AIR POLLUTION PREVENTION AND CONTROL

M J Pawari

Pollution Prevention Strategies

- Pollution prevention [vs. control] offers important economic benefits and at the same time allows continued protection of the environment.

- While most pollution control strategies cost money, pollution prevention has saved many firms thousands of dollars in treatment and disposal costs.

- More importantly, pollution prevention should be viewed as a means to increase company productivity.

- By reducing the amount of raw materials that are wasted and disposed of; manufacturing processes become more efficient, resulting in cost savings to the company.

- Pollution prevention should be the first consideration in planning for processes that emit air contaminants.

- Undertaking pollution prevention practices may reduce air emissions enough to allow a business or industry to avoid classification as a major air emission source.

What is Pollution Prevention?

- Pollution prevention is the elimination or prevention of wastes (air emissions, water discharges, or solid/hazardous waste) at the source. In other words, pollution prevention is eliminating wastes before they are generated.

- Pollution prevention approaches can be applied to all pollution generating activity: hazardous and nonhazardous, regulated and unregulated. Pollution prevention does not include practices that create new risks of concern.

SOURCE REDUCTION

- **Product Changes**

- Designing and producing a product that has less environmental impact
- Changing the composition of a product so that less hazardous chemicals are used in, and result from, production
- Using recycled materials in the product
- Reusing the generated scrap and excess raw materials back in the process
- Minimizing product filler and packaging
- Producing goods and packaging reusable by the consumer
- Producing more durable products

- **Input Material Changes**

- Material substitution Using a less hazardous or toxic solvent for cleaning or as coating

- Purchasing raw materials that are free of trace quantities of hazardous or toxic impurities

Equipment and Process Modifications

- Changing the production process or flow of materials through the process.

- Replacing or modifying the process equipment, piping or layout.

- Using automation.
- Changing process operating conditions such as flow rates, temperatures, pressures and residence times.

- Implementing new technologies

Good Operating Practices

- Instituting management and personnel programs such as employee training or employee incentive programs that encourage employees to reduce waste.
- Performing good material handling and inventory control practices that reduce loss of materials due to mishandling, expired shelf life, or improper storage.
- Preventing loss of materials from equipment leaks and spills.
- Segregating hazardous waste from non-hazardous waste to reduce the volume of hazardous waste disposed.

- **Using standard operating procedures for process operation and maintenance tasks**

- **Performing preventative maintenance checks to avoid unexpected problems with equipment.**

- **Turning off equipment when not in use.**

- **Improving or increasing insulation on heating or cooling lines.**

- **Environmentally Sound Reuse and Recycling**

Control of Gaseous Pollutants

- A**b**sorption
- A**d**sorption
- Oxidation
- Reduction

Absorption

Primary application: inorganic gases

Example: SO_2

Mass transfer from gas to liquid

Contaminant is dissolved in liquid

Liquid must be treated

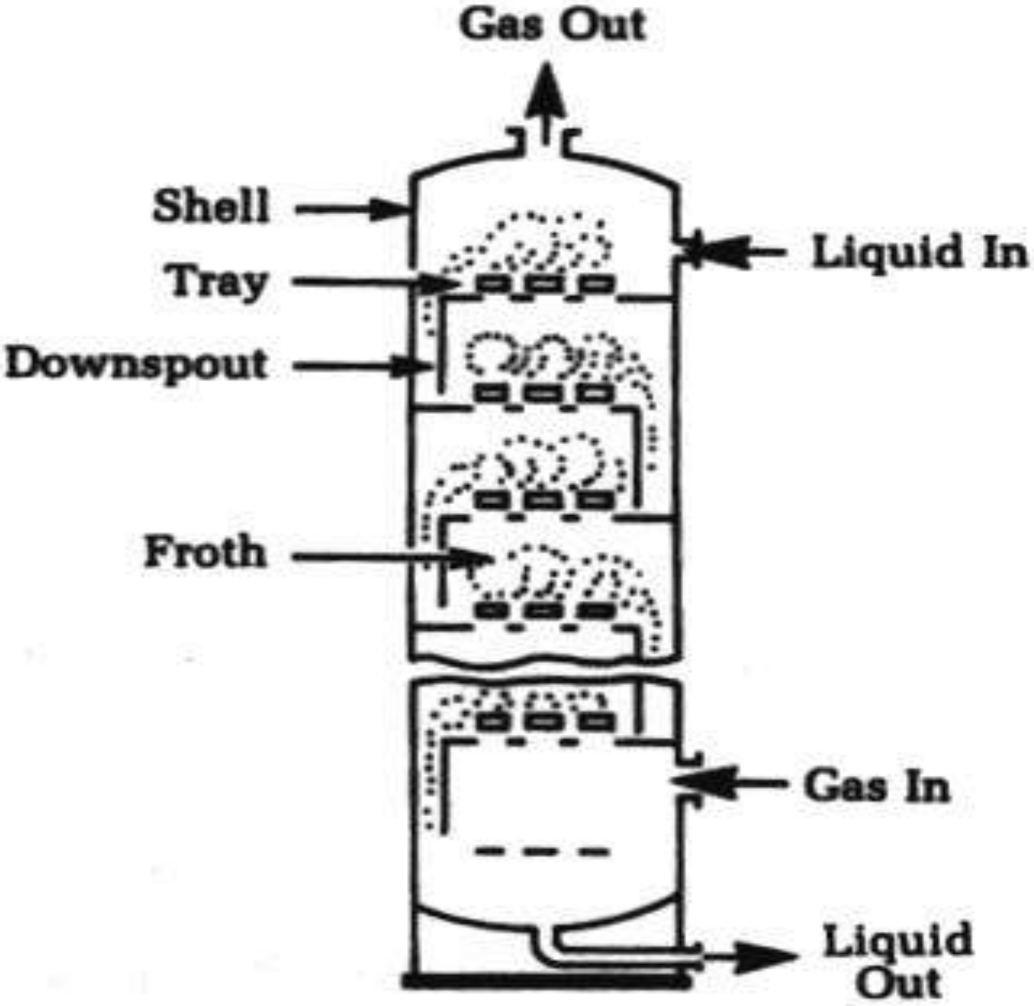
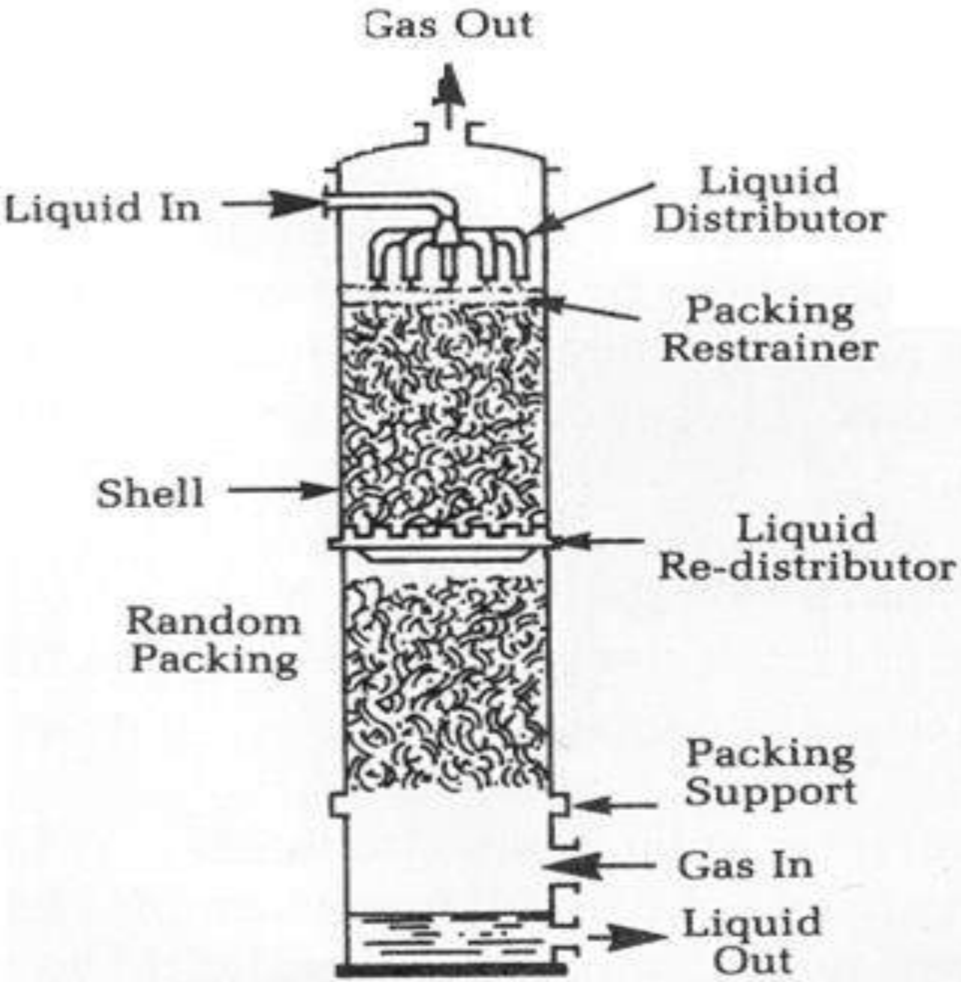

Gas Out
Shell
Liquid In
Tray
Downspout
Froth
Gas In
Liquid Out

Plate Tower



Packed Tower

Adsorption

Primary application: organic gases

Example: trichloroethylene

Mass transfer from gas to solid

Contaminant is ‘bound’ to solid

Adsorbent may be regenerated

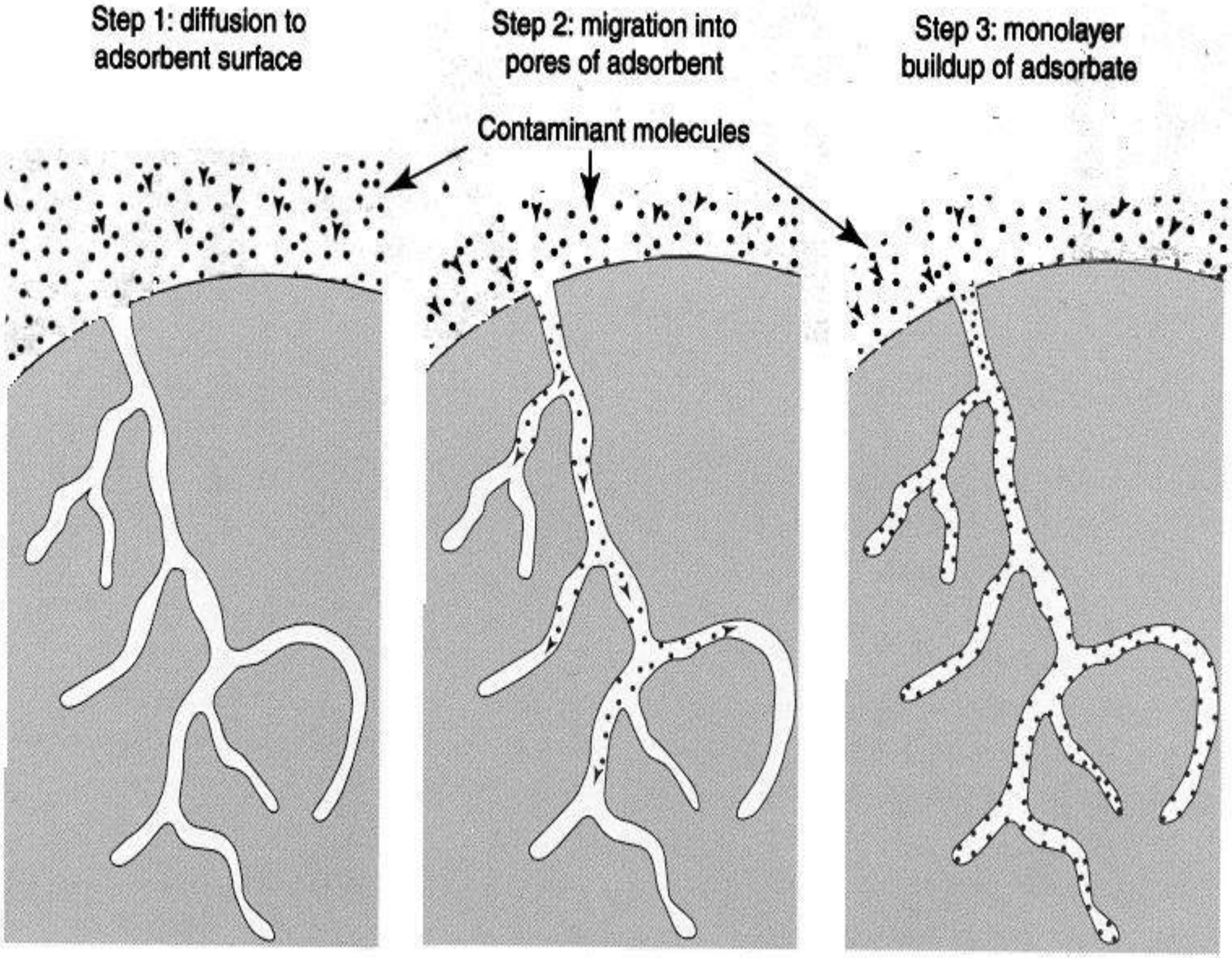
Common Adsorbents

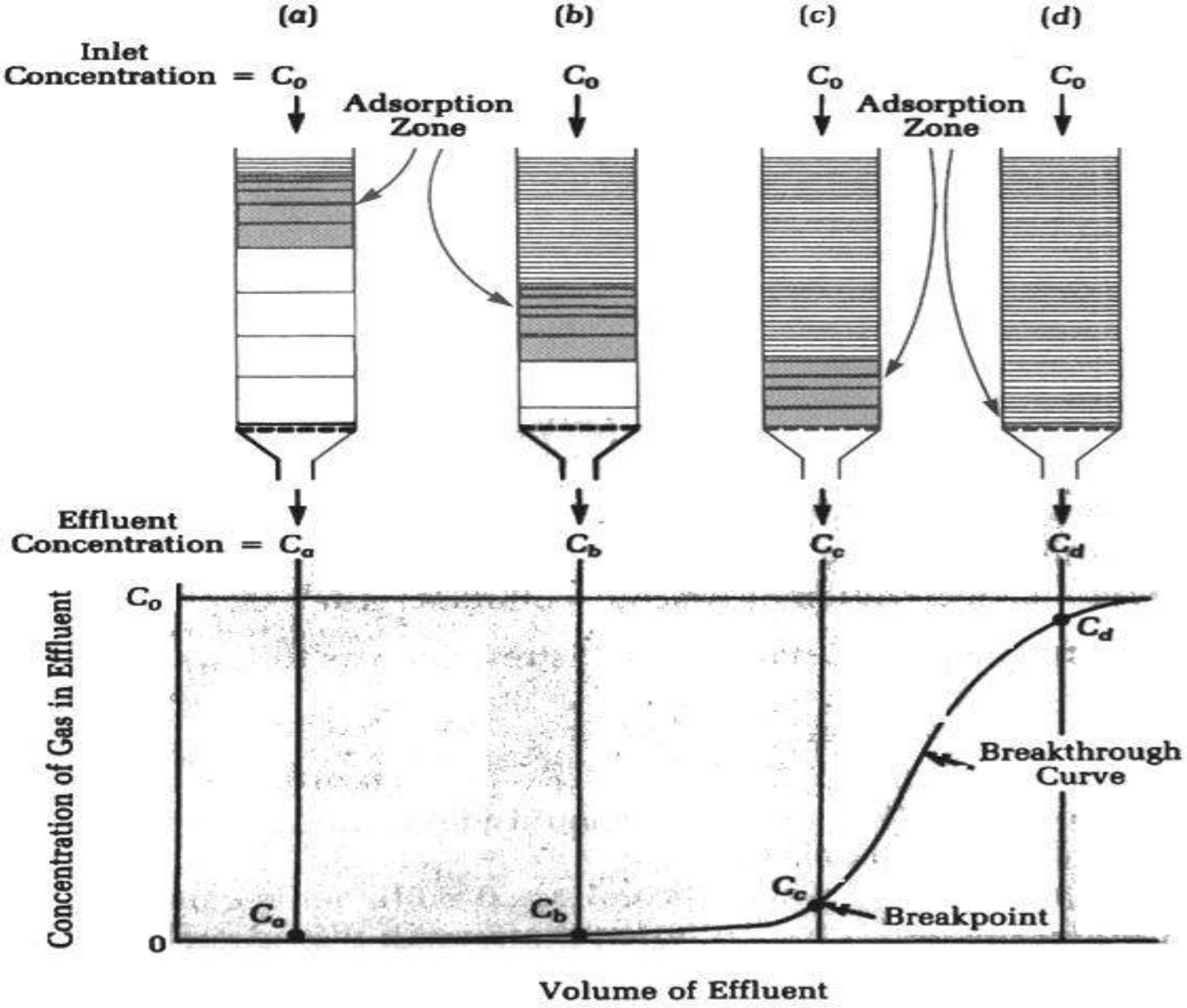
Activated carbon

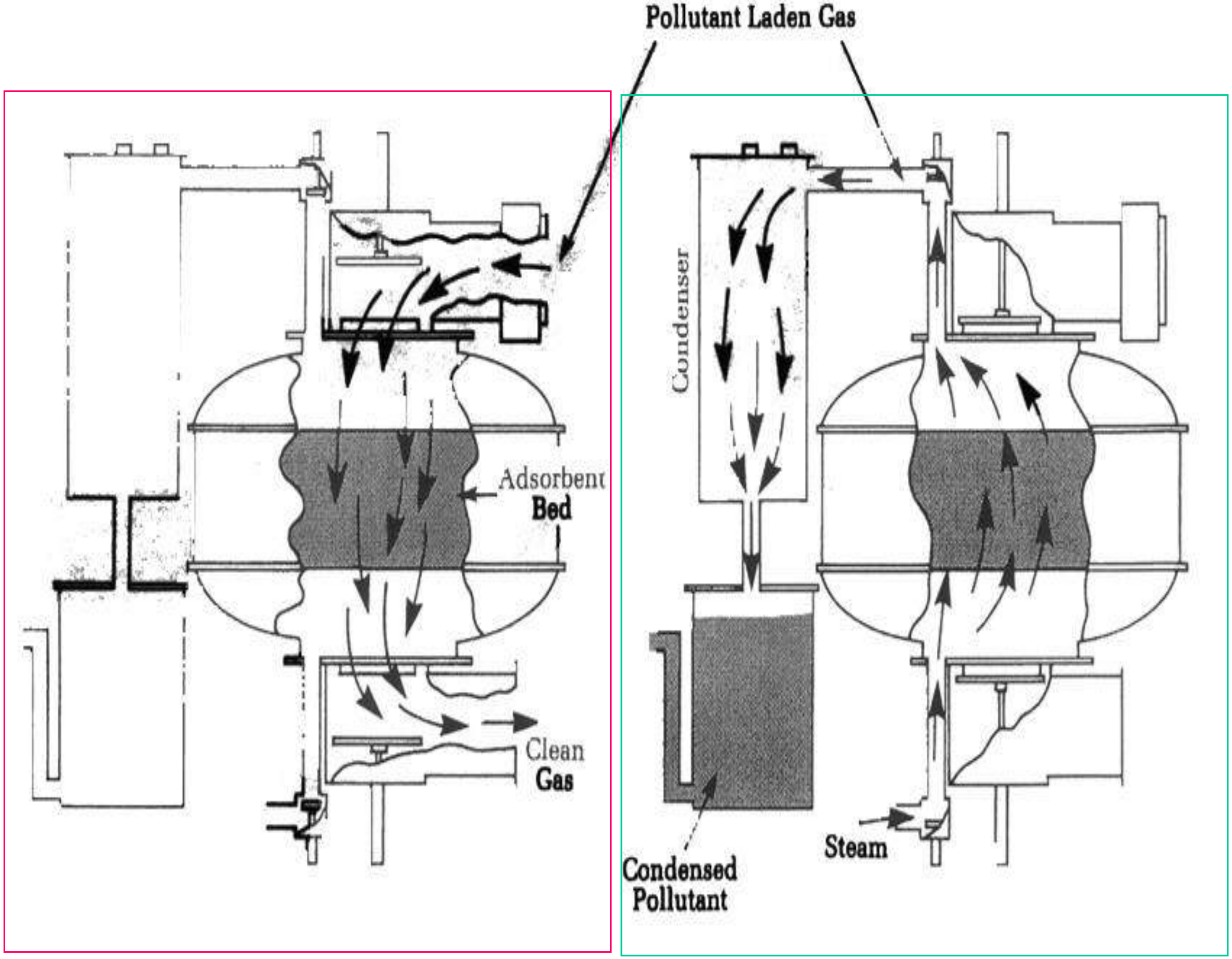
Silica gel

Activated alumina

Zeolites (molecular sieves)


Step 1: diffusion to adsorbent surface
Step 2: migration into pores of adsorbent
Step 3: monolayer buildup of adsorbate
Contaminant molecules


(a)
(b)
(c)
(d)
Inlet Concentration = C_o
C_o
C_o
C_o
Adsorption Zone
Adsorption Zone
Effluent Concentration = C_a
C_b
C_c
C_d
Concentration of Gas in Effluent
C_o
C_d
Breakthrough Curve
C_c
Breakpoint
C_a
C_b
0
Volume of Effluent



Adsorption Cycle

Desorption Cycle

Oxidation

- Thermal Oxidation
- Catalytic Oxidation

- A **thermal oxidizer** (or **thermal oxidiser**) is a process unit for air pollution control in many chemical plants that decomposes hazardous gases at a high temperature and releases them into the atmosphere.

- Thermal Oxidizers are typically used to destroy Hazardous Air Pollutants (HAPs) and Volatile Organic Compounds (VOCs) from industrial air streams.

- These pollutants are generally hydrocarbon based and when destroyed via thermal combustion they are chemically changed to form CO_2 and H_2O.

Thermal Oxidation

Application: organic gases

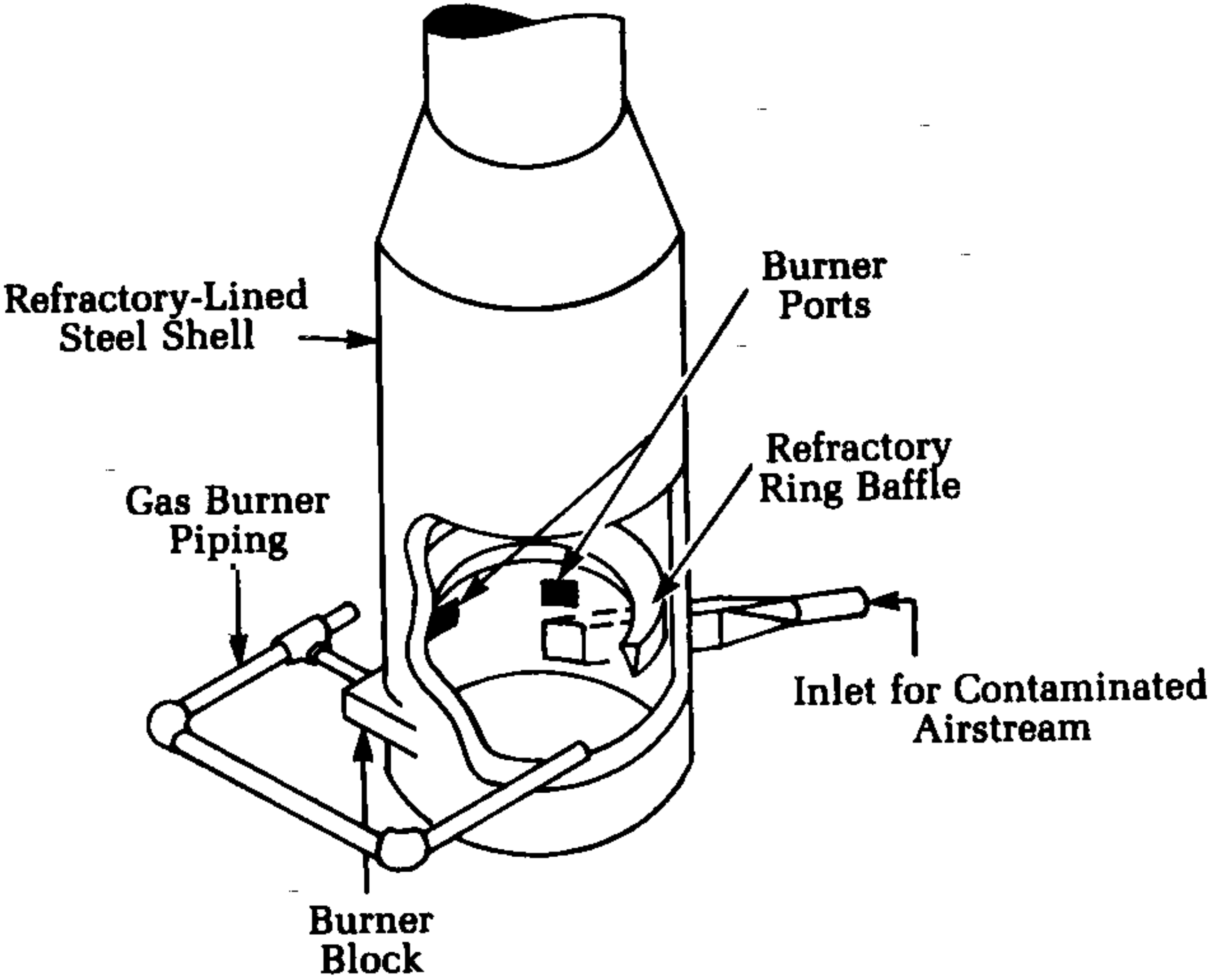
Autogenous gases = 7 MJ/kg (heat value)

Operating temperatures: 700 - 1300 ^{o}C

Efficiency = 95 - 99%

By-products must not be more hazardous

Heat recovery is economical necessity


Refractory-Lined Steel Shell
Burner Ports
Refractory Ring Baffle
Gas Burner Piping
Inlet for Contaminated Airstream
Burner Block

Catalytic Oxidation

- Catalytic oxidation is a relatively recently applied alternative for the treatment of VOCs in air streams resulting from remedial operations.

- The addition of a catalyst accelerates the rate of oxidation by adsorbing the oxygen and the contaminant on the catalyst surface where they react to form carbon dioxide, water, and hydrochloric gas.

- The catalyst enables the oxidation reaction to occur at much lower temperatures than required by a conventional thermal oxidation

Catalytic Oxidation

Application: organic gases

Non-autogenous gases < 7 MJ/kg

Operating temperatures: 250 - 425 ºC

Efficiency = 90 - 98%

Catalyst may be poisoned

Heat recovery is not normal

Selective Catalytic Reduction (SCR)

Application: NO_x control

Ammonia is reducing agent injected into exhaust

NO_x is reduced to N_2 in a separate reactor containing catalyst

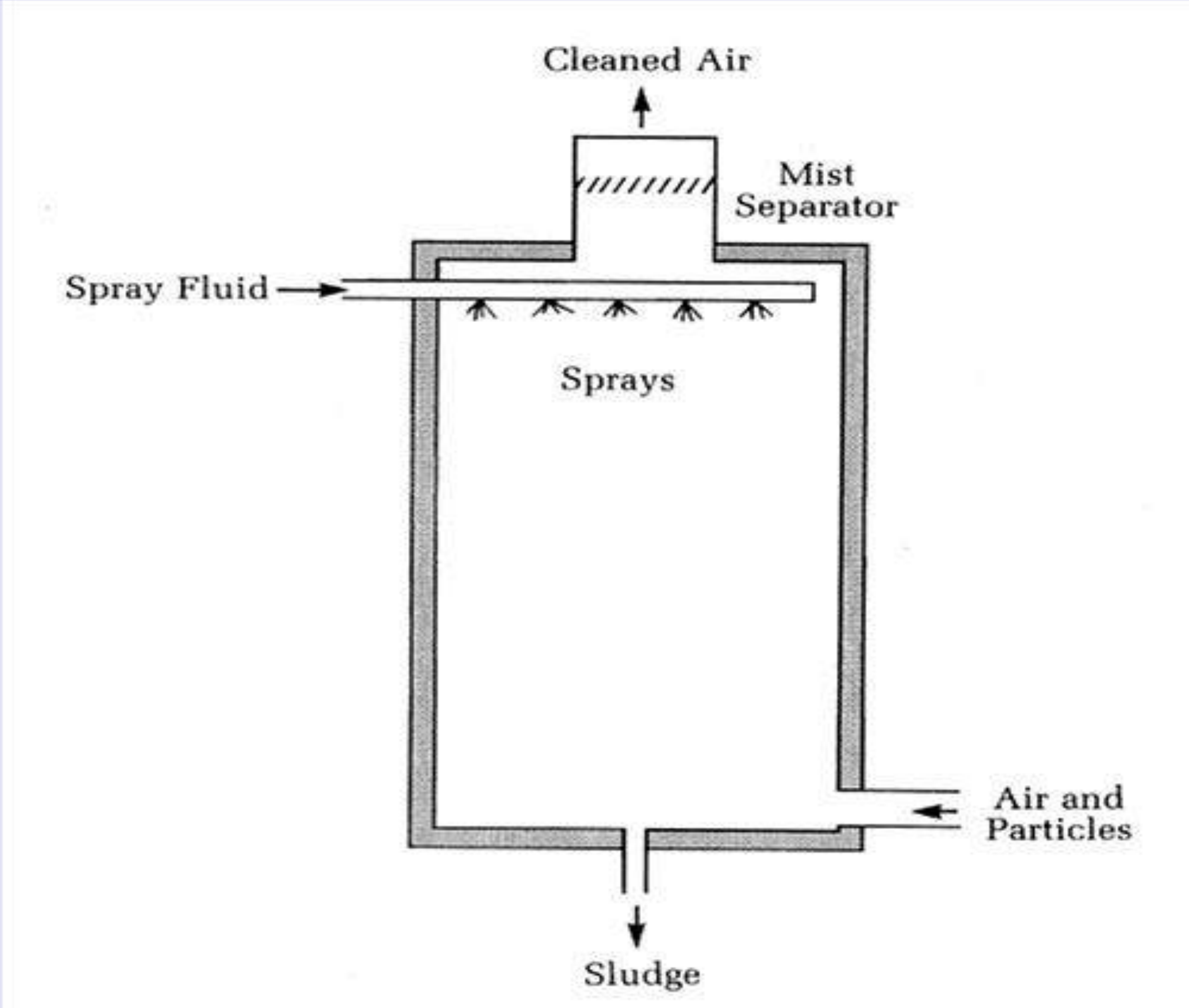
Reactions:

$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$

$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$

Control of Particulate Pollutants

- Spray chamber
- Cyclone
- Bag house
- Venturi
- Electrostatic Precipitator (ESP)



Spray Chamber

Spray Chamber

Primary collection mechanism:

Inertial impaction of particle into water droplet

Efficiency:

< 1% for < 1 um diameter

>90% for > 5 um diameter

Pressure drop: 0.5 to 1.5 cm of H_2O

Water droplet size range: 50 - 200 um

Spray Chamber

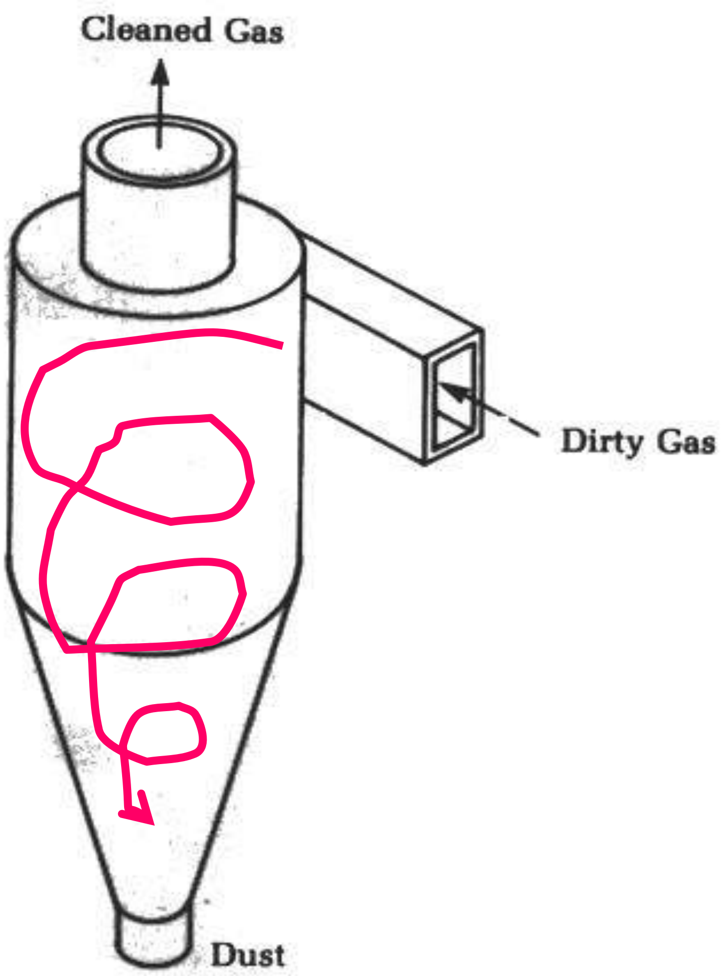
Applications:

1. Sticky, wet corrosive or liquid particles

   Examples: chrome plating bath

   paint booth over spray

2. Explosive or combustible particles
3. Simultaneous particle/gas removal



Cyclone

Cyclone

(Multi-clones for high gas volumes)

Primary collection mechanism:

Centrifugal force carries particle to wall

Efficiency:

<50% for <1 um diameter

>95% for >5 um diameter

Cyclone

(Multi-clones for high gas volumes)

Pressure drop: 8-12 cm of H_2O

Applications:

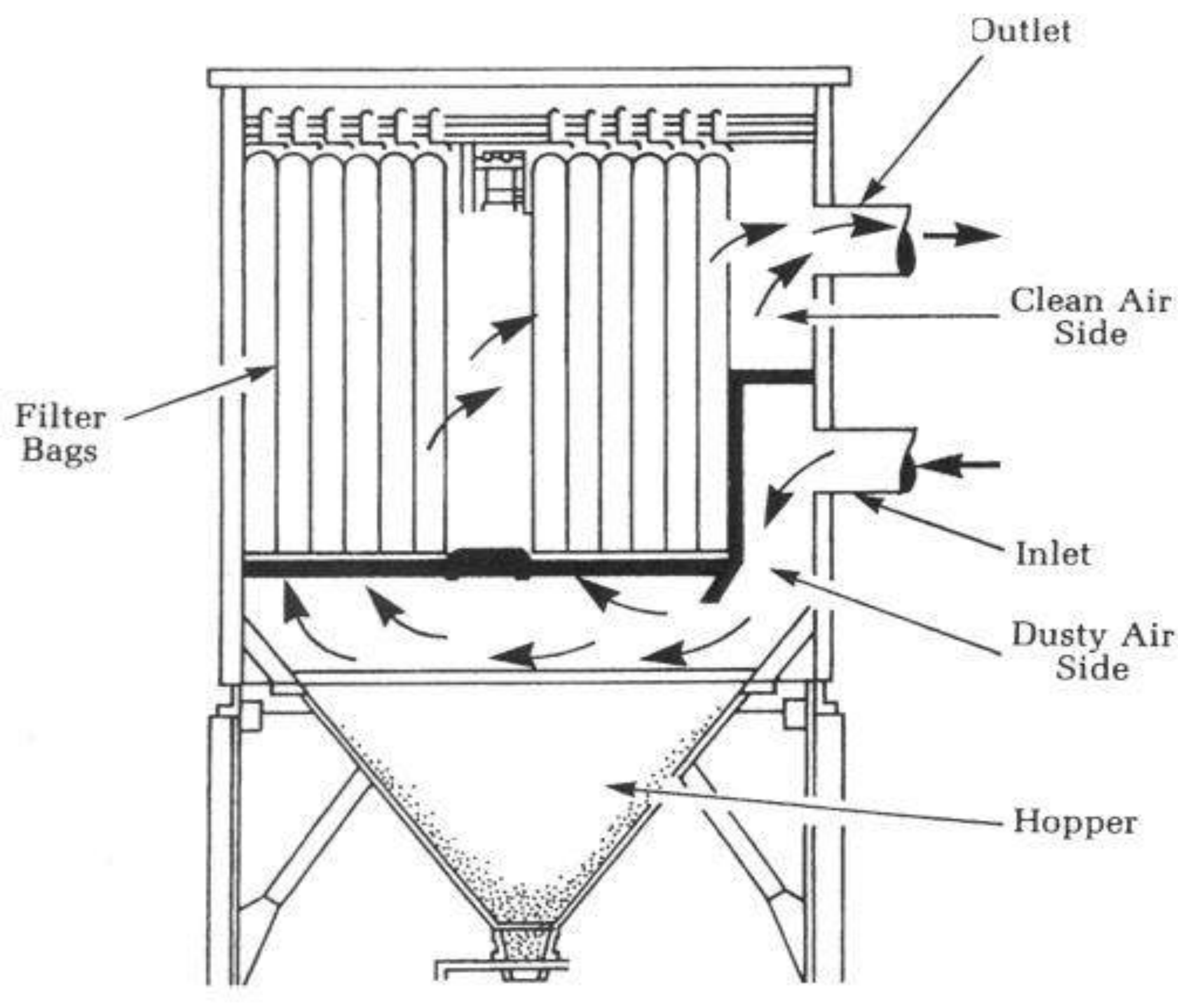
1. Dry particles

   Examples: fly ash pre-cleaner

   saw dust

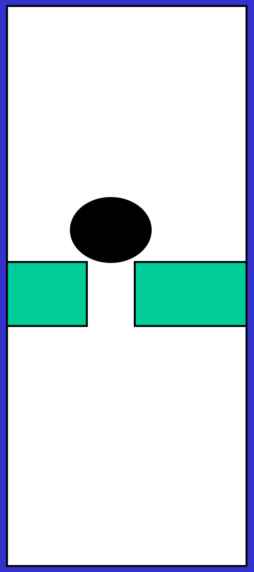
2. Liquid particles

   Examples: following venturi

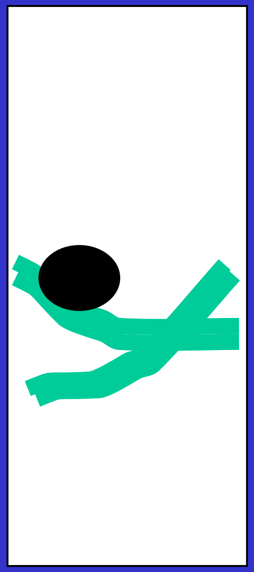

Outlet
Clean Air Side
Filter Bags
Inlet
Dusty Air Side
Hopper

Bag House

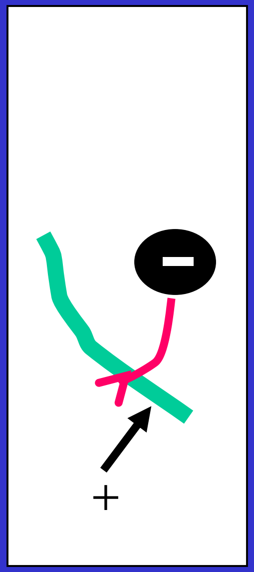
Bag House
Particle Collection Mechanisms



Screening



Impaction



Electrostatic

Bag House

Efficiency:

>99.5% for <1 um diameter

>99.8% for >5 um diameter

Fabric filter materials:

1. Natural fibers (cotton & wool)
   Temperature limit: 80 ^{o}C
2. Synthetics (acetates, acrylics, etc.)
   Temperature limit: 90 ^{o}C
3. Fiberglass
   Temperature limit: 260 ^{o}C

Bag House

Bag dimensions:

15 to 30 cm diameter

~10 m in length

Pressure drop: 10-15 cm of H_2O

Cleaning:

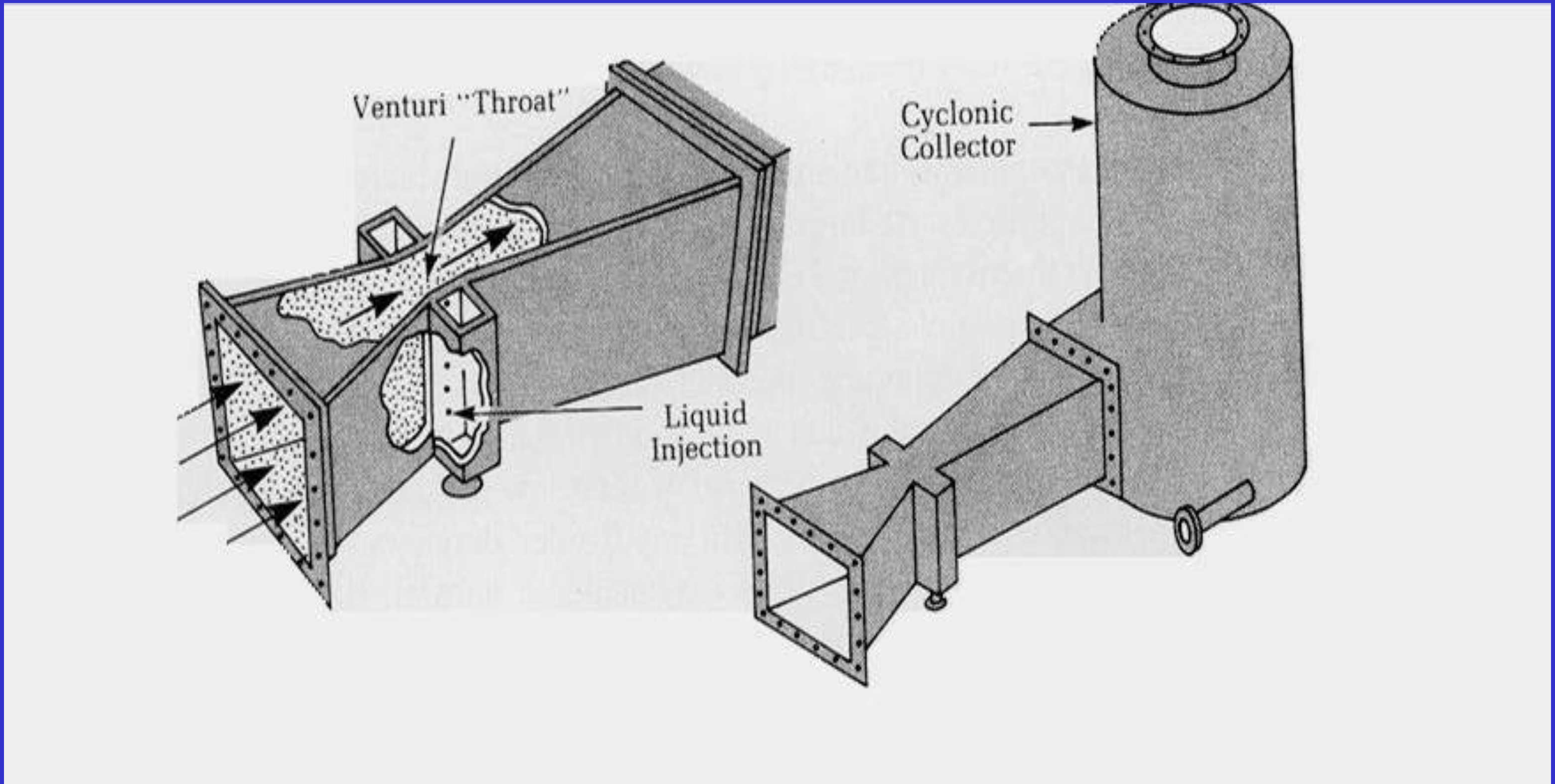
1. Shaker
2. Reverse air
3. Pulse jet

Bag House

Applications:

- Dry collection
    - Fly ash
    - Grain dust
    - Fertilizer

May be combined with dry adsorption media to control gaseous emission (e.g. SO_2)



Venturi

Venturi

Primary collection mechanism:

Inertial impaction of particle into water droplet

Water droplet size: 50 to 100 um

Water drop and collected particle are removed by cyclone

Venturi

Efficiency:

- >98% for >1 um diameter
- >99.9% for > 5 um diameter

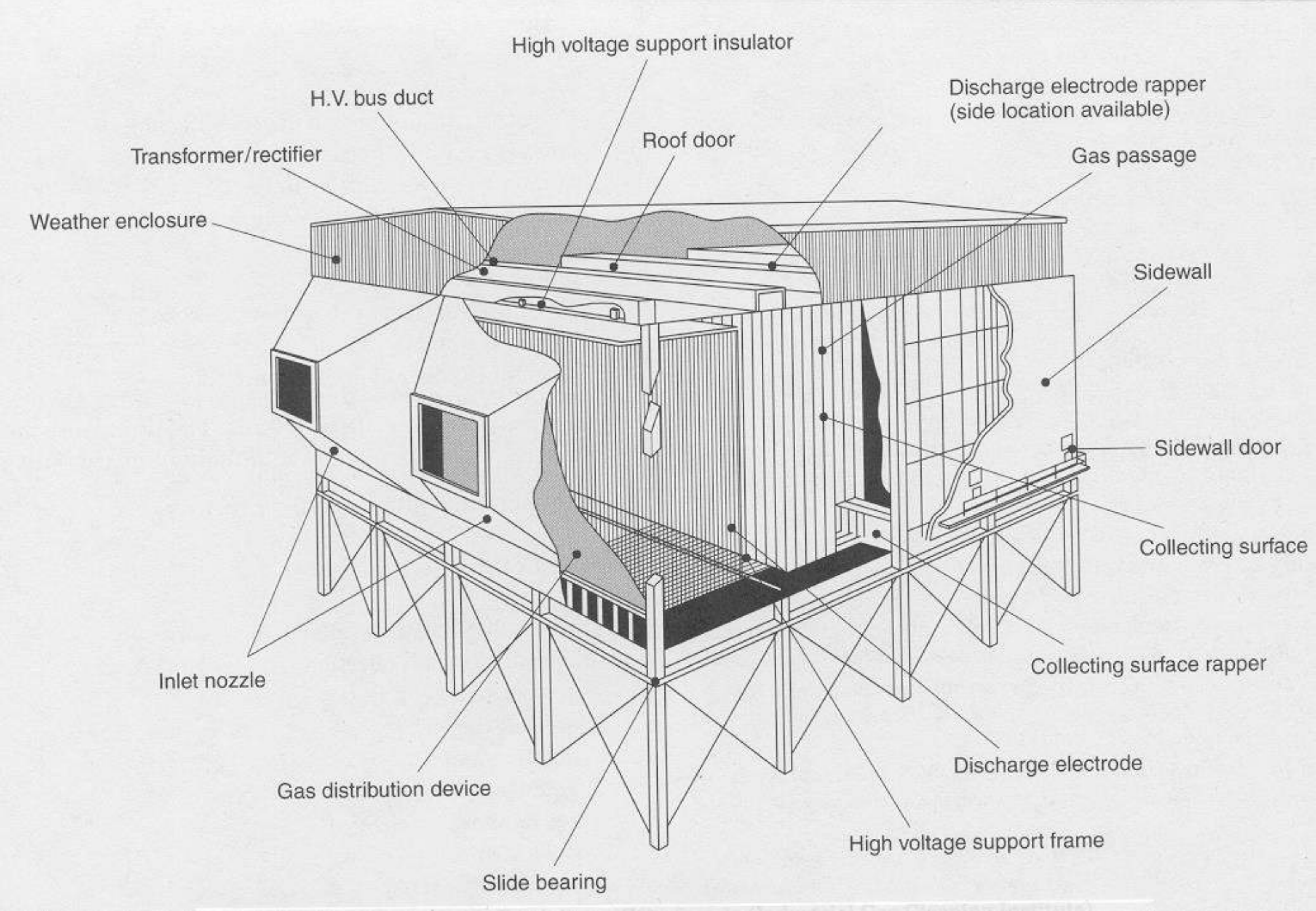
Very high pressure drop: 60 to 120 cm of H_2O

Liquid/gas ratios: 1.4 - 32 gal/1000 ft^3 of gas

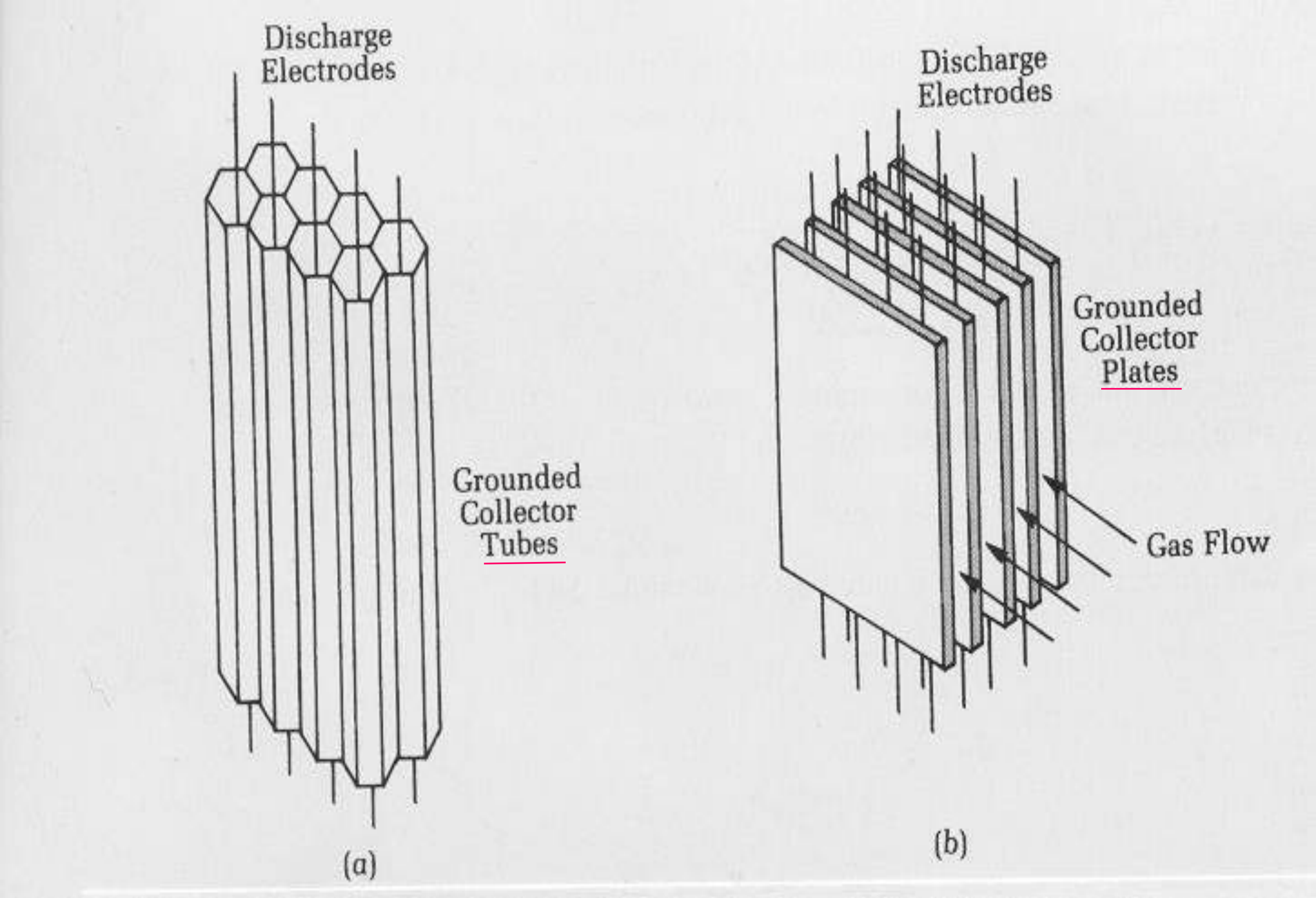
Venturi

Applications:

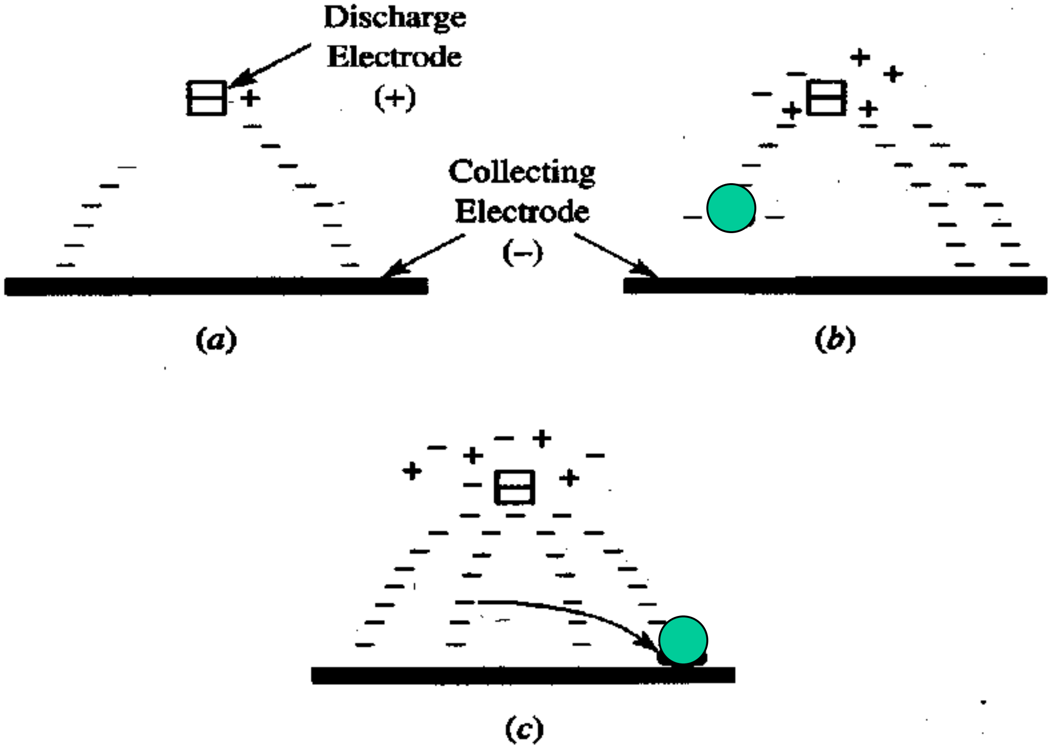
- Phosphoric acid mist
- Open hearth steel (metal fume)
- Ferro-silicon furnace



Electrostatic Precipitator (ESP)



ESP Tube (a) and Plate (b) collectors



ESP Collection Mechanism

Electrostatic Precipitator (ESP)

Efficiency:

- >95% for >1 um diameter
- >99.5% for > 5 um diameter

Pressure drop: 0.5 to 1.5 cm of H_2O

Voltage: 20 to 100 kV dc

Plate spacing: 30 cm

Plate dimensions: 10-12 m high x 8-10 m long

Gas velocity: 1 to 1.5 m/s

Cleaning: rapping plates

Electrostatic Precipitator (ESP)

Applications (non-explosive):

1. Fly ash
2. Cement dust
3. Iron/steel sinter

Flue Gas Desulfurization (FGD)

Predominant Processes (all non-regenerative):

1. Limestone wet scrubbing
2. Lime wet scrubbing
3. Lime spray drying

Typical scrubbers: venturi, packed bed and plate towers and spray towers

Flue Gas Desulfurization (FGD)

Spray dryer systems include a spray dryer absorber and a particle-collection system (either a bag house or an ESP)

In 1990 the average design efficiency for new and retrofit systems was 82% and 76% respectively

Flue Gas Desulfurization (FGD)

Overall reactions:

Limestone: $SO_2 + CaCO_3$ --> $CaSO_3 + CO_2$

Lime: $SO_2 + Ca(OH)_2$ --> $CaSO_3 + H_2O$