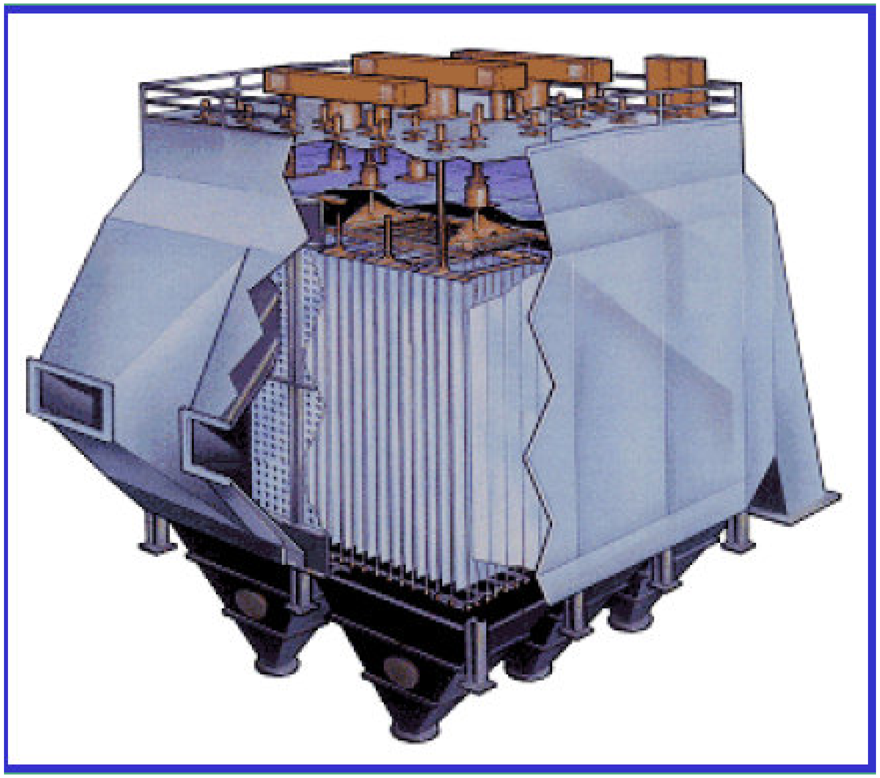


ELECTRO STATIC PRECIPITATOR [ESP]

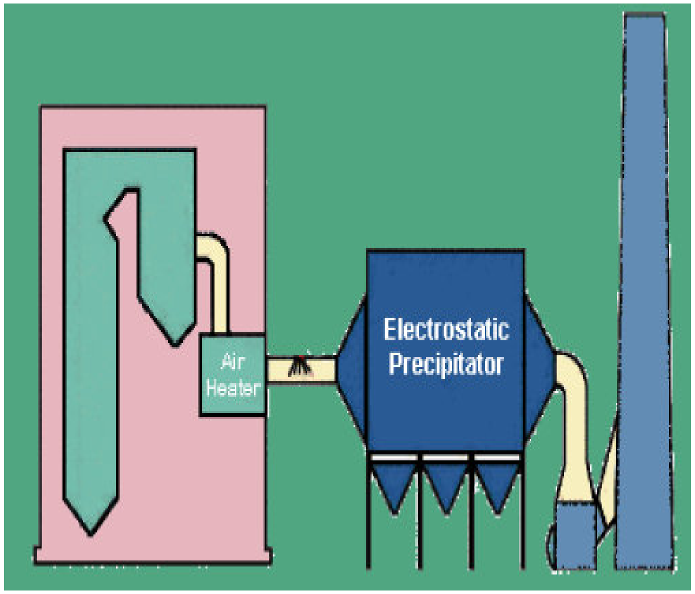
Controlling Air Pollution

Clean Air is an essential resource to the people surrounding the industrial belts. Air pollution is one of the major contributor for Environmental Pollution. The industrial gases have pollutants that directly impacts on health and restrict in industrial developments.

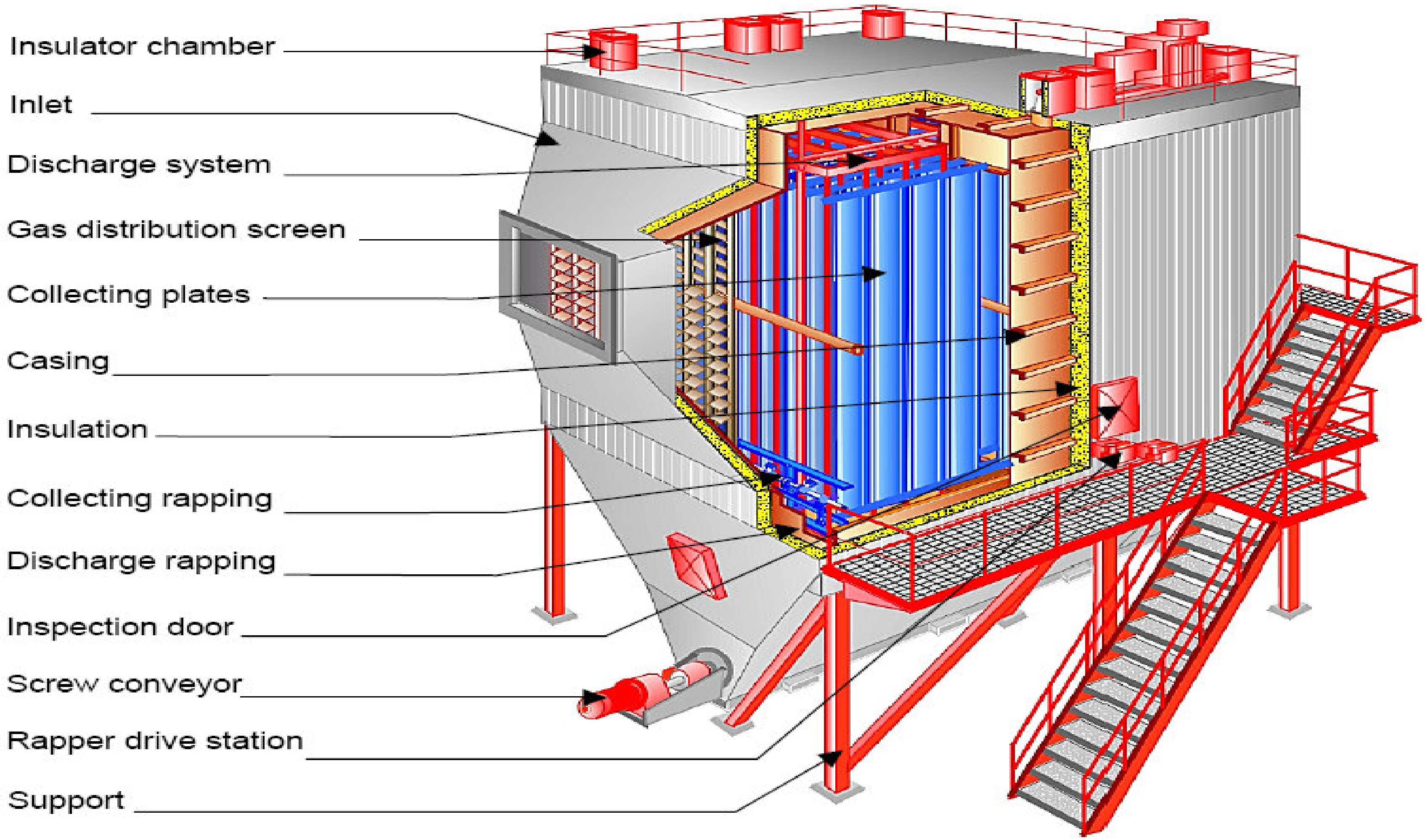
Today Electrostatic Precipitators have come a long way and are widely used in all major Power Plants, Chemical , Cement and Steel Industries. They absorbs more than 99% of dust particles and other substances while passing through the ESP and the exhaust gasses coming out of the chimney are with in line of the Emission Standards prescribed by Central Pollution Control Board.

What is ESP

- **Particulate Collection Device used in industries to minimize air pollution**
- **Principle of operation→ Electrostatic attraction**
- **Efficiency of 99% in many industries**
- **Can handle large gas volumes with a wide range of inlet temperatures, pressures, dust volumes, and acid gas conditions**
- **Can collect particles of varying sizes in dry and wet states**

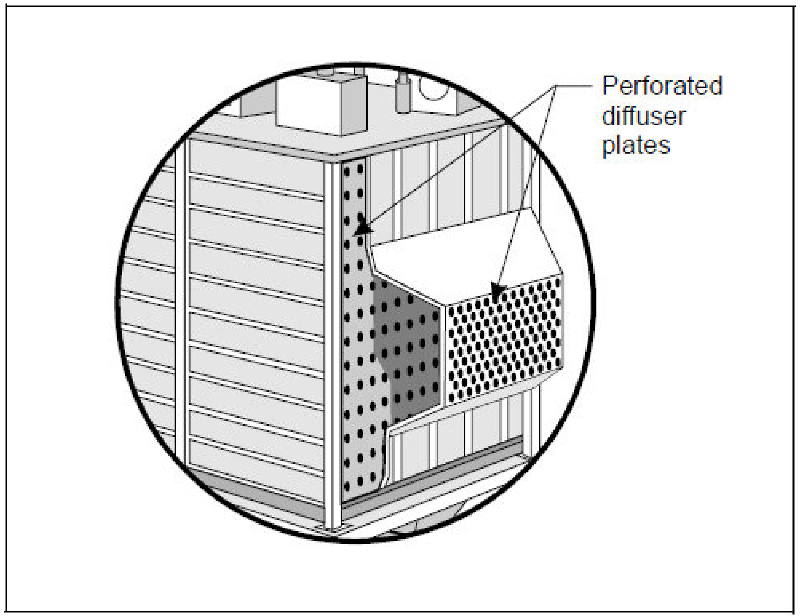


Components of an Electrostatic Precipitator



Gas Distribution Screen

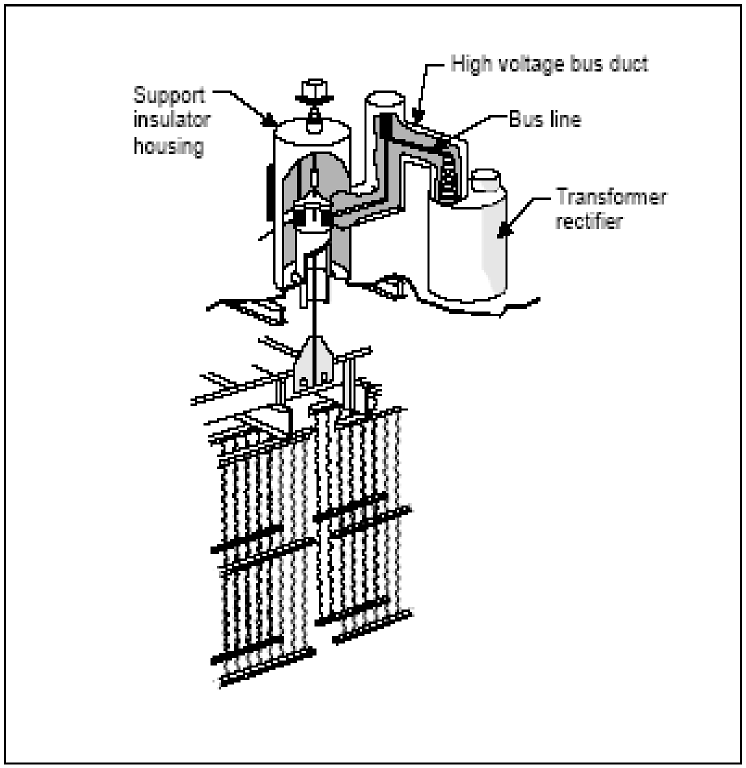
These screens are of modular design manufactured out of steel sheets and hang within a framework in the ESP inlet casing to maintain uniform distribution pattern of gas flow throughout the cross section of ESP



Support and Shaft Insulator

The whole emitting frame system is suspended from the roof through Supporting Insulator to avoid any short circuiting.

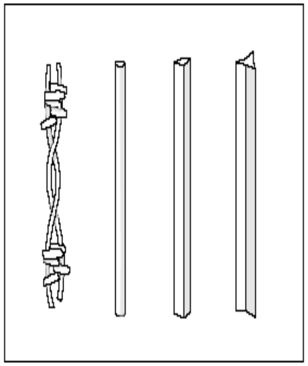
The Rapping Mechanism Shaft for electrodes is connected to the driving mechanism through shaft insulator.



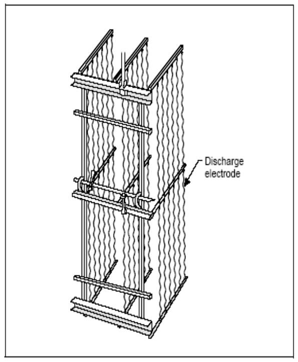
Discharge Electrodes

Discharge electrodes emit charging current and provide voltage that generates an electrical field between the discharge electrodes and the collecting plates. The electrical field forces dust particles in the gas stream to migrate toward the collecting plates. The particles then precipitate onto the collecting plates. Common types of discharge electrodes include:

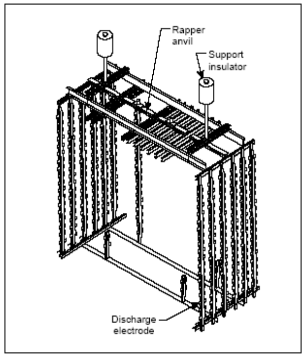
- Straight round wires
- Twisted wire pairs
- Rigid masts
- Rigid frames
- Rigid spiked pipes
- Spiral wires
- Barbed discharge wires



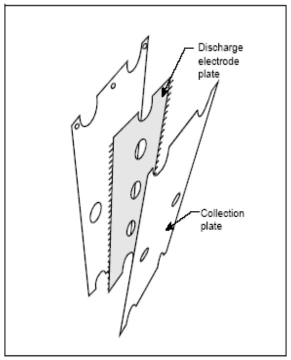
Wire discharge electrodes



Rigid frame



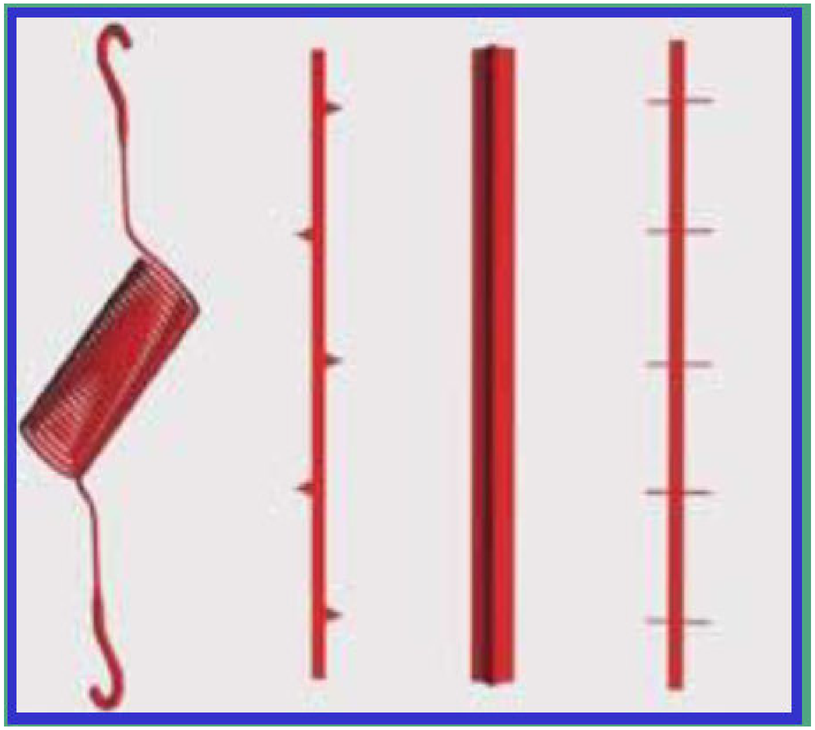
Rigid discharge electrode



Flat-plate

Discharge Electrodes (Contd.)

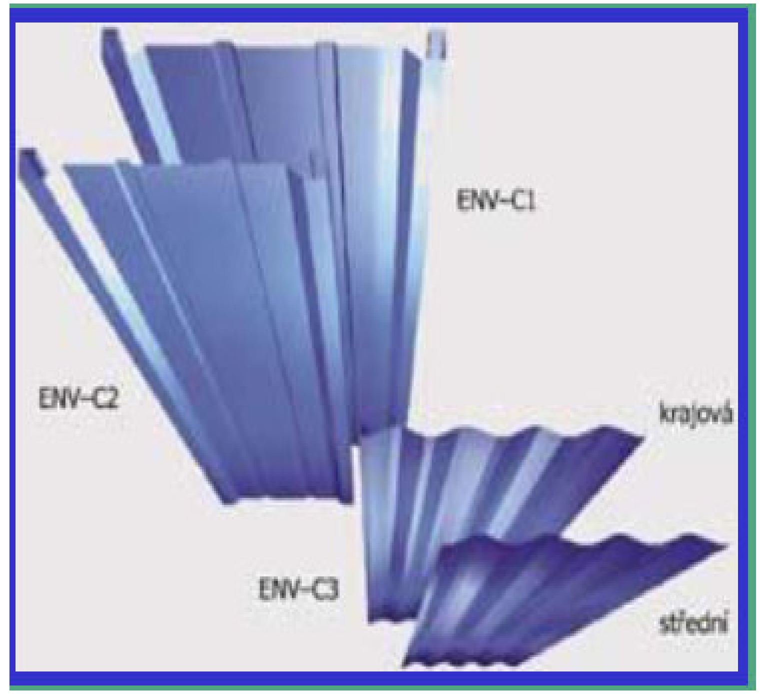
Discharge electrodes are typically supported from the upper discharge frame and are held in alignment between the upper and lower discharge frames. The upper discharge frame is in turn supported from the roof of the precipitator casing. High-voltage insulators are incorporated into the support system. In weighted wire systems, the discharge electrodes are held taut by weights at the lower end of the wires.



Collecting Electrodes

Collecting plates are designed to receive and retain the precipitated particles until they are intentionally removed into the hopper. Collecting plates are also part of the electrical power circuit of the precipitator. Plate baffles shield the precipitated particles from the gas flow while smooth surfaces provide for high operating voltage. Collecting plates are suspended from the precipitator casing and form the gas passages within the precipitator.

Collecting plates are connected at or near the center by rapper beams which serves as an impact point for rapping system. Top, center or bottom spacer bars may be used to keep the plates aligned for maintaining electrical clearances to the discharge system.



Suspension and Rapping Mechanism

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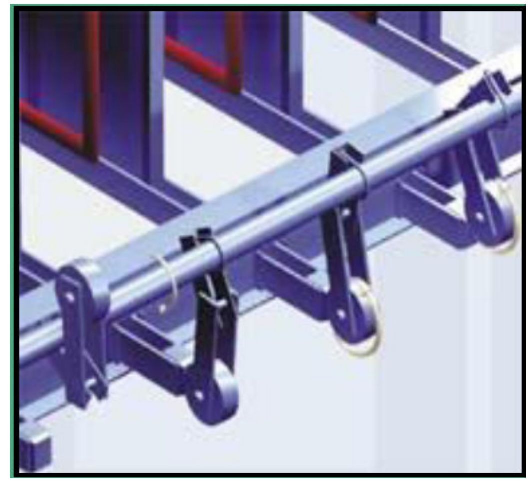
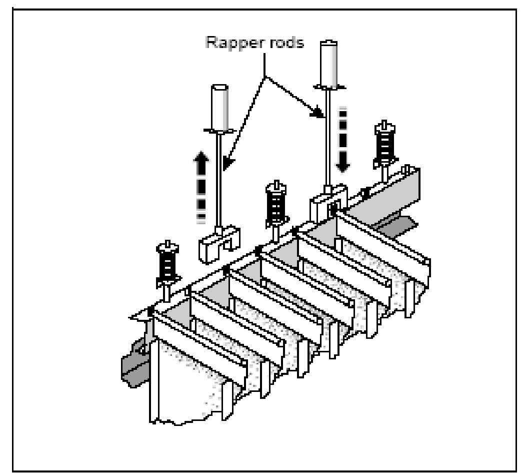
Collecting plate rapping must remove the bulk of the precipitated dust. The collecting plates are supported from anvil beams or directly with hooks from the precipitator casing. With anvil beam support, the impact of the rapping system is directed into the beams located at the leading and/or trailing edge of the collecting plates. For direct casing support, the impact is directed into the rapper beams located at or near the center of the top of the collecting plates. The rapping is carried out in a regular programmed intervals and guaranteed removal of deposited dust from the electrodes to the hopper.



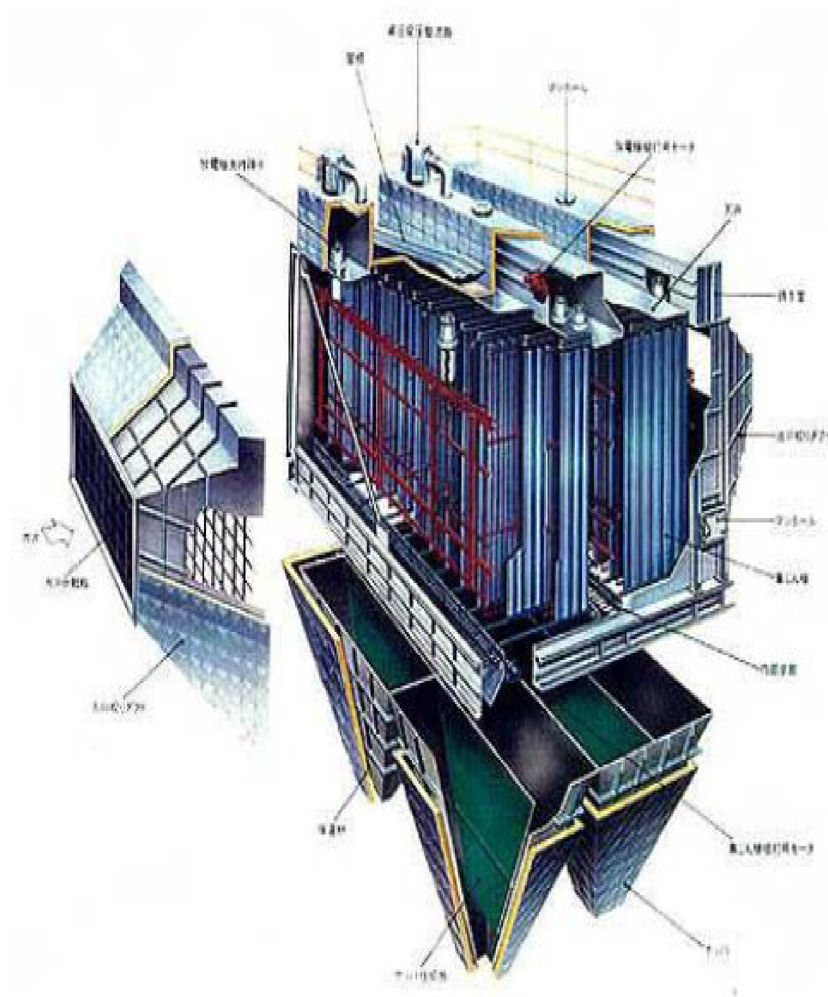
Hammer/Anvil rappers



Magnetic-Impulse rappers

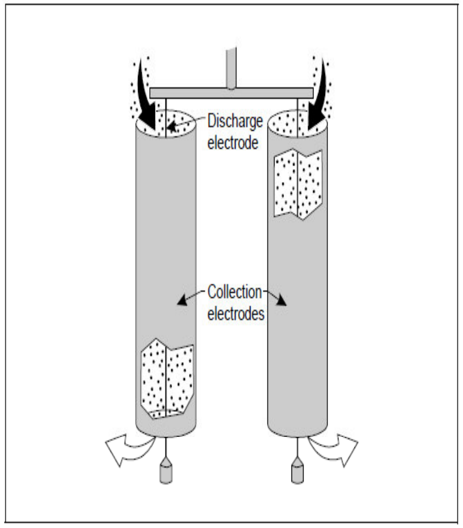
Hoppers

Precipitator hoppers are designed to completely discharge their dust load on demand. Usually the hoppers are rectangular in cross section with sides of at least 60 Deg slope. They are insulated from neck above the discharge flange with the insulation covering the entire hopper area. Lower part of the hopper (usually 1/3 to ¼ of height) is heated to avoid caking of ash and to ensure free flow.



Types of Electrostatic Precipitators

- Tubular precipitators are generally used for collecting mists or fogs, and are most commonly used when collecting particles that are wet or sticky. Tubular ESPs have been used to control particulate emissions from sulfuric acid plants, coke oven byproduct gas cleaning (tar removal), and iron and steel sinter plants



Tubular Precipitators

- Plate electrostatic precipitators primarily collect dry particles and are used more often than tubular precipitators. Plate ESPs can have wire, rigid-frame, or occasionally, plate discharge electrodes.

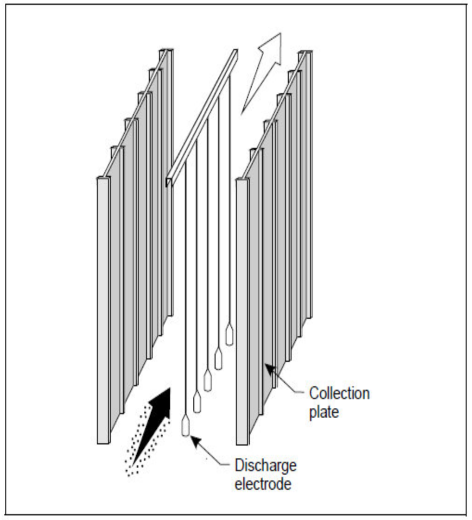
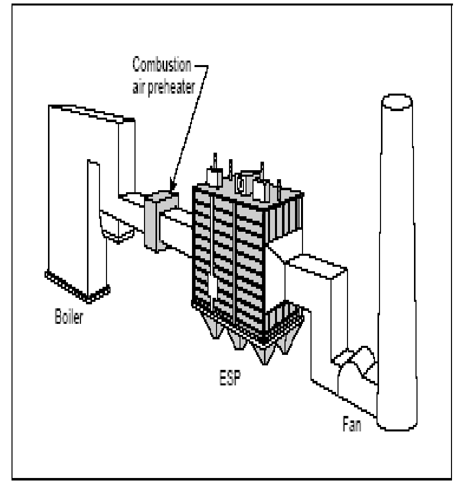


Plate Precipitators

Types of Electrostatic Precipitators (Contd.)

Cold side ESPs is used where:

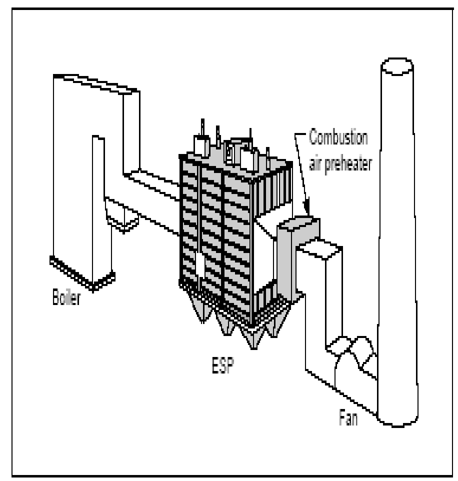
- Volume of flue gas that is handled is less
- Cost involvement is less.
- Overall size of the unit is smaller
- Used to remove fly ash from boilers that burn high sulfur coal



Cold side ESPs

Hot side ESPs is used where:

- In high-temperature applications (Cement kiln)
- The gas volume treated in the ESP is larger
- The overall size of the precipitator is larger making it more costly
- Structural and mechanical problems occur in the precipitator shell



Hot side ESPs

Types of Electrostatic Precipitators (Contd.)

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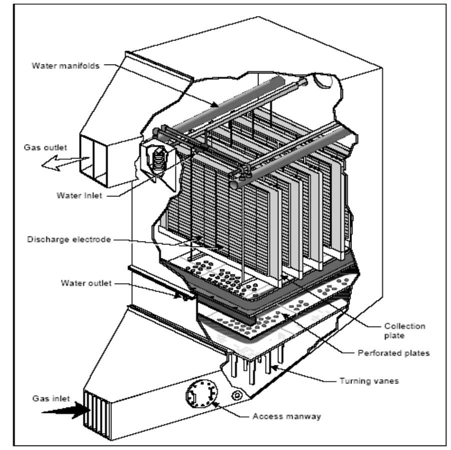
Wet side ESPs is used where:

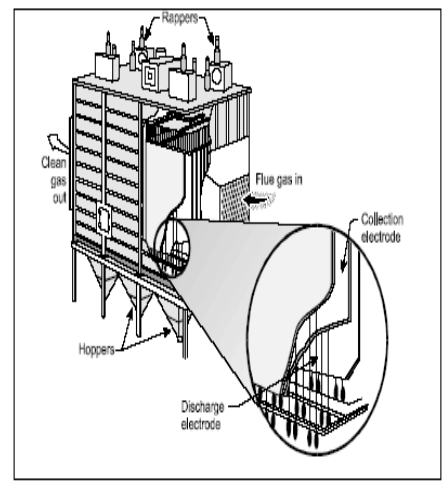
- Wet ESPs are used for industrial applications where the potential for explosion is high .
- When dust is very sticky, corrosive, or has very high resistivity.
- It does not have problems with rapping re entrainment or with back corona.

Dry side ESPs is used where:

- Particles are charged and collected in a dry state .
- Dust particles collected are removed by rapping.
- Used in steel furnaces, cement kilns and fossil-fuel-fired boilers.



Wet side ESPs

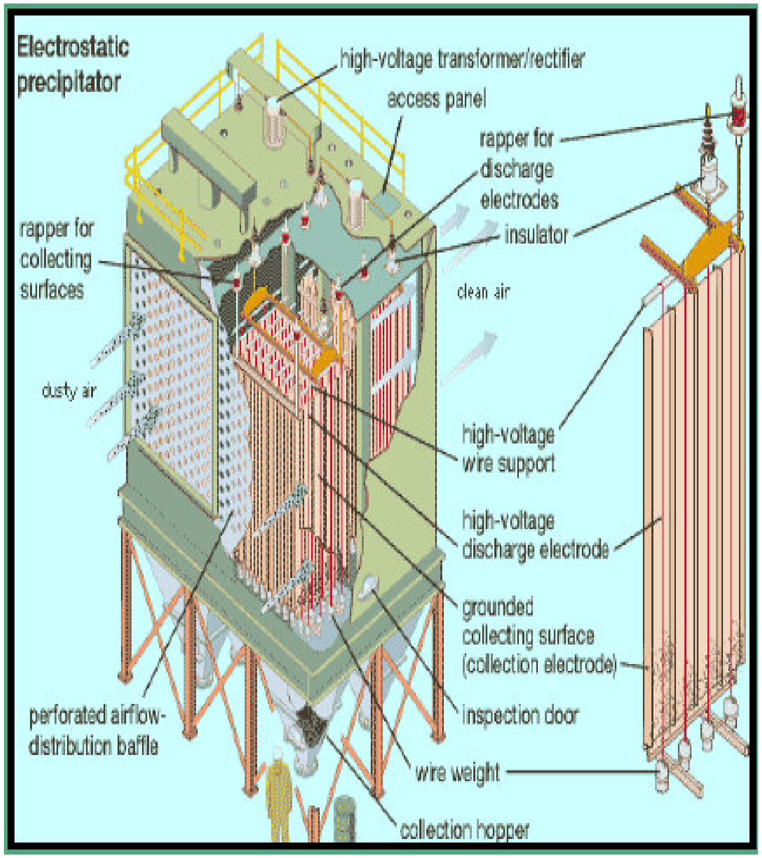


Dry side ESPs

Principles of ESP Operation

Electrostatic precipitation removes particles from the exhaust gas stream of an industrial process. Often the process involves combustion, but it can be any industrial process that would otherwise emit particles to the atmosphere. Six activities typically take place

- **Ionization** - Charging of particles
- **Migration** - Transporting the charged particles to the collecting surfaces
- **Collection** - Precipitation of the charged particles onto the collecting surfaces
- **Charge Dissipation** - Neutralizing the charged particles on the collecting surfaces
- **Particle Dislodging** - Removing the particles from the collecting surface to the hopper
- **Particle Removal** - Conveying the particles from the hopper to a disposal point



Principles of ESP Operation (Contd.)

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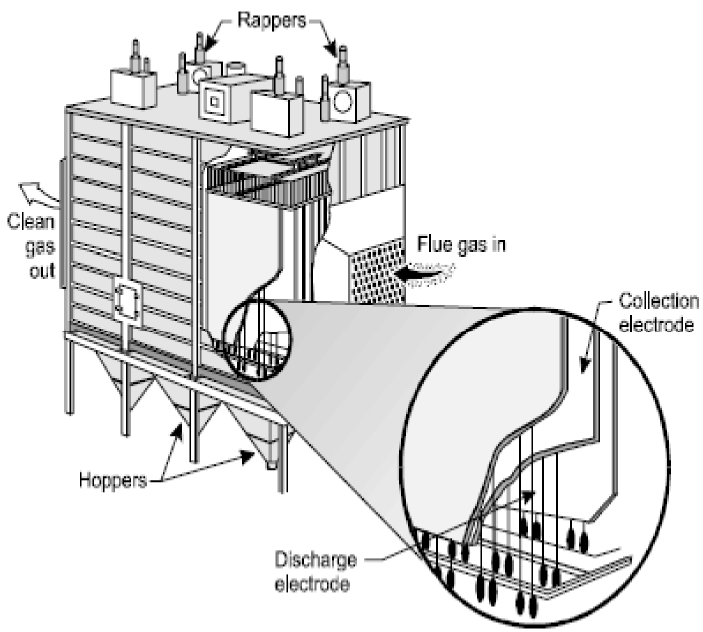
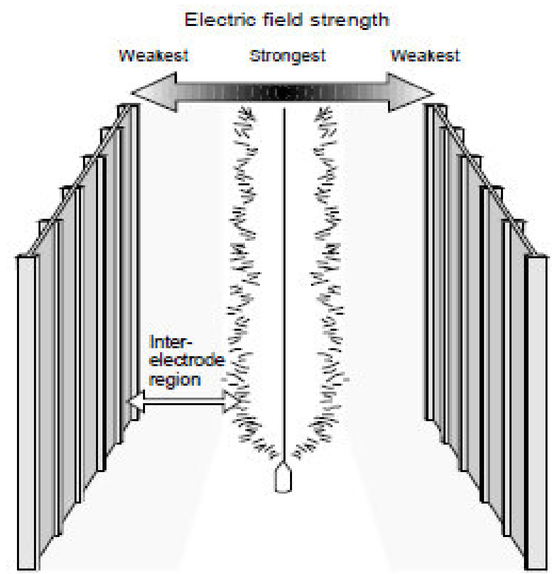
Gas Particle Charging



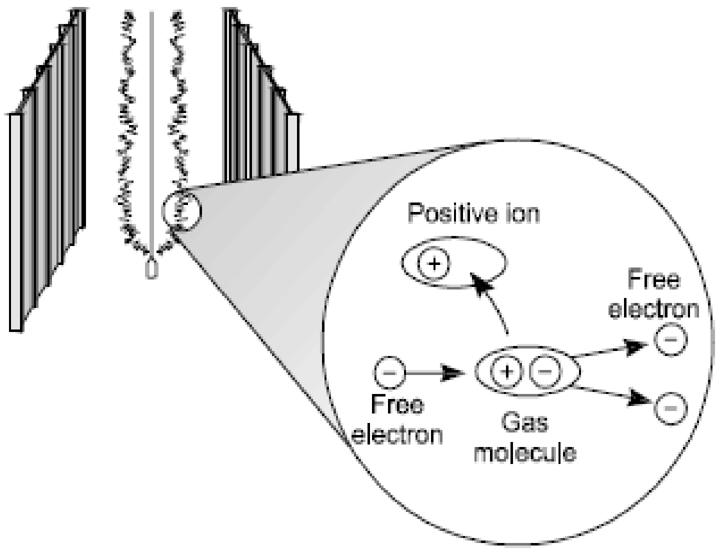
Dry ESPs



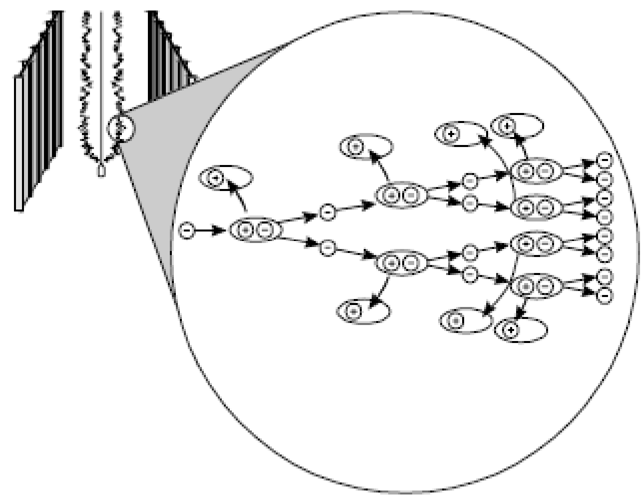
ESP Electric Field

Principles of ESP Operation (Contd.)

Corona Discharge : Free Electron Generation



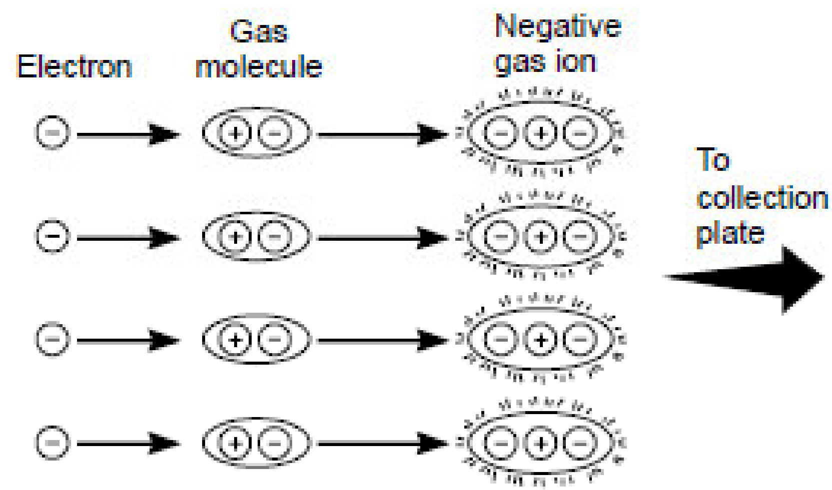
Corona Generation



Avalanche multiplication of gas molecules

Principles of ESP Operation (Contd.)

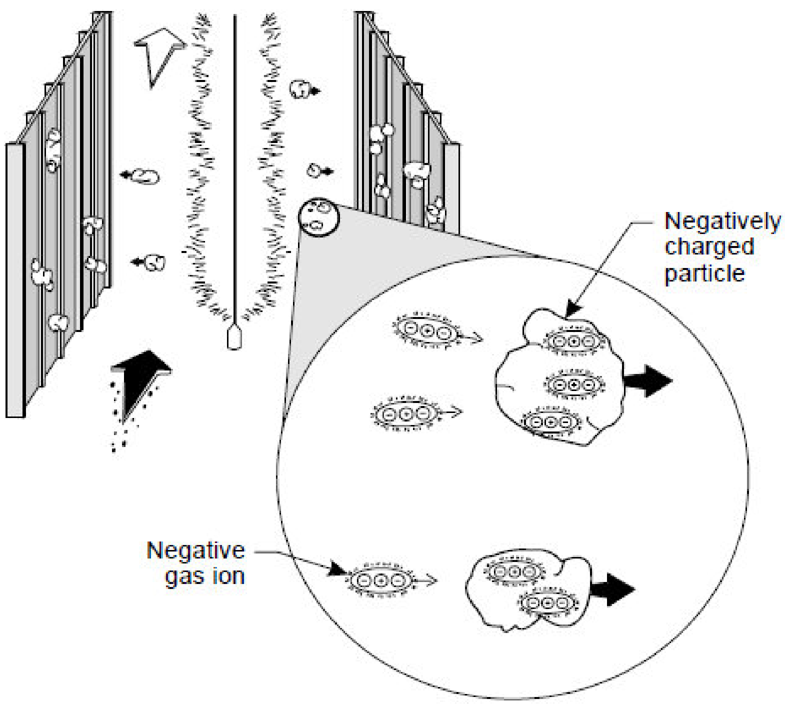
Ionization of Gas Molecules

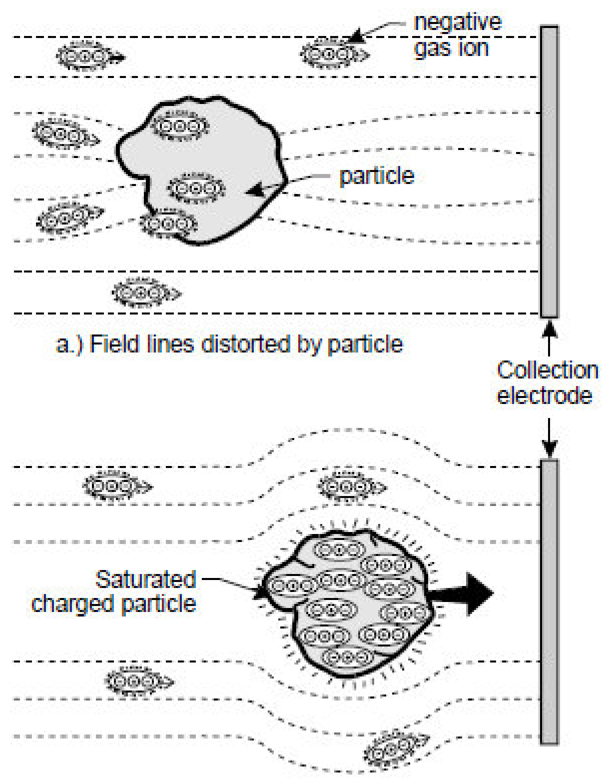


Negative gas ions formed in the inter-electrode region

Principles of ESP Operation (Contd.)

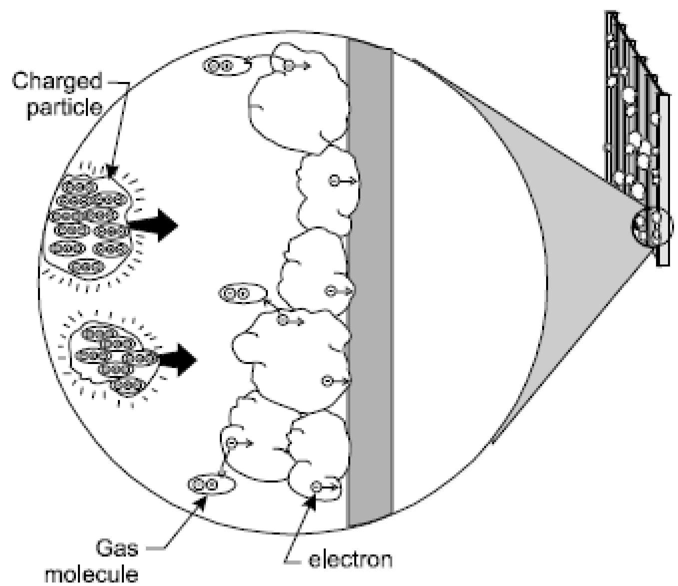
Charging of Dust Particles





Principles of ESP Operation (Contd.)

Collection & Removal of Dust Particles



Particle collection at collection electrode

Fabric Filters

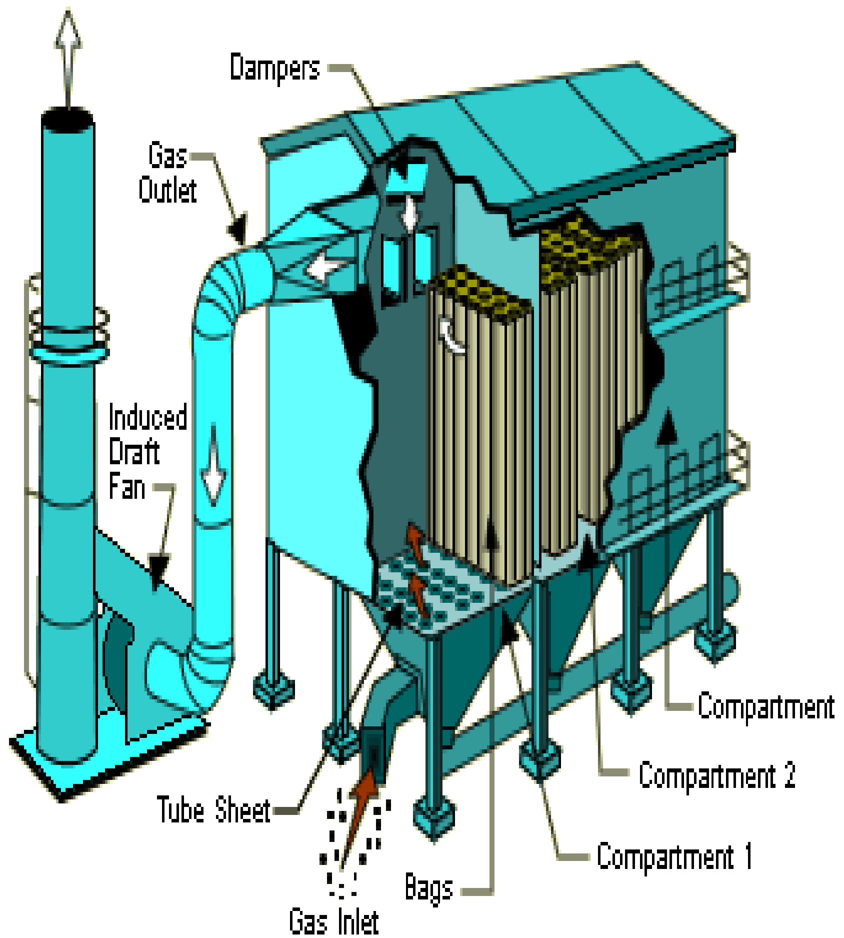
Fabric filters are also referred to as bag-houses or dust filters. These particulate matter control devices can effectively remove unintentional particulate matters and any vapors that adsorb to the particles in the exhaust gas stream.

Filters are usually 16 to 20 cm diameter bags, 10 m long, made from woven fiberglass material, and arranged in series. Fabric filters are sensitive to acids; therefore, they are usually operated in combination with spray dryer adsorption systems for upstream removal of acid gases.

Types of Fabric Filters

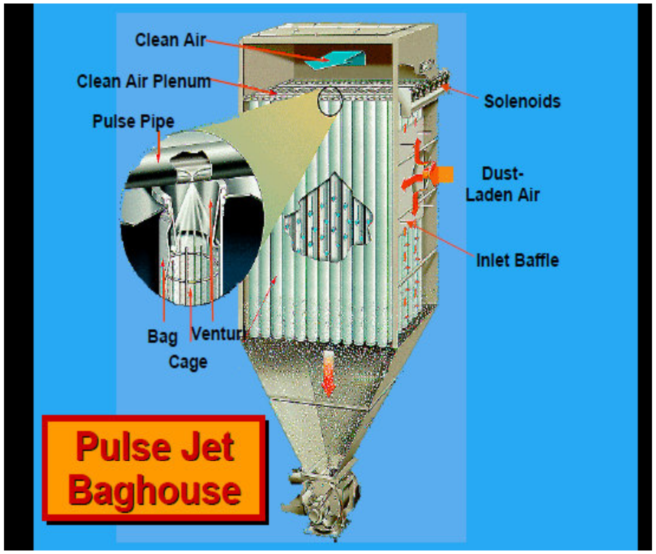
- The particle-laden gas stream enters from the bottom and passes into the inside of the bags.
- The dust cake accumulates on the inside surfaces of the bags.
- Filtered gas passes through the bags and is exhausted from the unit.
- When cleaning is necessary, dampers are used to isolate a compartment of bags from the inlet gas flow.
- Then, some of the filtered gas passes in the reverse direction (from the outside of the bag to the inside) in order to remove some of the dust cake.
- The gas used for reverse air cleaning is re-filtered and released.

Figure 13. Reverse Air Fabric Filter



Types of Fabric Filters (Contd.)

- In this type, the bags are supported on metal wire cages that are suspended from the top of the unit.
- Particulate-laden gas flows around the outside of the bags, and a dust cake accumulates on the exterior surfaces.
- When cleaning is needed, a very-short-duration pulse of compressed air is injected at the top inside part of each bag in the row of bags being cleaned.



Resistivity

Resistivity is the electrical resistance of a dust sample 1.0 cm2 in cross-sectional area, 1.0 cm thick, and is recorded in units of ohm-cm.

Resistivity, which is a characteristic of particles 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 composition as well as flue gas operating conditions such as temperature and moisture. Particles can have high, moderate (normal), or low resistivity.

Resistivity	Range of measurement
Low	between 10^4 and 10^7 ohm • cm
Normal	between 10^7 and 10^{10} ohm • cm
High	above 10^{10} ohm • cm (usually between 10^{10} and 10^{14} ohm • cm)

In high resistivity dust layers, the dust is not sufficiently conductive, so electrical charges have difficulty moving through the dust layer. Consequently, electrical charges accumulate on and beneath the dust layer surface, creating a strong electric field. Voltages can be greater than 10,000 volts. Dust particles with high resistivity's are held too strongly to the plate, making them difficult to remove and causing rapping problems.

In low resistivity dust layers, the corona current is readily passed to the grounded collection electrode. Therefore, a relatively weak electric field, of several thousand volts, is maintained across the dust layer. Collected dust 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.

Resistivity (Contd.)

Resistivity Level, ohm-cm	ESP Characteristics
Less than 10^7 (Low Resistivity)	1. Normal operating voltage and current levels unless dust layer is thick enough to reduce plate clearances and cause higher current levels 2. Reduced electrical force component retaining collected dust, vulnerable to high reentrainment losses 3. Negligible voltage drop across dust layer 4. Reduced collection performance due to (2)
10^7 to 10^{10} (Normal Resistivity)	1. Normal operating voltage and current levels 2. Negligible voltage drop across dust layer 3. Sufficient electrical force component retaining collected dust 4. High collection performance due to (1), (2), and (3)
10^{11}	1. Reduced operating voltage and current levels with high spark rates 2. Significant voltage loss across dust layer 3. Moderate electrical force component retaining collected dust 4. Reduced collection performance due to (1) and (2)
Greater than 10^{12} (High Resistivity)	1. Reduced operating voltage levels; high operating current levels if power supply controller is not operating properly 2. Very significant voltage loss across dust layer 3. High electrical force component retaining collected dust 4. Seriously reduced collection performance due to (1), (2), and probable back corona
Typical values	
Operating voltage:	30 to 70 kV, dependent on design factors
Operating current density:	5 to 50 nA/cm^2
Dust layer thickness:	1/4 to 1 inch

Ways to reduce Ash Resistivity in Indian Coal

- Controlling of operating gas temperature.
- Intermittent energization.
- Wide pitch electrodes.
- Pulsed power supply or semi pulsed operation.
- Conditioning of flue gas (Ammonia, Ammonium Sulphate, Sodium Carbonate, Sodium conditioning by Sodium Sulphate etc.).
- Addition of additives like Ammonia, Sulphur trioxide, Sulphuric acid, Sulphamic acid.

ESP Power Supply & Control

The power supply system is designed to provide voltage to the electrical field at the highest possible level. The voltage must be controlled to avoid causing sustained arcing or sparking between the electrodes and the collecting plates.

Electrically, a precipitator is divided into a grid, with electrical fields in series (in the direction of the gas flow) and one or more bus sections in parallel (cross-wise to the gas flow). When electrical fields are in series, the power supply for each field can be adjusted to optimize operation of that field. Likewise, having more than one electrical field in parallel allows adjustments to compensate for their differences, so that power input can be optimized. The power supply system has four basic components:

- Automatic voltage control
- Step-up transformer
- High-voltage rectifier
- Sensing device

Voltage Control

Automatic voltage control varies the power to the transformer-rectifier in response to signals received from sensors in the precipitator and the transformer-rectifier itself. It monitors the electrical conditions inside the precipitator, protects the internal components from arc-over damages, and protects the transformer-rectifier and other components in the primary circuit.

The ideal automatic voltage control would produce the maximum collecting efficiency by holding the operating voltage of the precipitator at a level just below the spark-over voltage. However, this level cannot be achieved given that conditions change from moment to moment. Instead, the automatic voltage control increases output from the transformer-rectifier until a spark occurs. Then the control resets to a lower power level, and the power increases again until the next spark occurs.

Major function of Voltage Controller

• ***Optimize power application*** – The primary purpose of a voltage controller is to deliver as much useful electrical power to the corresponding electrostatic precipitator field(s) as possible. This is not an easy job; electrical characteristics in the field(s) are constantly changing, which is why a voltage controller is required.

• ***Spark reaction*** – When the voltage applied to the electrostatic precipitator field is too high for the conditions at the time, a spark over (or corona discharge) will occur. Detrimentally high amounts of current can occur during a spark over if not properly controlled, which could damage the fields. A voltage controller will monitor the primary and secondary voltage and current of the circuit, and detect a spark over condition. Once detected, the power applied to the field will be immediately cut off or reduced, which will stop the spark. After a short amount of time the power will be ramped back up, and the process will start over.

• ***Protect system components by adhering to component limitations*** – The Transformer Rectifier set (TR set) can be damaged by excessive amounts of current or voltage flowing through it. Each TR set has voltage and current limits established by the manufacturer, which are labeled on an attached nameplate. These nameplate limit values (typically primary and secondary current, and voltage) are programmed into the voltage controller. Through metering circuits, the voltage controller will monitor these values, and ensure these limits are not exceeded.

• ***Tripping*** – When a condition occurs that the voltage controller cannot control, often times the voltage controller will trip. A trip means the voltage controller (by way of the contactor) will shut off the individual precipitator power circuit. A short inside the electrostatic precipitator field caused by a fallen discharge electrode (wire), or a shorted out Silicone Controlled Rectifier are examples of conditions that a voltage controller cannot control.

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