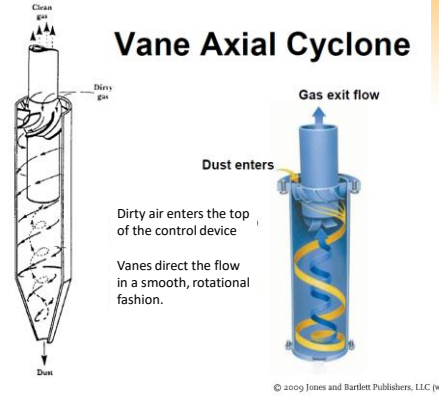
EVE 402
Air Pollution Generation and Control

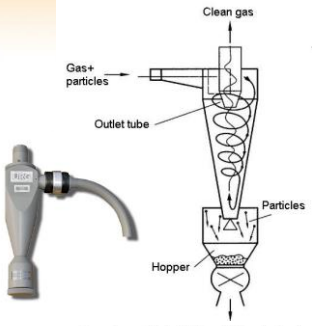
Chapter #5 Lectures (Part 4)

Cyclones

- A mechanical gas cleaning device
  - Gas is spun (centrifugal force) to separate particles
- Two types
  - Vane axial
    - A ring of vanes around an inner cylinder imparts the circular motion
  - Involute
    - A tangential gas inlet (rectangular cross-section) blends gradually to the cylinder over a 180° involute



Small Involute Cyclones

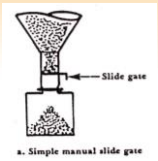


Large Involute Cyclones

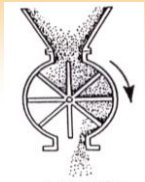
Cyclones in Series (or Parallel)

Units in series: increased removal efficiency
Units in parallel: increased volumetric capacity

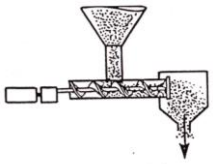
What happens to the collected particles??

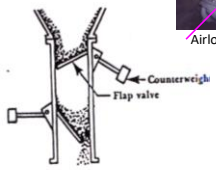


a. Simple manual slide gate


b. Rotary valve


Airlock system


c. Discharge screw feeder



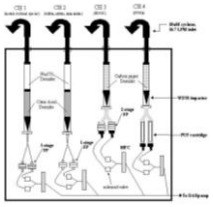
d. Automatic flap valve

Cyclones are used when:

- Particles are coarse (d_p > 10 μm)
- Concentrations are high (> 2 g/m³)
- Size classification is desired
- High efficiency is not required

General applications include:
Oil refineries to separate oils and gases
Cement industry
Vacuum cleaners

Cyclones are often used to pre-clean



Cyclone Design Characteristics

- High efficiency type
  - High pressure drop (ΔP)
  - Good collection of small d_p (< 10 μm)
- High throughput type
  - Low pressure drop
  - High flowrate
  - Poor collection of small d_p (< 10 μm)
- Conventional type
  - Intermediate to high efficiency and high throughput

Efficiency Range of Cyclones

Particle size range (μm)	Efficiency Percentage	
	Conventional	High Efficiency
Less than 5	Less than 50	50 – 80
5 – 20	50 – 80	80 – 95
15 – 40	80 – 95	95 – 99
Greater than 40	95 - 99	95 – 99

Irrespective of design, removal efficiency of any cyclone drops rapidly below a certain d_p.

Cyclones (Centrifugal Force)

In settling chambers, gravitation force is used to remove large particles (d_p > 10 μm) from gas streams but is not very effective for smaller particles.

Centrifugal force can be used to achieve larger removal efficiencies for smaller particles.

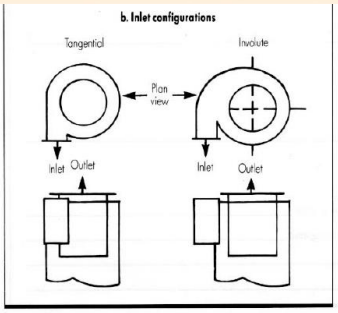
The gas stream is forced to change its direction, but the particles have **inertia**.

Centrifugal force causes the particles to be transported in a different direction than the gas stream, allowing for their separation and collection.

Tangential Inlet and Involute Inlet—A Comparison

- A straight tangential entry creates quite a bit of turbulence which will lead to back mixing and loss of efficiency
- The involute brings the gas in parallel to the outer edge of the cyclone (tangent at that point) and leads it around a spiral for 180˚ to enter the top section with minimum turbulence

Tangential Inlet and Involute Inlet—A Comparison



Operating Problems

- **Erosion**: Heavy, hard, sharp-edged particles, in a high concentration, moving at high velocity in the cyclone, continuously scrape against the wall and can erode the metallic surface unless suitable materials are used.
- **Corrosion**: it is a problem if the cyclone is operating below the condensation point when reactive gases are present in the effluent stream. Best to operate above the dew point.
- **Build-up**: of dust cake on the cyclone walls, especially around the vortex finder, at the ends of any internal vanes, and opposite the entry can become a severe problem. Frequently occurs with hygroscopic dusts.

Cyclone Advantages

- Low capital cost
- High efficiency over a broad flow range
- Ability to optimize the design for flowrate
- Simple construction and operation
- Potential for low ΔP resulting in energy savings
- Low maintenance requirements
- No moving parts
- High safety during operation under pressure
- Continuous disposal of solid particles
- Any material can be used for construction that meets temperature, pressure and corrosion resistant requirements

Cyclone Disadvantages

- Low collection efficiency for particles below 5 – 10 µm in diameter
- Equipment is subject to severe abrasive deterioration
- Collection efficiency decreases as particulate loading decreases

Involute Cyclone and its Standardized Proportions

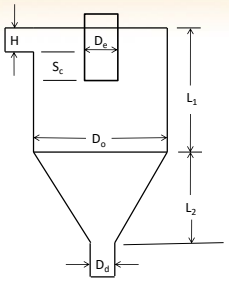
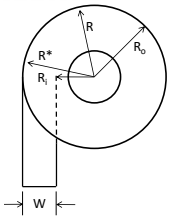


Table 5-6. Standard Cyclone Proportions	
Length of cylinder	$L_1 = 2D_o$
Length of cone	$L_2 = 2D_o$
Height of entrance	$H = D_o/2$
Width of entrance	$W = D_o/4$
Diameter of exit cylinder	$D_e = D_o/2$
Diameter of dust exit	$D_d = D_o/4$

There is interest in determining the particle removal efficiency of an involute cyclone with standardized proportions



Where:
R_o = outer radius of cyclone
R_i = inner radius of cyclone
$W = R_o - R_i$ = width of cyclone's inlet
R* = minimum or "critical" radius for which a particle of diameter, d_p, will just reach the outer wall of the cyclone and be removed from the gas stream.

$$\eta_d = \frac{R_o - R^*}{R_o - R_i}$$