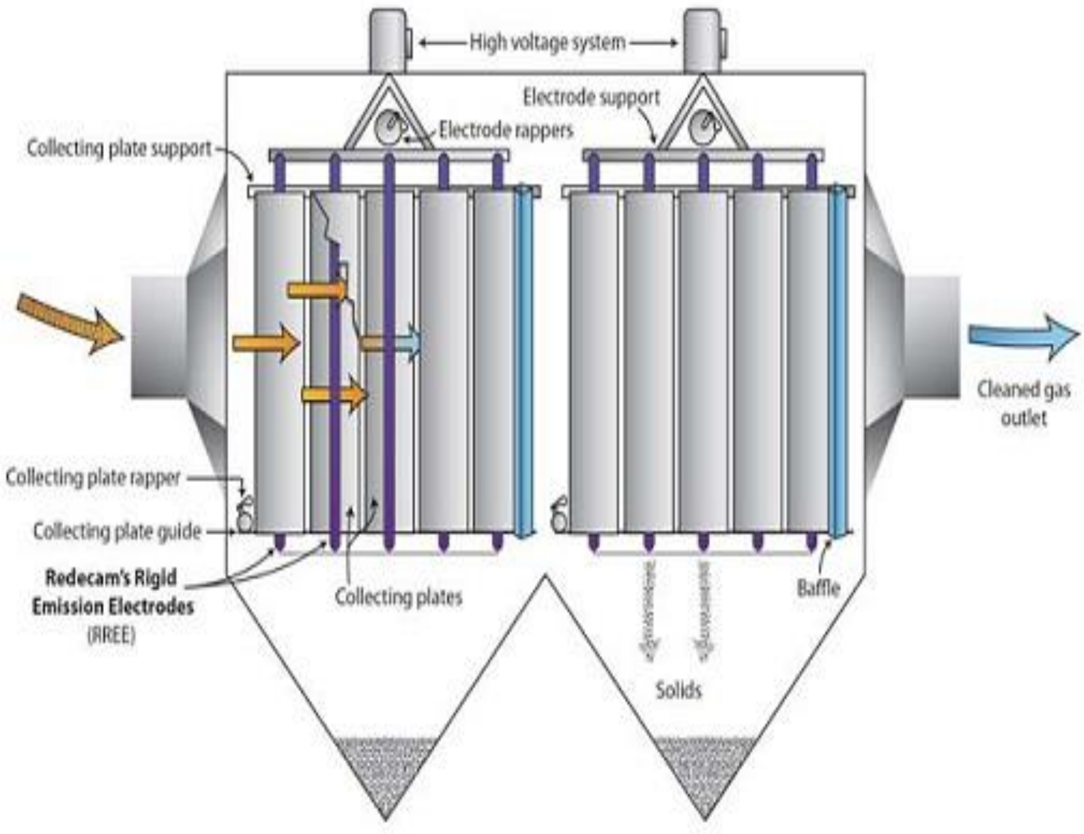

Figure 3.7.1 Electrostatic Precipitators

[Source:http://www.redecam.com/wp-content/uploads/2015/01/ESP1.jpg]

It is often considered worthwhile to retain an existing cyclone as a primary collector in cases where collection efficiencies must be upgraded especially where there is large amount of unburnt carbon in fly ash(about 15%) because the presence of large quantities of carbon in the gas can adversely affect the collection efficiency of a precipitator.

General Arrangements of an ESP:

- **Ionization**

  Charging of particles.
- **Migration**

  Transporting the charge particles to collecting surface
- **Collection**

  Precipitation of the charged onto the collecting surfaces.
- **Particle discharge:**

  Removing the particles from the collecting surface to the hopper.
- **Particle removal:**

  Conveying the particles from the hopper to a disposal point

Components of ESP:

i.Control cabinet

Control cabinet is used to interconnect the 3φ ac supply and transformer through cables Transformer. Transformer is used to step up or step down voltage as per design of Electrostatic precipitator.

ii.Rectifier

Rectifier is used to convert ac supply into dc supply.

iii. Hooper

Hooper is used to store dust particles and ash content coming out from the Electrostatic precipitator.

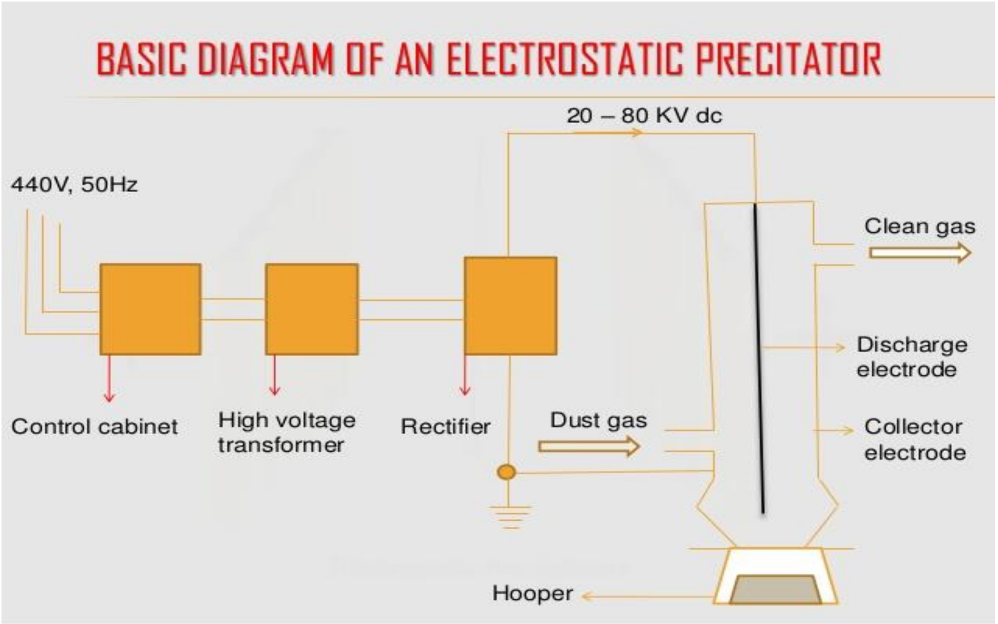

Figure 3.7.2 Basic Diagram for ESP

[Source:https://images.app.goo.gl/PXjCWhC6RUm4c1Zk8]

iv. Electrodes

Based on DC current flow terminals electrodes can be divided as below

v. Discharge electrode

Electrodes wire which carries negatively charged high voltage (between 20 to 80KV) act as discharge or emitting electrodes.

vi.Collector electrode

Electrode plate / wire which carries positively charged high voltage act as Collecting electrodes. Collector electrodes Discharge electrode

Working Principle /Operational Considerations:

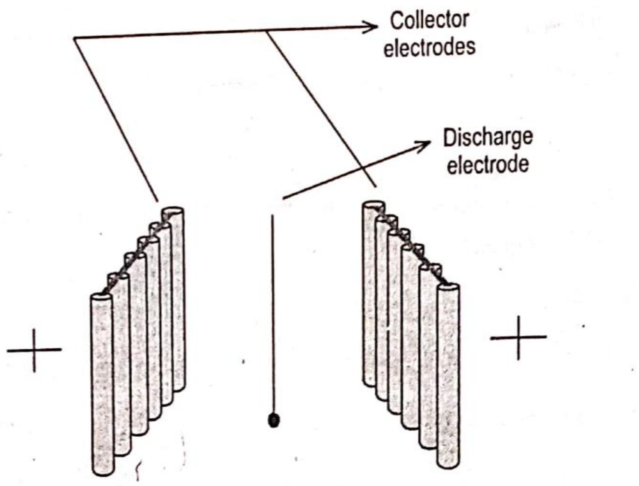

Figure 3.7.3 Electrode in ESP

[Source:https://cdn1.byjus.com/wp-content/uploads/2019/03/word-image356.png]

The dust laden gas is passed between oppositely charged conductors and it becomes ionized as the voltage applies between the conductors is sufficiently large.

As the dust laden ad is passed through these highly charged electrodes, both negative and positive ions are formed, the later being as high as 80%. The ionized gas is further passed through the collecting units which consist of a set of vertical metal plates. Alternate plates are positively charged and earthed.

As the alternate plates are earthed, high intensity electrostatic field exerts a force on positively charged dust particles and drives them toward the grounded plates. The deposited dust particles are removed from the plates by giving the shaking motion to the plates with the help of cam driven by external means.

The dust removed from the plates with the help of shaking motion is collected in the dust hoppers. Care should be taken that the dust collector in the hopper should not be entrained in the clean gas.

Advantages of Electrostatic Precipitator

- 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.
- This is also most effective for high dust loaded gas (as high as 100 grams per cu. meter)
- The draught loss of this system is the least of all forms(1 cm of water)
- It provides ease of operation.
- The dust is collected in dry form and can be removed either dry or wet.

Disadvantages of Electrostatic Precipitator

- 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.
- The running charges are also considerably high as the amount of power required for charging is considerably large.
- The space required is larger than the wet system.
- 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.
- 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.

Factors affecting the performance of E.S.P.

The present trend in adopting the gas cleaning device is to discharge the clean gas without containing SO2 to the atmosphere. One solution to this problem is to burn fuels containing less sulphur, but unfortunately low sulphur fuels are costly to use.

- In most cases burning low sulphur fuel increases the electrical resistivity of fly ash, particularly at low temperatures.
- This higher and unpredictable resistivity at low temperatures coupled with high collection efficiencies demand can spell trouble for low temperature precipitators.
- That's why pollution engineers are leaning towards precipitators operating at about 345 degrees where resistivity is not dependent on sulphur level in the flue gases.
- The principle of electrostatic precipitator is described in 3 stages as charging of the suspended particles, collecting of particulates under the influence of electrostatic field and removal of the precipitate from the collector plate.
- Many factors influence these three fundamental steps but they are critical to the reliability and performance of high temperature precipitators which are listed below:

1.Corona characteristics:

- Initiation of corona depends upon free electrons by random sources such as natural radioactivity.
  - Under the influence of an electrical field, these electrons are accelerated to a terminal velocity.
  - The rapidly moving electrons produce additional free electrons y colliding with the orbital electrons of gas molecules and by ionization.
- At higher temperatures, flue-gas density is reduced, resulting in a reduced starting potential.
  - At higher temperatures, lower voltages initiate the corona to start the precipitation process, resulting in more collection for a given voltage than at lower temperatures.
- Electrostatic precipitators operated at maximum power input have steep corona characteristics.

- The rate of change of corona current is much greater than the concurrent charge in precipitator-circuit voltage.
- The steeply rising corona current is further enhanced by increasing temperature of the stack gases.
- The net effect is to maximize power levels to achieve high efficiency.

2.Resistivity of the particles:

- Particulate resistivity is probably the most important basic variable influencing the precipitator and therefore is an important design consideration.A too high level of electrical resistivity or too low level causes collection difficulty.
- A high resistivity dust, such as sulphur, does not readily give up its negative charge and assumes a positive charge. This causes the particulate to be repelled back into the gas stream of negatively charged particles.
- A low resistivity dust can be collected and repelled in this manner many times before finally being emitted to the atmosphere. Therefore, the presence of large quantities of carbon in the ash can adversely affect the collection efficiency of a precipitator.
- One thumb rule followed by designer is to downgrade the efficiency of the unit by 1% for every 1% of carbon in the gas over 15%. Therefore, one always wishes a medium resistivity for good collection efficiency.
- In coal fired boilers, sulphur in the form of SO2 affects resistivity. Resistivity has two components, one related to the bulk of the material and another is related to the surface of the particle, absorbed layer of gas.
- As the temperature increases, the absorbed surface contaminants evaporate and surface resistivity increases. And with all insulating materials, the volume resistivity increases with decreasing temperature.

3.Rapping behaviour:

- This is perhaps the most complex among the three performance steps. Non electrical adhesive forces which play a significant role in plate rapping, vary inversely with particle diameter, but depend generally on the chemical and physical nature of the particle. Moisture can increase adhesion at lower temperatures.
- Particle resistivity has a critical effect on the electrical force causing particles to slick to the collection plates: the more resistive the particle, the greater the force.
- Operation at low temperatures and high resistivity requires considerably more rapping acceleration on the collection plates than it does under normal resistivity, and higher temperatures.
- Conventional practice limits maximum average gas velocity in high resistivity and low temperature operation to approximately 1.2 m/s.
- This limit avoids losses due to re-entrainment of particles which can occur when the dust layer is dislodged violently. In contrast, precipitators run at 1.7 m/s gas velocity at higher temperature.

4.Gas velocity:

- There are two forces acting on a particle having direct right angles to each other.
  - First is due to the flow of gas
  - Second is produced by the electric force on the ionized particle perpendicular to the motion of the gas.
- The path followed by the particle will take direction which is resultant of the two forces mentioned above.
- Therefore the efficiency of the collector decreases with an increase in velocity which can be compensated by increasing the voltage supplied to the plates.