

EQUIPMENTS TO CONTROL AIR
POLLUTION

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COMMON CONTROL DEVICES	POLLUTANTS	EXAMPLES WHERE USED
Packed towers, spray chambers, venturi scrubbers	Gases, vapours, sulphur oxides, solid particles, liquid droplets	Asphalt and concrete batch plants, coal burning power plants
Carbon absorbers	Vapour phase VOCs, Hazardous Air Pollutants (HAPs)	Soil remediation facilities, oil refineries, steel mills, printers
Fabric filters or baghouses	Particulate Matter (PM)	Asphalt batch plants, steel mills, foundries', fertilizer plants,
Catalytic reactors	VOCs, Gases	Land fills, oil refineries, printing or paint shops
Cyclones	Large PM	Wood shops, pharmaceutical manuf,acture rock crushers, cement plants
ESPs	PM	Power plants, steel & paper mills, smelters, cement plants, refineries
Incinerators	VOCs, gases, fumes, Haps, PM	Soil contaminated with gasoline, ink and printing, hazardous waste disposal
Biofilters	VOCs, odours, H ₂ S, marcaptans	Wastewater treatment plants

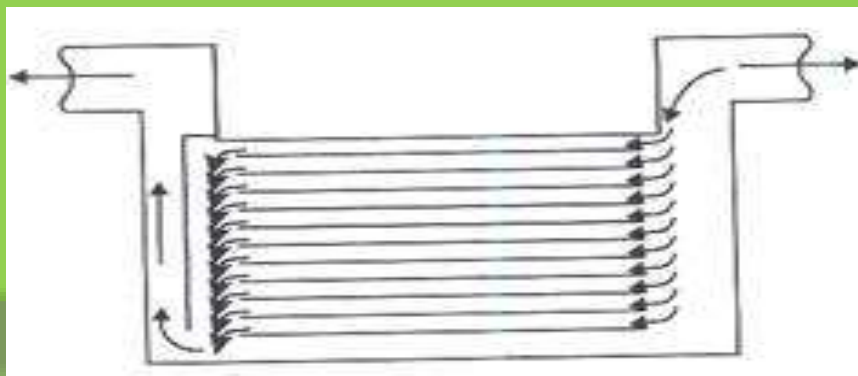
PARTICULATE CONTROL EQUIPMENT – Basic

Mechanisms

- Gravitational settling
- Centrifugal impaction
- Inertial impaction
- Direct interception
- Diffusion
- Electrostatic perception

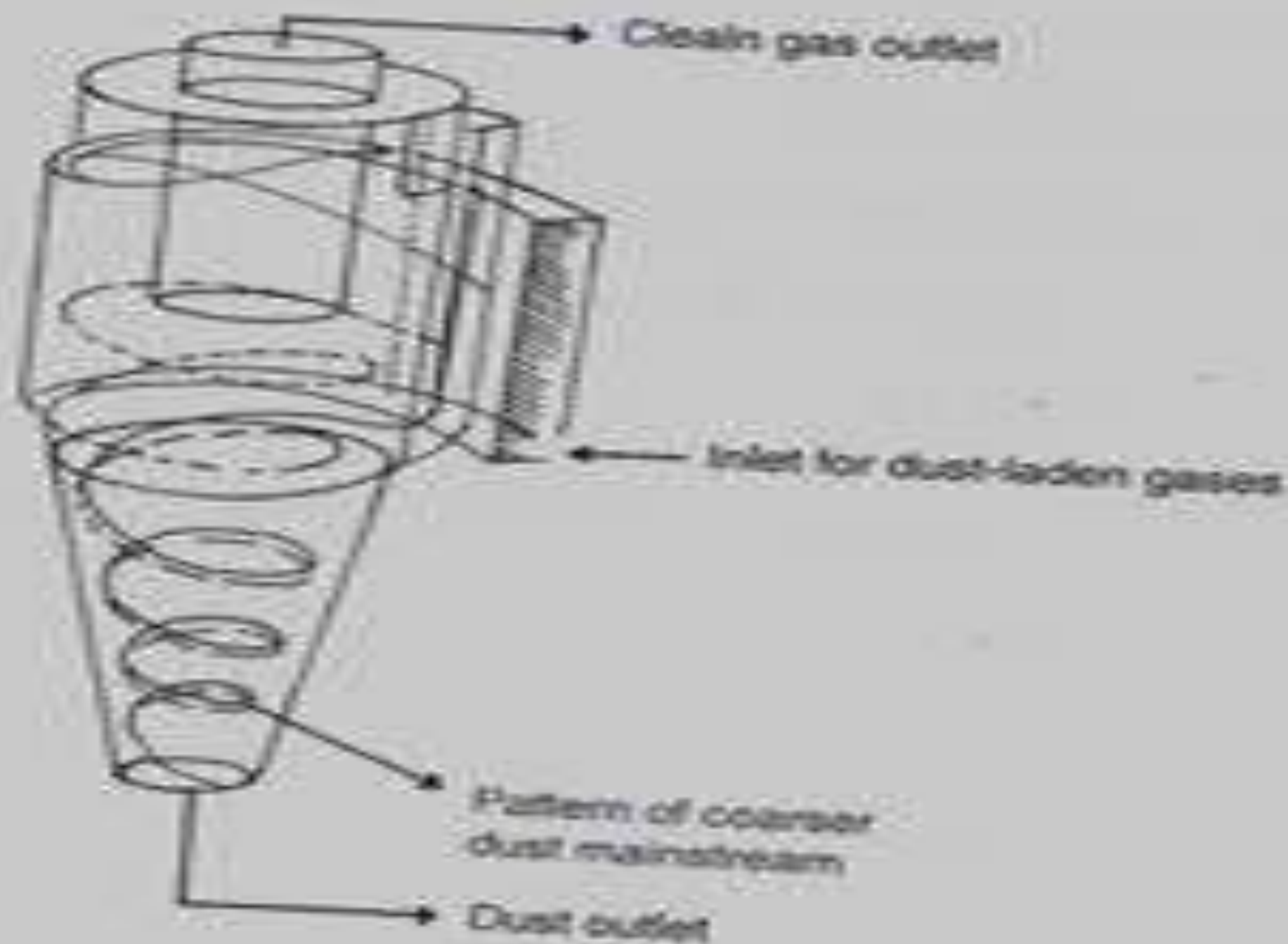
GRAVITATIONAL SETTLING CHAMBERS

- To remove large, abrasive particles from gas streams
- Require simple maintenance
- The particulate matter is settled by its own weight by lowering the flue gas velocity.
- It essentially consists of a chamber in which the velocity of the carrier gas is decreased so that particles in the gas settle down by gravity.
- Velocity of a gas is reduced by expanding the ducting into a chamber of a suitable dimension so that a low gas velocity is obtained. Its efficiency can be increased by providing plates or baffles



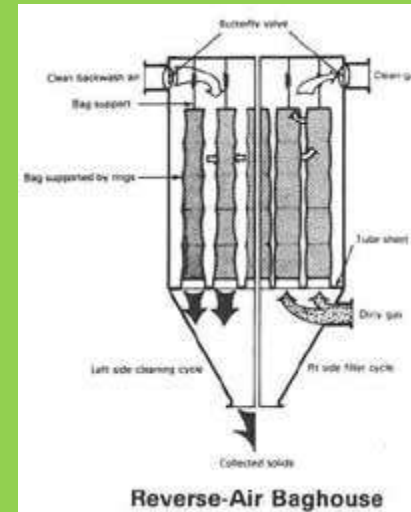
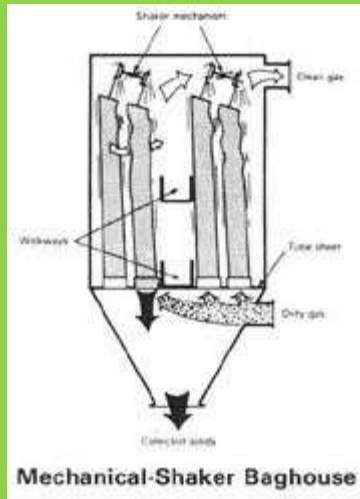
CYCLONE SEPARATOR

- Used for the separation of solids from fluids
- Separation based both on particle size and particle density
- It uses centrifugal force to effect the separation
- It consists essentially a short vertical cylinder closed at the top and by a conical bottom. The air with its load of solid introduced tangentially at the top, solids particles drop into the hopper and outlet air pass through the top central portion.
- Widely used for the collecting of wood chips ,heavy and coarse dusts



FABRIC FILTERS OR BAGHOUSES

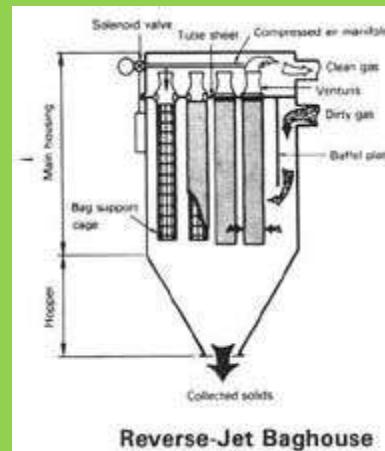
- Fabric collectors use filtration to separate dust particulates from dusty gases.
- The most efficient and cost effective types of dust collectors available and can achieve a collection efficiency of more than 99% for very fine particulates.
- Dust-laden gases enter the bag house and pass through fabric bags that act as filters. The bags can be of woven or felted cotton, synthetic, or glass-fiber material in either a tube or envelope shape.
- Their advantages include retention of finest particles, collection of particulates in dry form and low pressure drop
- As classified by cleaning method, three common types of bag houses are:



Mechanical shaker

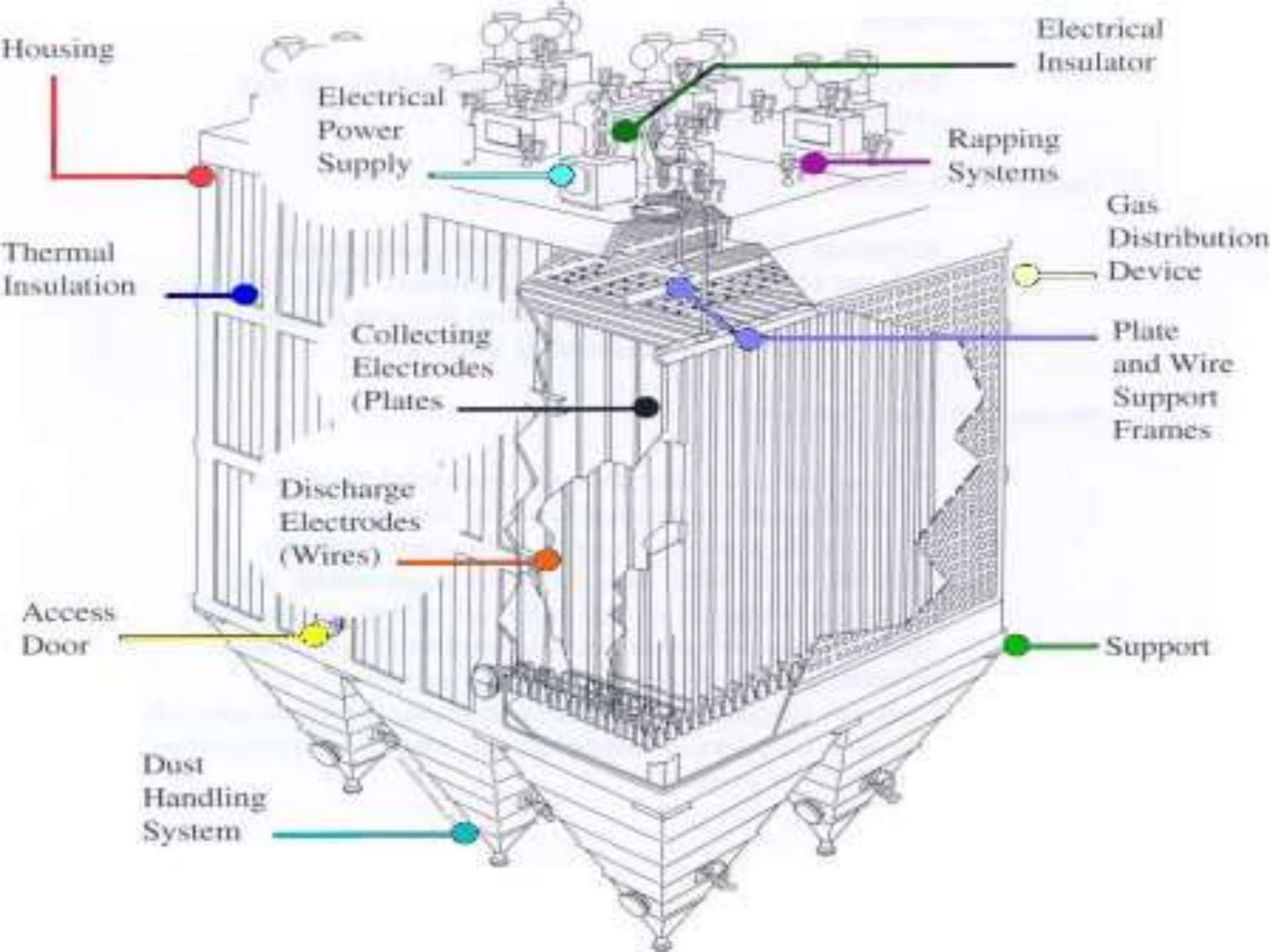
Reverse air

Reverse jet



ELECTROSTATIC PRECIPITATOR

- Particulate collection device that removes particles from a flowing gas (such as air) using the force of an induced electrostatic charge.
- Highly efficient filtration devices that minimally impede the flow of gases through the device, and can easily remove fine particulate matter such as dust and smoke from the air stream.
- ESP applies energy only to the particulate matter being collected and therefore is very efficient in its consumption of energy



ACID GAS (SO₂ CONTROL)

FLUE GAS DESULPHURISATION

- Used to remove SO_2 from the exhaust flue gases of fossil fuel power plants.
- Most FGD systems employ two stages: one for fly ash removal and the other for SO_2 removal.
- In wet scrubbing systems, the flue gas normally passes first through a fly ash removal device, either an electrostatic precipitator or a wet scrubber, and then into the SO_2 absorber.
- In dry injection or spray drying operations, the SO_2 is first reacted with the sorbent and then the flue gas passes through a particulate control device.
- Hydrodesulfurization of fuel has been used for treating fuel oils before use.
- Fluidized bed combustion adds lime to the fuel during combustion. The lime reacts with the SO_2 to form sulfates which become part of the ash.

HYDRODESULPHURIZATION

- HDS is a catalytic chemical process widely used
- The industrial hydrodesulphurization processes include facilities for the capture and removal of the resulting H₂S gas which is converted into byproduct elemental sulfur or sulfuric acid
- $C_2H_5SH + H_2 \rightarrow C_2H_6 + H_2S$
- Reaction takes place in a fixed-bed reactor at elevated temperatures ranging from 300 to 400 °C and elevated pressures ranging from 30 to 130 atmospheres in the presence of a catalyst consisting of an alumina base impregnated with cobalt and molybdenum (usually called a CoMo) catalyst or nickel and molybdenum (called NiMo)

DRY SCRUBBER

- Dry scrubbing systems are often used for the removal of odorous and corrosive gases
- Dry scrubbing systems can be categorized as dry sorbent injectors (DSIs) or as spray dryer absorbers (SDAs)
- **Dry sorbent injection** involves the addition of an alkaline material (usually hydrated lime or soda ash) into the gas stream to react with the acid gases.
- In **spray dryer absorbers**, the flue gases are introduced into an absorbing tower (dryer) where the gases are contacted with a finely atomized alkaline slurry.

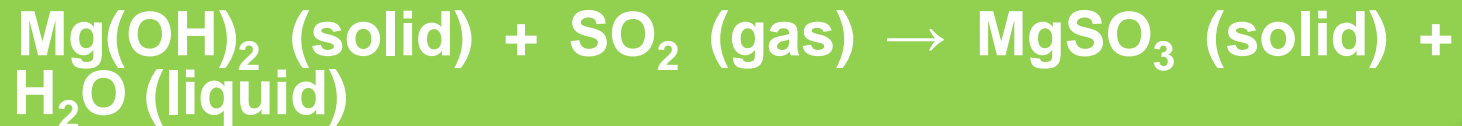
WET SCRUBBER

- The polluted gas stream is brought into contact with the scrubbing liquid, by spraying it with the liquid or by forcing it through a pool of liquid, so as to remove the pollutants.

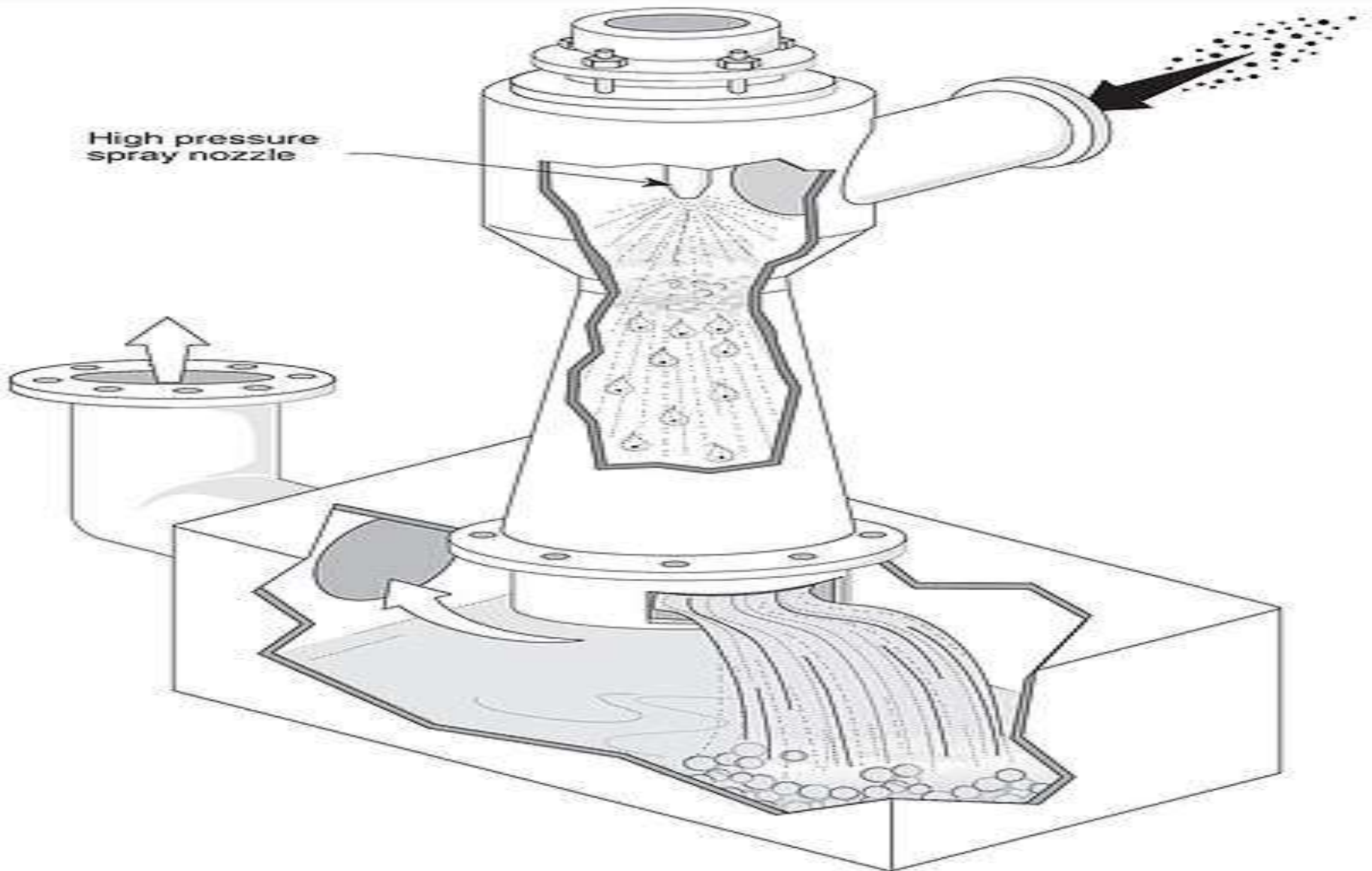
- The reaction taking place in wet scrubbing using a CaCO_3 (limestone) slurry can be expressed as:



- When wet scrubbing with a $\text{Mg}(\text{OH})_2$ (magnesium hydroxide) slurry



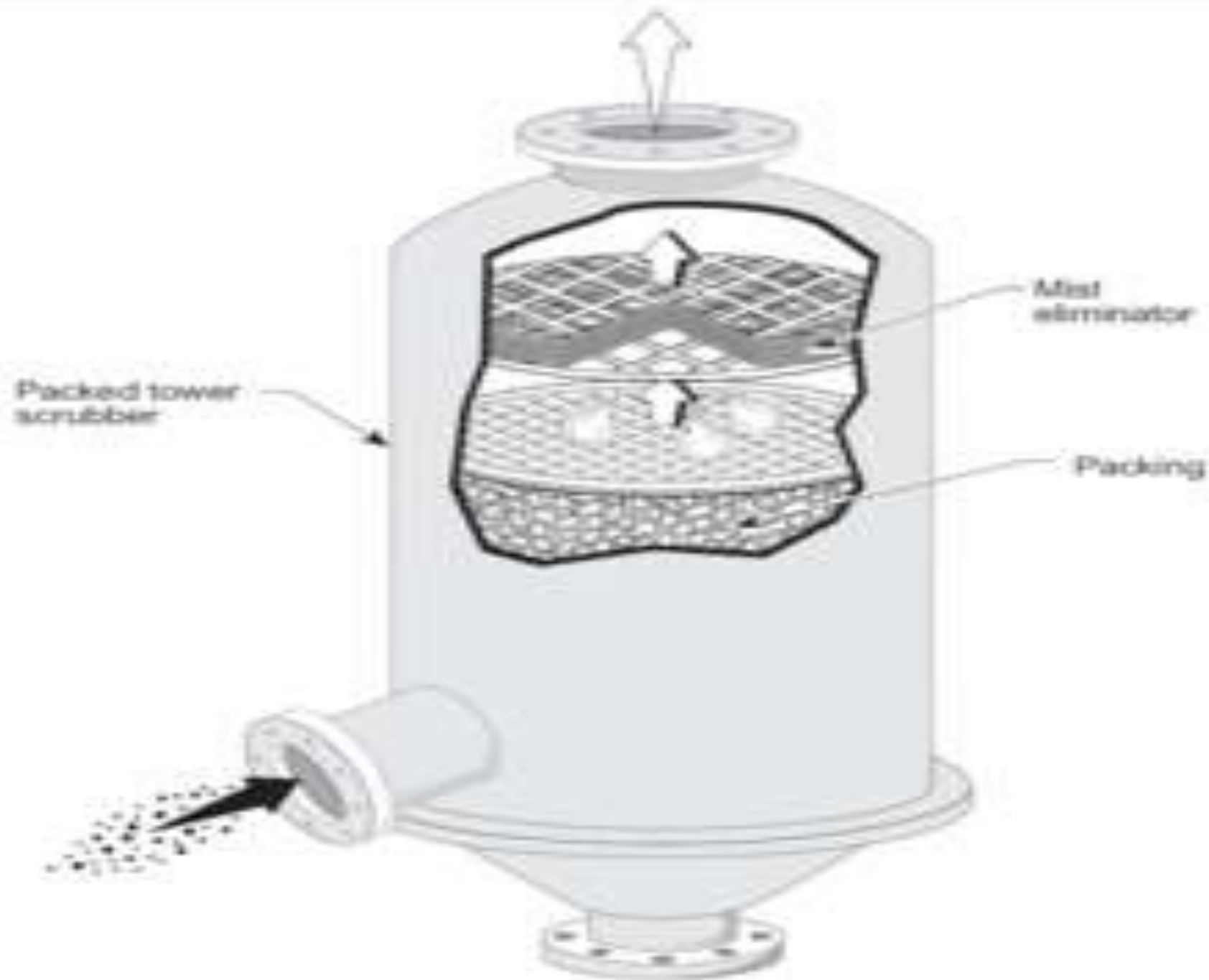
VENTURI SCRUBBER



- A converging/diverging section of duct.
- The converging section accelerates the gas stream to high velocity. When the liquid stream is injected at the throat, which is the point of maximum velocity, the turbulence caused by the high gas velocity atomizes the liquid into small droplets, which creates the surface area necessary for mass transfer to take place.
- The higher the pressure drop in the venturi, the smaller the droplets and the higher the surface area.
- The penalty is in power consumption.
- For simultaneous removal of SO_2 and fly ash, venturi scrubbers can be used.

PACKED BED SCRUBBER

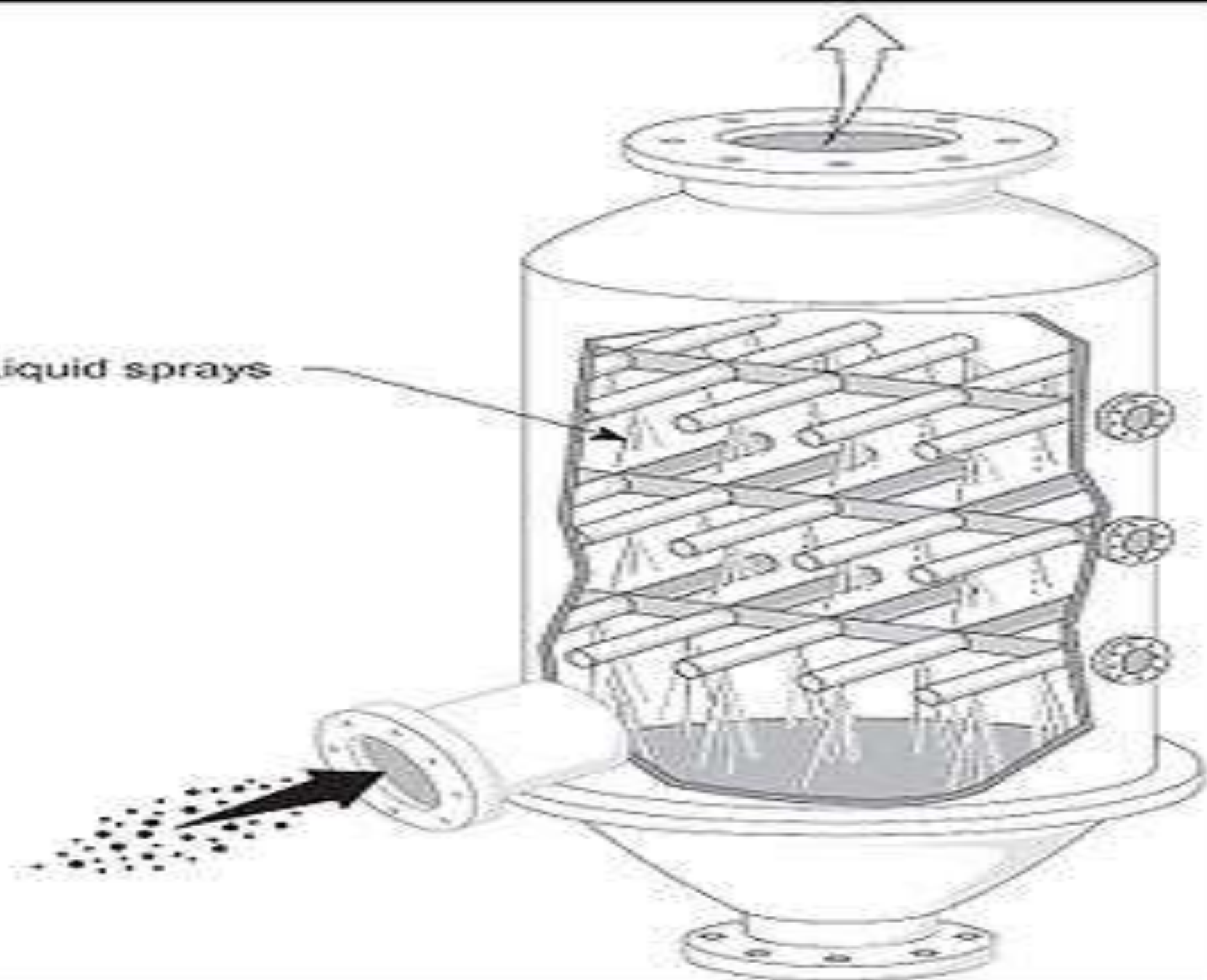
- Consists of a tower with packing material inside in the shape of saddles, rings, or some highly specialized shapes designed to maximize contact area between the dirty gas and liquid.
- Packed towers typically operate at much lower pressure drops than venturi scrubbers and are therefore cheaper to operate. They also typically offer higher SO₂ removal efficiency.
- The drawback is that they have a greater tendency to plug up if particles are present in excess in the exhaust air stream.



SPRAY TOWERS

- The simplest type of scrubber.
- It consists of a tower with spray nozzles, which generate the droplets for surface contact.
- Spray towers are typically used when circulating a slurry .
- The high speed of a venturi would cause erosion problems, while a packed tower would plug up if it tried to circulate a slurry.

Liquid sprays



VOC ABATEMENT

ADSORPTION SYSTEMS

- Involves the molecular attraction of gases or vapours onto the surface of adsorbent solids – activated carbon or molecular sieves
- The attraction maybe physical or chemical
- After the activated carbon is saturated with VOCs, it is treated to strip off the collected VOCs
- VOCs – further treatment & Carbon – reused in adsorption reactor
- Commonly used for removing gases from contaminated soil, oil refineries, industrial paint shops and steel mills

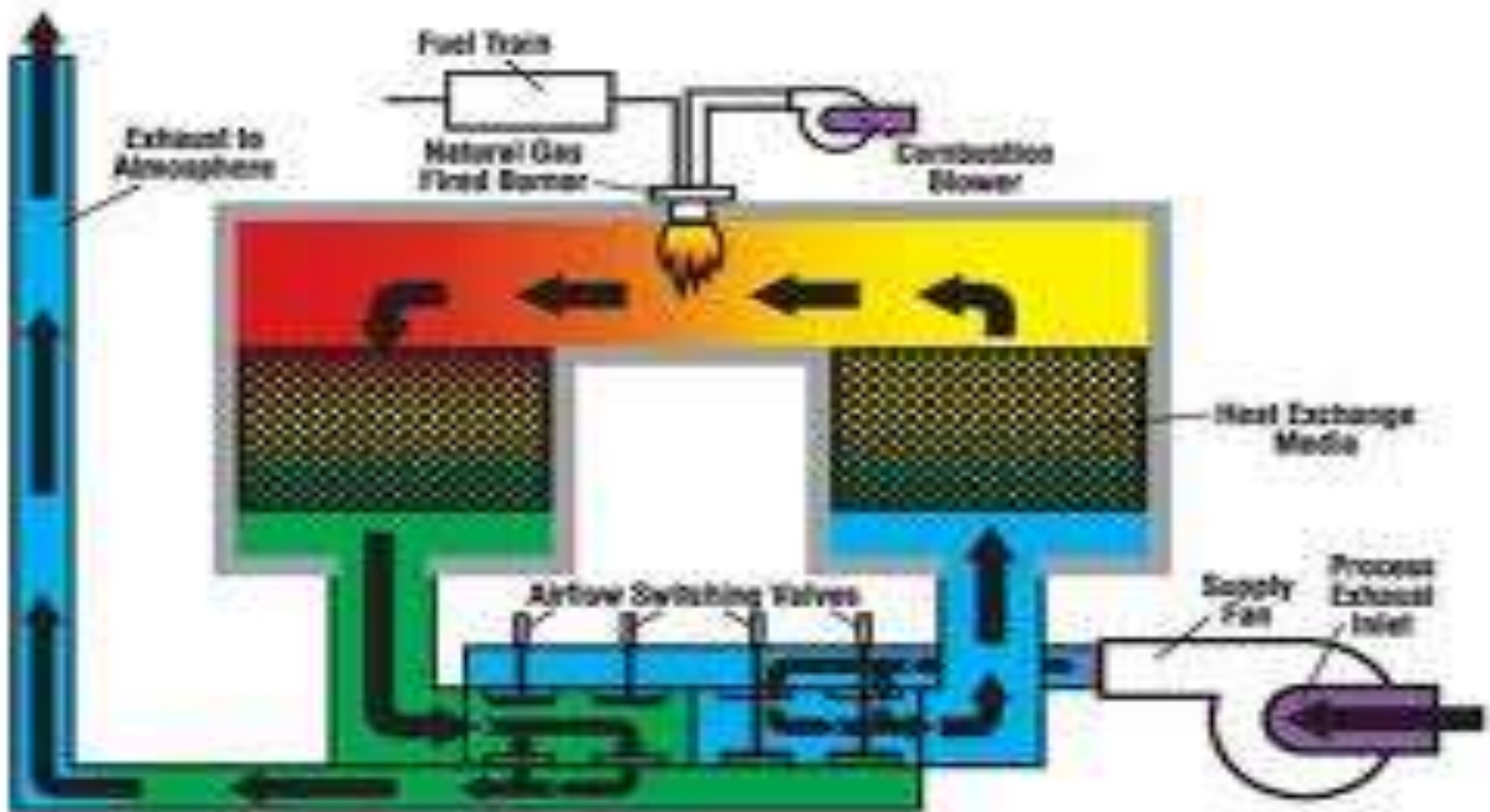
FLARE



- Also known as a **flare stack**, it is an elevated vertical conveyance found accompanying the presence of oil wells, gas wells, rigs, refineries, chemical plants, natural gas plants, and landfills.
- They are used to eliminate waste gas which is otherwise not feasible to use or transport. They also act as safety systems for non-waste gas and is released via pressure relief valve when needed to ease the strain on equipment.

THERMAL OXIDIZERS OR INCINERATORS

Regenerative Thermal Oxidizer Airflow Diagram



- 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.
- Used to destroy HAPs and VOCs from industrial air streams.
- Pollutants are destroyed via thermal combustion where they are chemically changed to form CO_2 and H_2O .
- Energy recovery efficiency can reach 95%
- Different types include :
 - Regenerative thermal oxidizer (RTO)
 - Regenerative catalytic oxidizer (RCO)
 - Ventilation air methane thermal oxidizer (VAMTOX)
 - Thermal recuperative oxidizer
 - Catalytic oxidizer
 - Direct fired thermal oxidizer - afterburner

BIOFILTERS

- Uses living material to capture and biologically degrade process pollutants.
- Common uses include processing waste water, capturing harmful chemicals or silt from surface runoff, and microbiotic oxidation of contaminants in air.
- The air flows through a packed bed and the pollutant transfers into a thin biofilm on the surface of the packing material. Microorganisms, including bacteria and fungi are immobilized in the biofilm and degrade the pollutant.
- Examples of biofiltration include Bioswales, Biostrips, Biobags, Bioscrubbers, and Trickle filters
Constructed wetlands and Natural wetlands, Slow sand filters, Treatment ponds

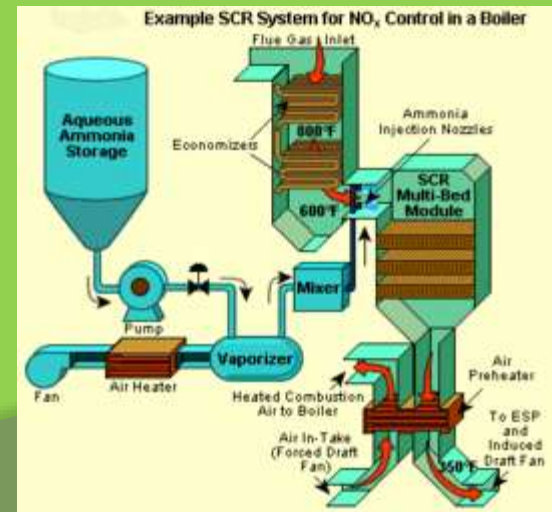
CRYOGENIC CONDENSERS

- Cryogenic condensation is a process that allows recovery of volatile organic compounds (VOCs) for reuse.
- The condensation process requires very low temperatures so that VOCs can be condensed and hence liquid nitrogen has emerged as a viable substance for use in the extremely low-temperature or cryogenic (less than -160 degrees C) condensation process.
- Cryogenic condensation is best suited to exhaust streams with low flowrates (below 2000 standard ft³/min) and/or vapor concentrations above 100 parts per million on a volumetric basis (ppmv).

NO_x CONTROL

SELECTIVE CATALYTIC REDUCTION

- A means of converting nitrogen oxides, also referred to as NO_x with the aid of a catalyst (ceramic as carrier, and oxides of base metals like V & W) into N_2 , and H_2O using a gaseous reductant - anhydrous NH_3 , aqueous NH_3 or urea, at a temp between 630 and 720 K.
- Application- large utility & industrial boilers (reduce NO_x by 70-95%). Diesel engines & gas turbines.
- Reactions



Selective non-catalytic reduction

- A method to lessen NO_x emissions in conventional power plants that burn biomass, waste and coal by injecting NH₃ or urea into the boiler at a location where the flue gas is between 1,400 & 2,000 °F producing N₂, CO₂ & H₂O.
- $\text{NH}_2\text{CONH}_2 + \text{H}_2\text{O} \rightarrow 2\text{NH}_3 + \text{CO}_2$
 $4\text{NO} + 4\text{NH}_3 + \text{O}_2 \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O}$
- It can achieve the same efficiency of about 90 % as SCR, but practical constraints of temperature, time, and mixing exist.
- SNCR has an economical advantage as the cost of the catalyst isn't there.

EXHAUST GAS RECIRCULATION

- It is a NO_x emissions reduction technique used in petrol and diesel engines.
- Recirculates a portion of the engine's exhaust gas back to the engine cylinders. In a gasoline engine, this inert exhaust displaces the amount of combustible matter in the cylinder. In a diesel engine, the exhaust gas replaces some of the excess oxygen in the pre-combustion mixture.
- The exhaust gas, added to the fuel, oxygen, and combustion products, increases the specific heat capacity of the cylinder contents, which lowers the adiabatic flame temperature. Because NO_x formation progresses much faster at high temperatures, EGR reduces the amount of NO_x the combustion generates

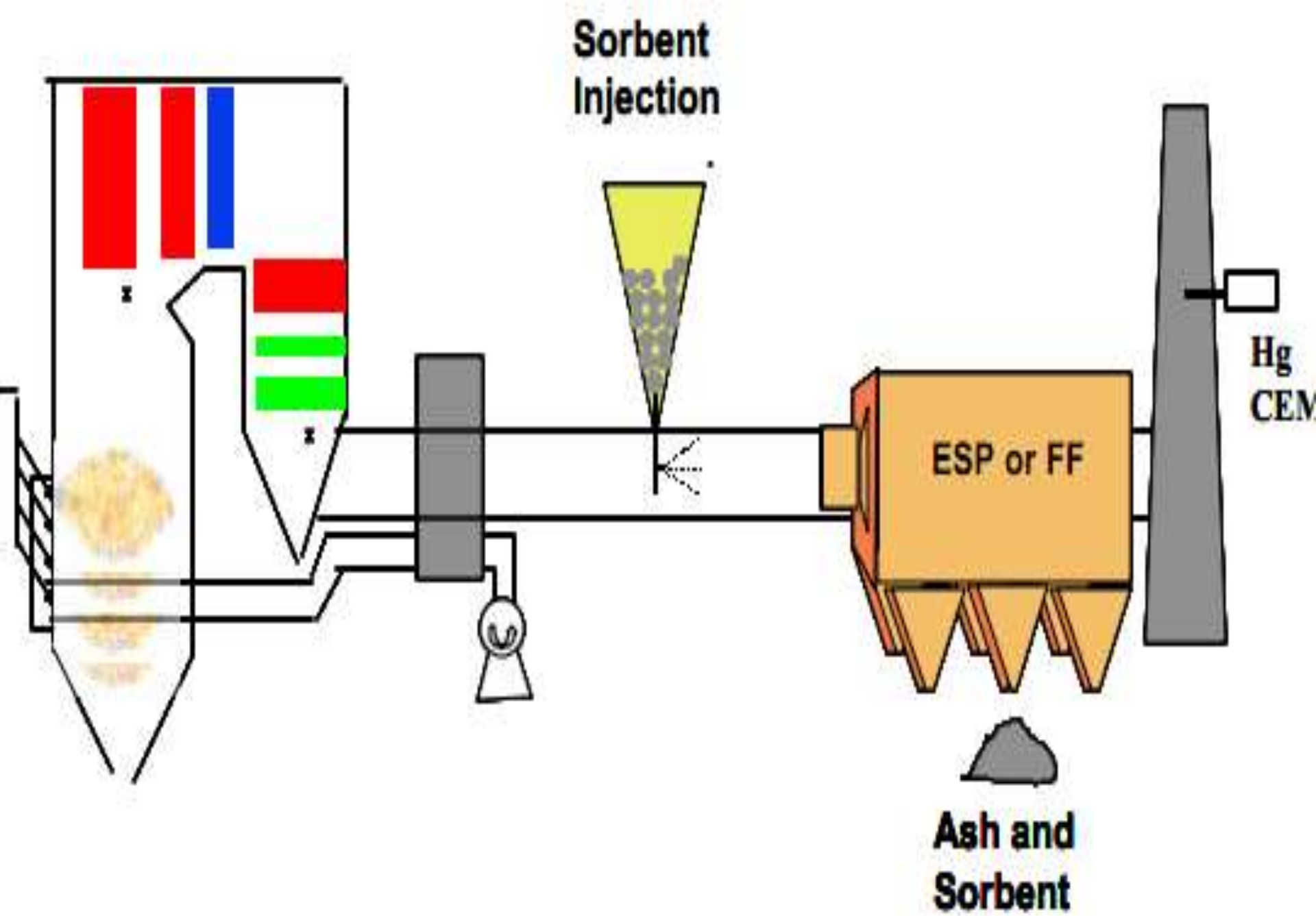
CATALYTIC CONVERTER

- A device used to reduce the toxicity of emissions from an IC engine.
- Works by using a catalyst to stimulate a chemical reaction in which toxic by-products of combustion are converted to less-toxic substances.
- 90% conversion of carbon monoxide, hydrocarbons, and nitrogen oxides into less harmful gases in automobiles.
- Pt-Rh – reduction catalyst & Pt-Pd – oxidation catalyst
- Two way : $2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2$
 $\text{C}_x\text{H}_{2x+2} + [(3x+1)/2] \text{O}_2 \rightarrow x\text{CO}_2 + (x+1) \text{H}_2\text{O}$
- Three way : $2\text{NO}_x \rightarrow x\text{O}_2 + \text{N}_2$
 $2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2$
 $\text{C}_x\text{H}_{2x+2} + [(3x+1)/2]\text{O}_2 \rightarrow x\text{CO}_2 + (x+1)\text{H}_2\text{O}$

MERCURY CONTROL

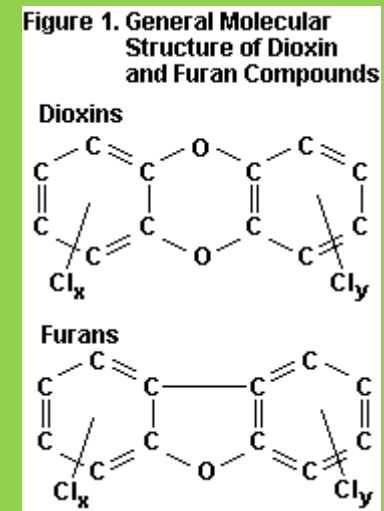
SORBENT INJECTION TECHNOLOGY

- Injecting a sorbent such as powdered activated carbon (PAC) into the flue gas represents one of the simplest and most mature approaches to controlling mercury emissions from coal- fire boilers.
- The gas phase mercury in the flue gas contacts the sorbent and attaches to its surface.
- The sorbent with the mercury attached is then collected by the existing particulate control device, either an electrostatic precipitator (ESP) or fabric filter. This combined material consisting of 99 percent flyash and one percent sorbent is then either disposed of or beneficially used.



DIOXIN AND FURAN CONTROL

- Sources of dioxins and furans include waste incinerators, cement production, fossil-fuel-fired combustors, and forest fires.
- Dioxin and furan compound emissions are calculated in two different ways:
 - As the total dioxin and furan compound concentrations
 - As the **Toxic Equivalency Quotient (TEQ)** concentration



CONTROL TECHNIQUES

- Both dioxin and furan compounds are destroyed when the gas temperatures exceeds approximately 1400°F
- These temperatures usually exist in the combustion zones of incinerators and fossil-fuel-fired boilers.
- The formation mechanisms decrease to negligible rates when the gas stream temperature decreases below 400°F. The gas stream should be sufficiently cooled prior to the air pollution control system can eliminate this formation mechanism.
- The best way to control dioxin and furan emissions is preventing their formation by reducing or eliminating the chlorine in the fuel and waste material being burned.

**THANK
YOU**