Air Pollution

Control Techniques:

Every day, around half a million tonnes of tiny particles, ranging from 100 μm to 0.1 μm or smaller, are released into the air due to human activities. These particles can seriously impact health, materials, and plants.

To control industrial air pollution, there are four main methods:

1. Reducing pollutants at the source using control equipment.
2. Reducing pollution by changing raw materials, modifying operations, or updating equipment.
3. Diluting emissions by building taller stacks.
4. Properly zoning industrial areas to spread out pollution sources.

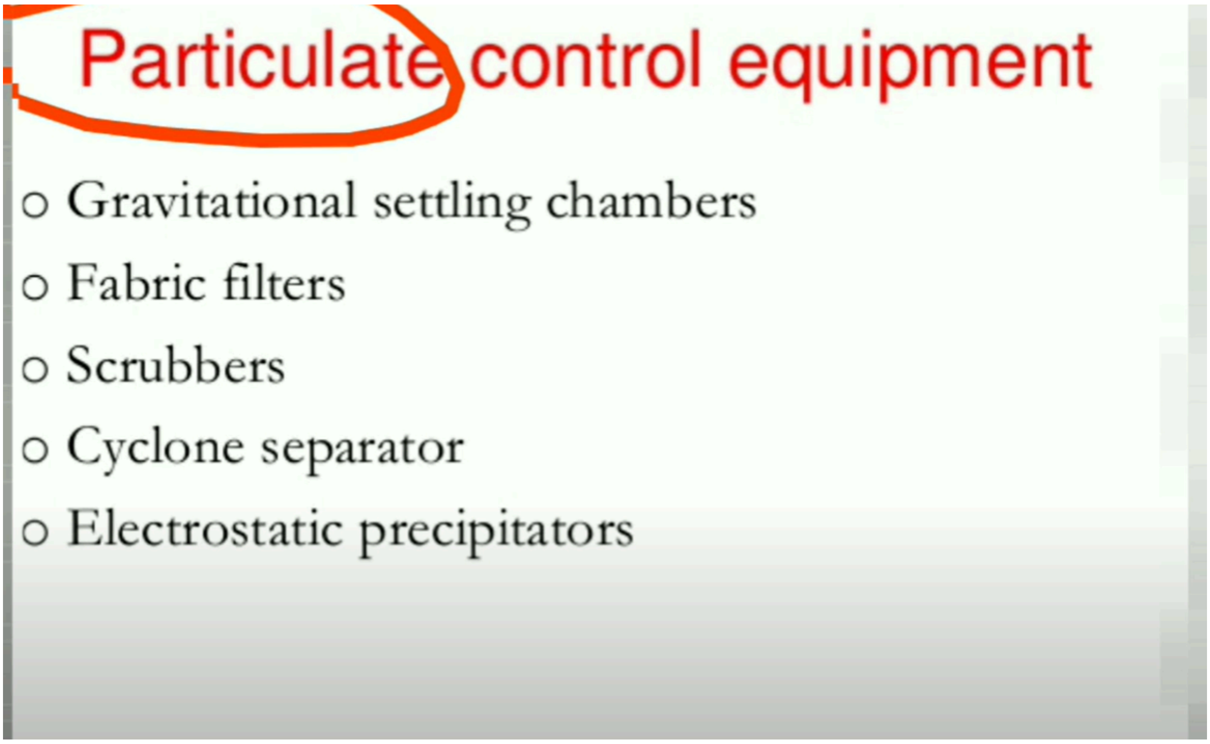
The most effective methods are using control equipment and process adjustments at the source.

When selecting equipment to remove particles from gas emissions,consider:

1. The gas quantity and its variations.
2. The chemical and physical properties of the particles.
3. The temperature and pressure of the gas.
4. The gas's corrosive properties or solubility.
5. The desired quality of the cleaned gas.

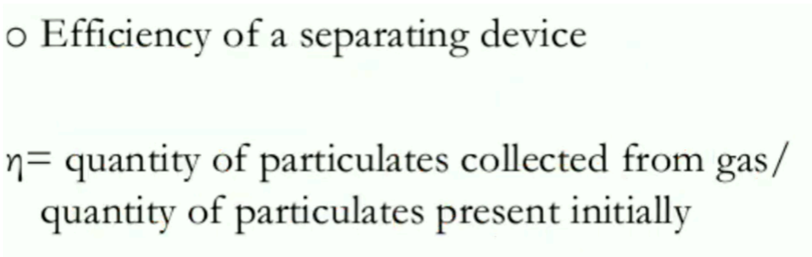
The goals of using control equipment are to:

1. Prevent nuisance.
2. Protect property from damage.
3. Safeguard health.
4. Recover valuable materials.
5. Lower maintenance costs.
6. Enhance product quality.



Settling Chambers

- **Principle:** Uses gravitational force to settle particles by slowing down the carrier gas velocity, allowing particles to settle due to gravity.



Settling Chambers

Gravitational settling chambers are simple, low-cost control devices that act as pre-cleaners to remove large particulate matter from gas streams. They work by slowing the gas velocity to allow gravity to settle particles out of the gas flow. There are two main types: expansion chambers and multiple-tray chambers.

Types of Settling Chambers

1. **Expansion Chamber**: Gas velocity is reduced as it expands into a large chamber, allowing larger particles to settle by gravity.
2. **Multiple-Tray (Howard's) Chamber**: Contains thin, closely spaced trays that force the gas to flow horizontally between them, improving collection efficiency by

shortening the fall height for particles. This type is effective for particles of 10-15 μm in size, but cleaning is challenging due to the tight tray spacing.

Principle, Construction, and Working of Settling Chambers

Principle: Settling chambers use gravitational force to separate particles from the gas stream. Reducing the gas velocity allows gravity to act on the particles, causing them to settle at the bottom of the chamber, a process governed by Stokes' Law. This method is effective for large and dense particles.

Construction: Typically, settling chambers are long, box-like structures with an inlet at one end and an outlet at the other, usually positioned horizontally on the ground. They are often made from brick or concrete, with a hopper at the bottom to collect settled particles.

Working: Gas enters the chamber at a low velocity (under 3 m/s to avoid re-entrainment), allowing denser particles to settle to the bottom by gravity. The clean gas exits through an outlet, and the settled particles are collected in a hopper for disposal. Additional components like curtains or wire mesh screens help to reduce turbulence and maintain uniform velocity.

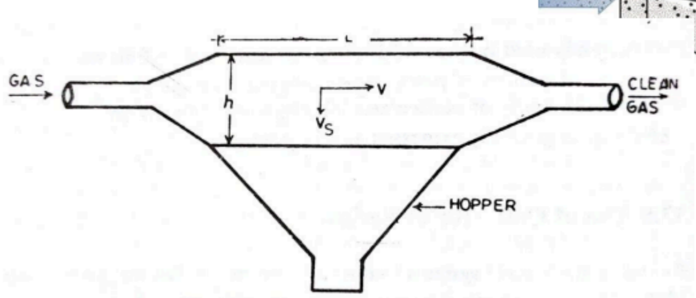
Advantages and Disadvantages of Settling Chambers

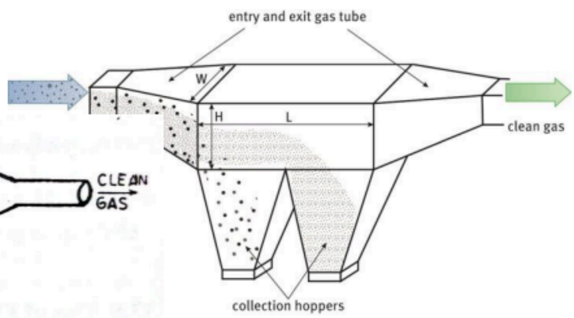
Advantages

- Low initial cost and simple construction
- Minimal maintenance and pressure drop
- Reliable and suitable for continuous, dry particle disposal
- Flexible material choices

Disadvantages

- Requires large space
- Ineffective for sticky particles
- Tray warping in Howard's chamber at high temperatures
- Limited to larger particles (>50 μm)





$$V_s = hV/L \quad \text{----------- (i)}$$

L= length of chamber

V= horizontal velocity of carrier gas

Vs= settling velocity of particulates

h= height through which particulates travel before settling down

By stokes law

$$V_s = g(\varrho_p - \varrho)D^2/18\mu \quad \text{--------- (ii)}$$

D= dia of particle

g= acceleration due to gravity

ϱ_p= density of particle

ϱ = density of gas

μ= viscosity of gas

Cyclone Separators

Cyclone separators are commonly used devices for removing particulate matter from gas streams. Also known as centrifugal or inertial separators, they rely on centrifugal force, rather than gravity, to separate particles from the gas, which allows them to capture much smaller particles than settling chambers.

Principle, Construction, and Working of Cyclone Separators

Principle: Cyclone separators use centrifugal force to separate particulates. As the gas enters the separator at high speed, it forms a vortex, creating centrifugal forces that push the heavier particles toward the outer wall of the cyclone, where they are removed from the gas stream.

Construction: A typical cyclone separator consists of:

- A cylindrical section with an inlet for dirty gas at the side.
- An inverted conical section at the bottom, leading to a dust collection hopper.
- A central outlet for clean gas at the top.

Working:

1. The gas enters the cylinder tangentially at high speed, creating a spinning vortex.
2. The gas spirals downward along the outer walls, carrying particles to the wall by centrifugal force.
3. Once the particles reach the wall, they fall by gravity into the dust hopper.
4. The cleaned gas follows an inner vortex that spirals upward and exits through the outlet.

Design Considerations

Several factors are critical for cyclone efficiency:

1. **Part Sizes**: Proper dimensions for components, such as the cylinder diameter and inlet/outlet sizes, help maintain optimal flow and separation.
2. **Separation Factor**: Cyclones use the centrifugal force generated by tangential velocity, which is a factor in determining the effectiveness of separation.
3. **Efficiency**: The efficiency of a cyclone can be calculated using particle size and density. Higher efficiency is achieved when particles are larger than a threshold size, known as the "cut size."
4. **Cut Size (dPC)**: This represents the smallest particle size that can be captured with 50% efficiency, depending on gas and particle properties.
5. **Number of Cyclones**: Multiple cyclones can be used together for larger gas volumes, improving efficiency.
6. **Number of Turns**: The number of turns the gas takes in the vortex (outer spiral) influences the separation time and efficiency.

Operating Problems

Cyclones may encounter issues like:

- **Erosion**: Particles scraping the walls at high velocity can wear down the interior. Durable materials are recommended.
- **Corrosion**: Moisture and reactive gases may cause corrosion, especially at lower temperatures. Higher temperatures can reduce corrosion.
- **Dust Build-Up**: Dust accumulation on walls can hinder efficiency and must be periodically removed.

Advantages and Disadvantages of Cyclone Separators

Advantages

1. Low initial cost, easy to construct and operate.
2. Low maintenance and pressure drop.

3. No moving parts, allowing for continuous particle removal.
4. Can be constructed from various materials.

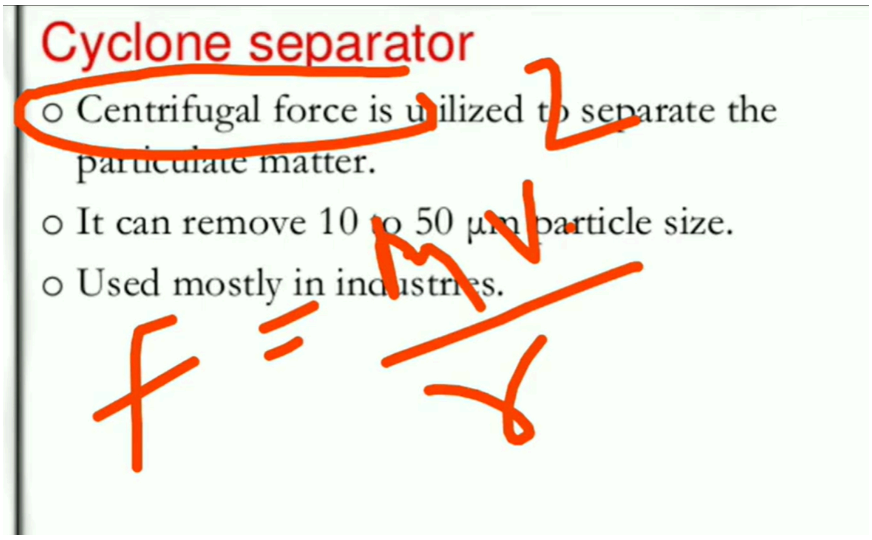
Disadvantages

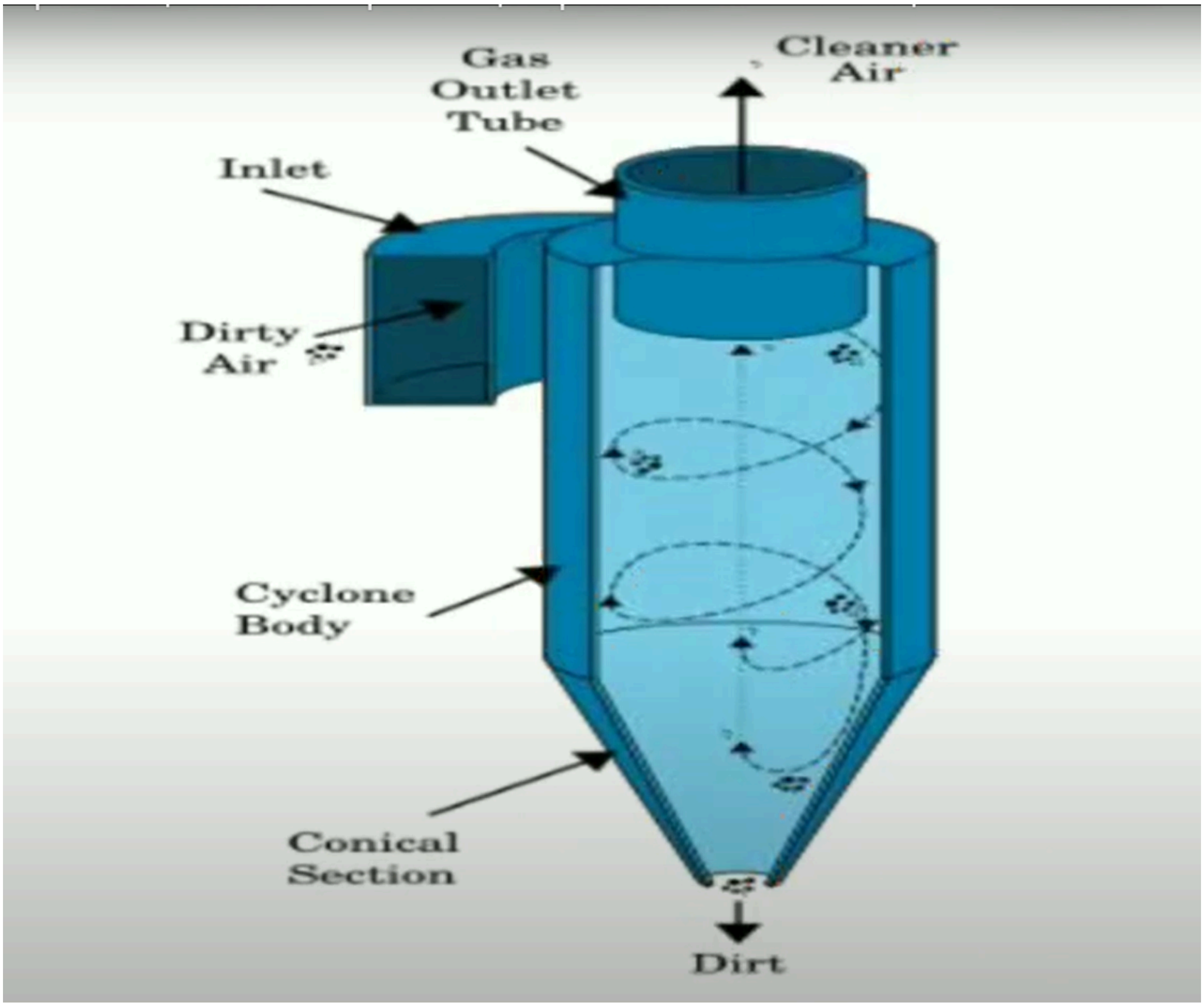
1. Low efficiency for particles smaller than 5-10 µm.
2. High abrasion may lead to rapid wear in severe conditions.
3. Efficiency decreases as particulate concentration drops.

Applications of Cyclone Separators

Cyclone separators are widely used in industries where particulate control is necessary:

1. **Cement, food, and textile industries**: Cyclones capture dust from processing operations.
2. **Rock crushing and ore handling**: Cyclones remove dust in mineral processing.
3. **Petroleum industry**: Used to recover valuable catalyst dusts.
4. **Power plants**: Cyclones help reduce fly ash emissions, contributing to cleaner air.





$D_{p,min} = [9\,\mu\,B / \pi\,V\,N_t(\varrho_p - \varrho)]^{1/2}$

Dp, min= dia of smallest particles that can be removed cm

μ = viscosity of the fluid

B= width of cyclone inlet duct

V= avg. inlet velocity

Nt= no of turns made by gas stream in cyclone

ϱ_p = density of particles

ϱ = density of fluid

Esp

Electrostatic precipitators

- Works on the principle of electrical charging of particulate Matter (-ve) and collecting it in a (+ve) charged surface.
- 99% efficiency.
- Can remove particle size range of 0.1 μm to 1 μm.

Six major components

- A source of high voltage
- Discharge electrodes and collecting electrodes
- Inlet and outlet for gas
- A hopper for disposal of collected material
- An electronic cleaning system
- An outer casing to form an enclosure around electrodes

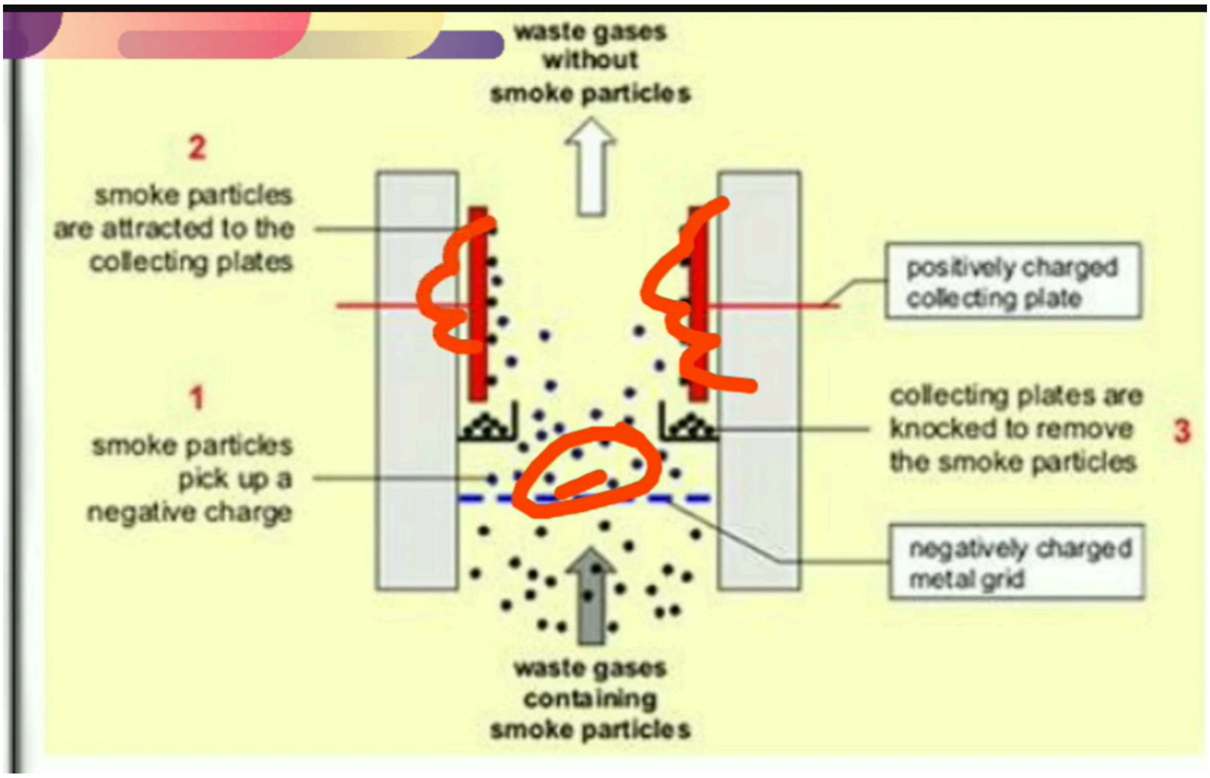


Plate Electrostatic Precipitators (ESPs) - Detailed Overview

Principle and Structure
Plate electrostatic precipitators (ESPs) are a common choice for collecting dry particles in industries. In these systems:

- **Construction**: Plate ESPs consist of discharge electrodes (wires or rigid frames) and collecting plates that are designed to create an electrical field across the gas flow. Dirty gas flows into a chamber with electrodes aligned between collection plates.
- **Operation**: As dirty gas passes through the chamber, particles get charged by the high-voltage discharge electrodes. These charged particles then migrate to the collecting plates due to electrostatic attraction, forming a dust layer. This layer is periodically removed by mechanical rapping or water sprays.

Specifications:

- **Discharge Electrodes**: Typically wires ranging from 0.13 to 0.38 cm in diameter.
- **Collection Plates**: Plates generally measure between 3 to 6 meters in height, with a spacing of 15 to 35 cm for wire discharge electrodes. For plate discharge types, spacing is wider, typically 30 to 38 cm with plate heights ranging from 8 to 12 meters.

Applications:
Plate ESPs are effective for applications requiring removal of fine particles from flue gases in:

1. **Cement Factories**: Used for flue gas cleaning and cement dust recovery.

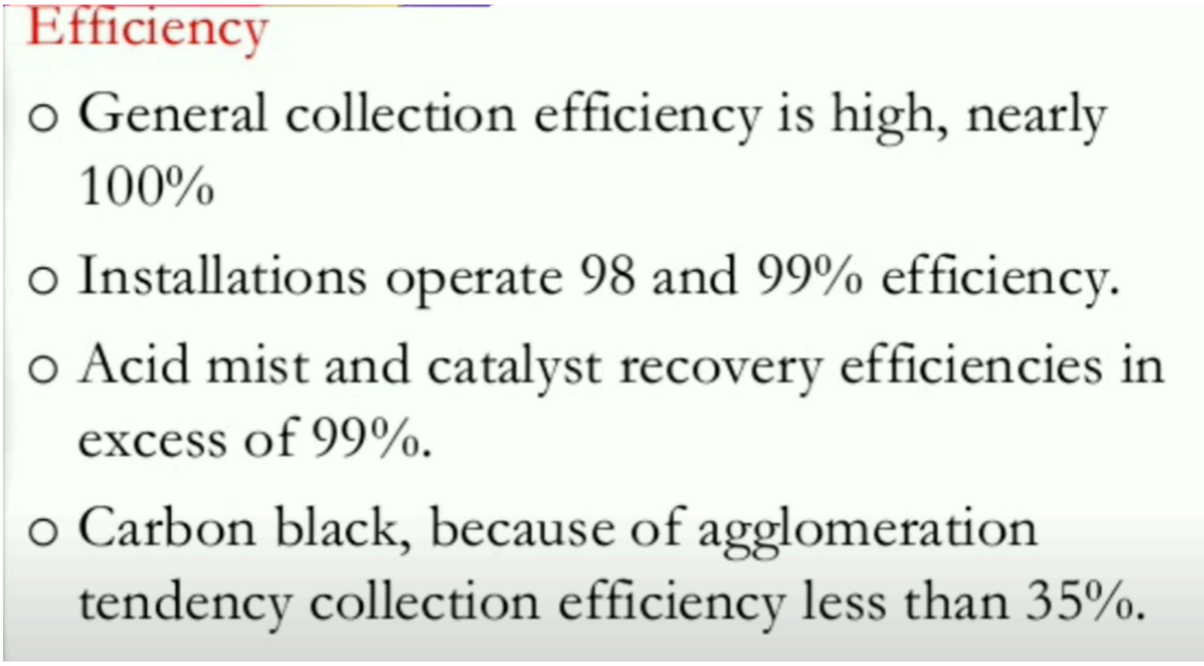
2. **Pulp and Paper Mills**: Effective in soda-fume recovery in Kraft pulp mills.
3. **Steel Plants**: Applied for cleaning gases in blast furnaces and removing tar from coke gases.
4. **Chemical Industries**: Collection of acid mists, removal of SO_2, CO_2, and other gases.
5. **Petroleum Industry**: Catalyst recovery.
6. **Carbon Black Industry**: Used for carbon black agglomeration and collection.
7. **Thermal Power Plants**: Primarily used to collect fly ash from coal-fired boilers.

Advantages of Plate ESPs:

1. High collection efficiency, even for particles as small as 0.1 μm.
2. Minimal maintenance and operating costs.
3. Low pressure drop across the ESP system.
4. Handles large volumes of high-temperature gases effectively.
5. Short treatment time and straightforward cleaning process.

Disadvantages:

1. High initial costs due to the equipment size and high-voltage requirements.
2. Large space requirements for the equipment.
3. Potential for explosion hazards due to particle buildup and high voltage.
4. Safety precautions are essential, as the ionization process can produce ozone, a toxic byproduct.



Fabric Filters (Baghouse Filters) - Overview

Principle

Fabric filters, also known as baghouse filters, remove particulates from gas streams using a sieving mechanism. The fabric's tiny pores capture large particles, allowing clean gas to pass through. As particulates deposit on the fabric, they form a **dust cake** layer, which becomes an additional filter layer, enhancing efficiency. Initially, efficiency may be lower until this pre-coat forms, after which it acts as a highly efficient filtering medium.

Construction

A typical baghouse filter consists of:

- **Fabric Bags**: These are tubular and vertical, with diameters of 120-400 mm and lengths of 2-10 m.
- **Baffle Plate**: Positioned at the inlet, it slows down the carrier gas, allowing larger particles to fall by gravity.
- **Suspension System**: Bags are held by a manifold, which may include a shaking or pulsing mechanism for periodic cleaning.
- **Dust Hopper**: Collects particulates that settle after separation.

Working

Gas enters the filter housing and strikes the baffle plate, which causes heavier particles to settle into the hopper. The gas continues upward into the bags, and particulates adhere to the inside walls, creating a dust layer. Clean gas exits through the outlet, and over time, dust buildup increases airflow resistance, necessitating periodic bag cleaning.

Factors Affecting Efficiency

1. **Filter Ratio**: Defined as the carrier gas volume per gross filter area per minute. Higher filter ratios can lower efficiency, as particles may escape through the fabric.
2. **Filter Media Selection**: Depends on factors such as particle size, gas composition, temperature resistance, and abrasion resistance. Proper media can significantly improve efficiency and reduce wear.
3. **Carrier Gas Velocity**: Higher velocities can increase filter ratios and allow particles to escape, decreasing efficiency.

Operating Problems

1. **Cleaning**: Dust buildup restricts airflow, requiring periodic cleaning using methods like rapping, shaking, or reverse air.
2. **Cloth Rupture**: Repeated cleaning can lead to fabric tears, which may be hard to detect and require filter replacement.
3. **Temperature Sensitivity**: Excessive temperatures, especially in reactive gases (e.g., with SO_2), can degrade filters. Insulation or auxiliary heaters are often used to prevent temperature dips below dew points.

4. **Bleeding**: High filtration velocities or loosely woven fabrics can lead to fine particles escaping.
5. **Humidity Control**: Hygroscopic dusts attract moisture, complicating cleaning and risking clogging.
6. **Chemical Attack**: Some carrier gases contain corrosive elements, so acid/alkali-resistant fabrics may be necessary.

Filter Cleaning Methods

1. **Shaking**: Bags are manually or mechanically shaken, causing dust to loosen and fall. Effective for non-sticky dust but requires filtration stoppage.
2. **Reverse Air Flow**: Air jets blow in reverse through the bag to remove dust. This method doesn't require stopping the filtration process but involves higher maintenance due to moving parts.
3. **Pulse Jet**: High-pressure air pulses inflate bags, dislodging dust without moving parts or filtration pauses.

Advantages and Disadvantages

Advantages:

1. High efficiency for a wide particle size range.
2. Straightforward construction and low operational complexity.
3. Low power needs.
4. Dry particulate disposal simplifies handling.

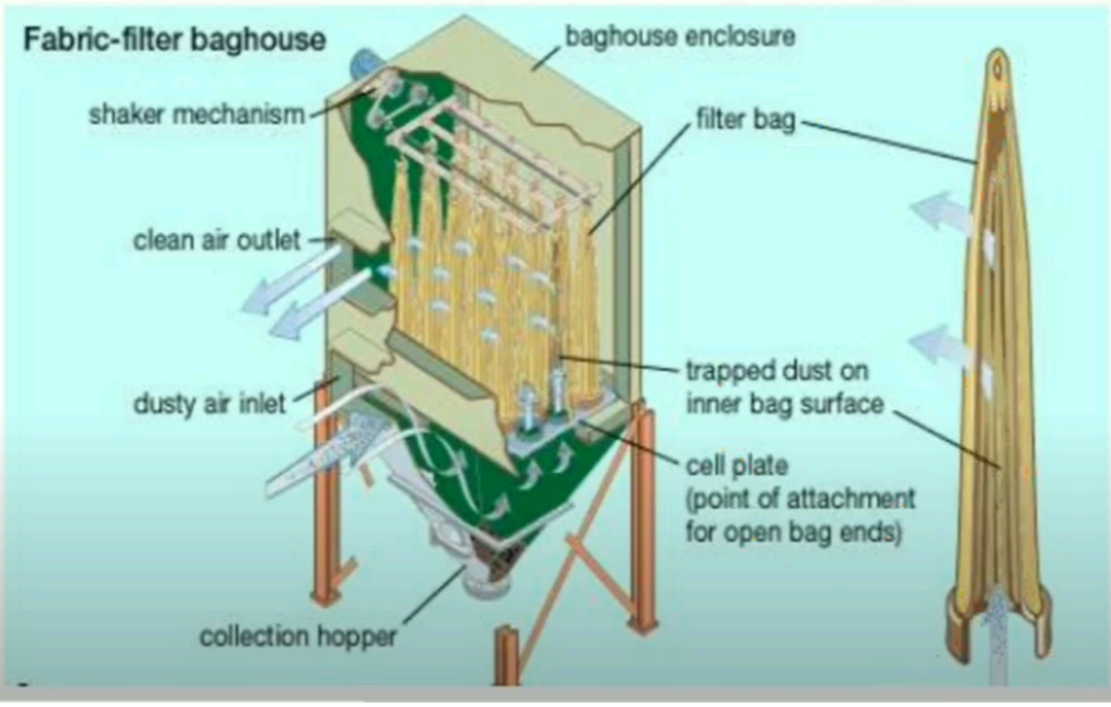
Disadvantages:

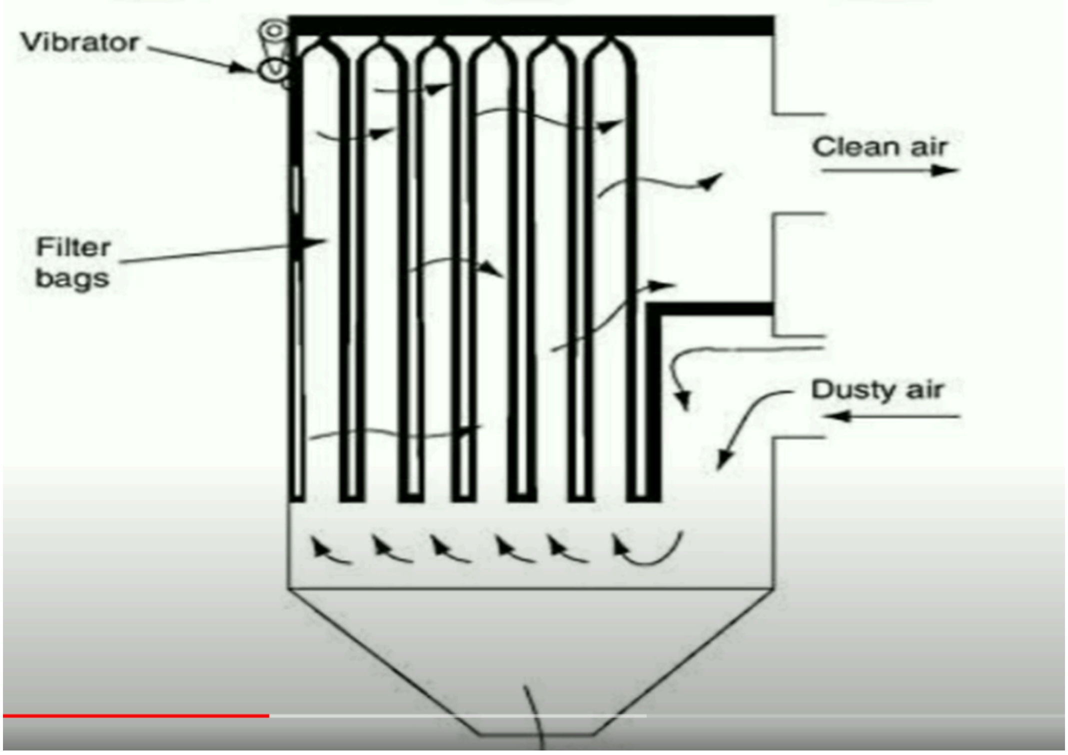
1. Sensitivity to high temperatures and humidity.
2. High maintenance and replacement costs.
3. Bulky size requirements.
4. Abrasion and clogging issues with certain dust types.

Fabric filters are particularly effective in applications requiring high filtration efficiency and dry disposal methods, but design and operational conditions must consider factors like dust properties, gas temperature, and cleaning methods to maintain efficiency and durability.

Fabric filters or cloth filters

- Flue gas is allowed to pass through a woven fabric, which filters out particulate matter.
- Small particles are retained on the fabric.
- Consists of numerous vertical bags 120-400 mm dia and 2-10 m long.
- Remove particles up to 1 μm.
- Its efficiency up to 99%.





Operating problems

- Cleaning
- Rupture of cloth
- Temperature
- Bleeding
- Humidity
- Chemical attack

Filter cleaning

- Rapping
- Shaking
- Back wash
- Pulse jet

Application

- Metallurgical industry
- Foundries
- Cement industry
- Chalk and lime
- Brick works
- Ceramic industry
- Flour mills