Air Pollution

Presentation outline

- Sampling of air pollutants
- Gaseous and Particulate pollutants
- Construction and working of Particulate control equipments
- Thermal incineration
- Methods for control of Sulfur dioxide emission
- Methods for control of Nitrogen Oxides

Air Pollution

- **Air pollution** may be defined as the presence of one or more contaminants in the air in large quantities and for long durations which may be or tend to be injurious to human, animal, plant life, or property, or which unreasonably interferes with the comfortable usage of air.

Measurement of Air Quality

- **Measurements of Emissions / Source Sampling** when a particular emission source is measured, generally by on the spot tests.
- **Meteorological Measurement** Measures meteorological factors that show how pollutants are transferred from source to recipient
- **Ambient Air Quality** Measures the quality of all the air in a particular place. Almost all the evidence of health effects is based on these measurements

Air Sampling

- Sampling and measurement of air pollutants is known as **Air Quality Monitoring**. It is an integral component of any air pollution control programme. By the help of thorough monitoring the current trends in **air quality can be determined by comparing the data with the regulated standards**. The information thus obtained can be **helpful in implementing proper control action/mechanisms** for reducing the amount of pollutants in the atmosphere

Aim of Air Sampling

- The principal requirement of a sampling system is to obtain a sample that is representative of the atmosphere at a particular place and time and that can be evaluated as a mass or volume concentration.
- The sampling system should not alter the chemical or physical characteristics of the sample in an undesirable manner.

Air Sampling Techniques

- Most air pollution monitoring equipment performs the act of sampling and analysis in one action i.e. **Real time measurement.**
- Older equipment : **Intermittent sampling** (time lag between when the sample was obtained and when data was available)
- Almost all **Gaseous Pollutants** are monitored by **Real Time Analysis**, whereas **Particulate Pollutants** are still mostly monitored by **Intermittent Sampling**.

Air Sampling Techniques

- Sample should be sufficient enough for analysis.
- Most pollutants are in very low levels and require a large volume of gas for accurate measurement
- Pollutants in very small quantities are easy to contaminate. Take care to purge sampling containers if grab samples are used
- Collection and analysis limitations may require collection over extended periods means data may only be a 24 hr avg.
- Real time produces so much data - are often set to give hourly avg. to make data more understandable

Types of Air Quality Measurement

- In **Ambient Air Quality** **Measurement** technique the pollutant level in the atmosphere is **measured by means of various devices.**

- Whereas **Stack Sampling** deals with the measurement of pollutants emitted from a particular source such as smoke stack etc.

Typical air sampling set up

- The major components of most sampling systems are:

a. An inlet manifold
b. An Air mover
c. A collection medium
d. Flow measurement device

Typical air sampling set up

An Inlet manifold

The inlet manifold transports the material from the ambient atmosphere to the collection medium or analytical device in an unaltered condition, all inlet of ambient air must be rainproof.

An Air mover

The air mover provides the force to create a vacuum or lower pressure at the end of the sampling system (pumps).

Typical air sampling set up

A Collection Medium

The collecting medium, may be solid or liquid sorbent for dissolving gases a filter surface for collecting particles.

Flow Measurement Device

The flow device measures the volume of air associated with the sampling system.

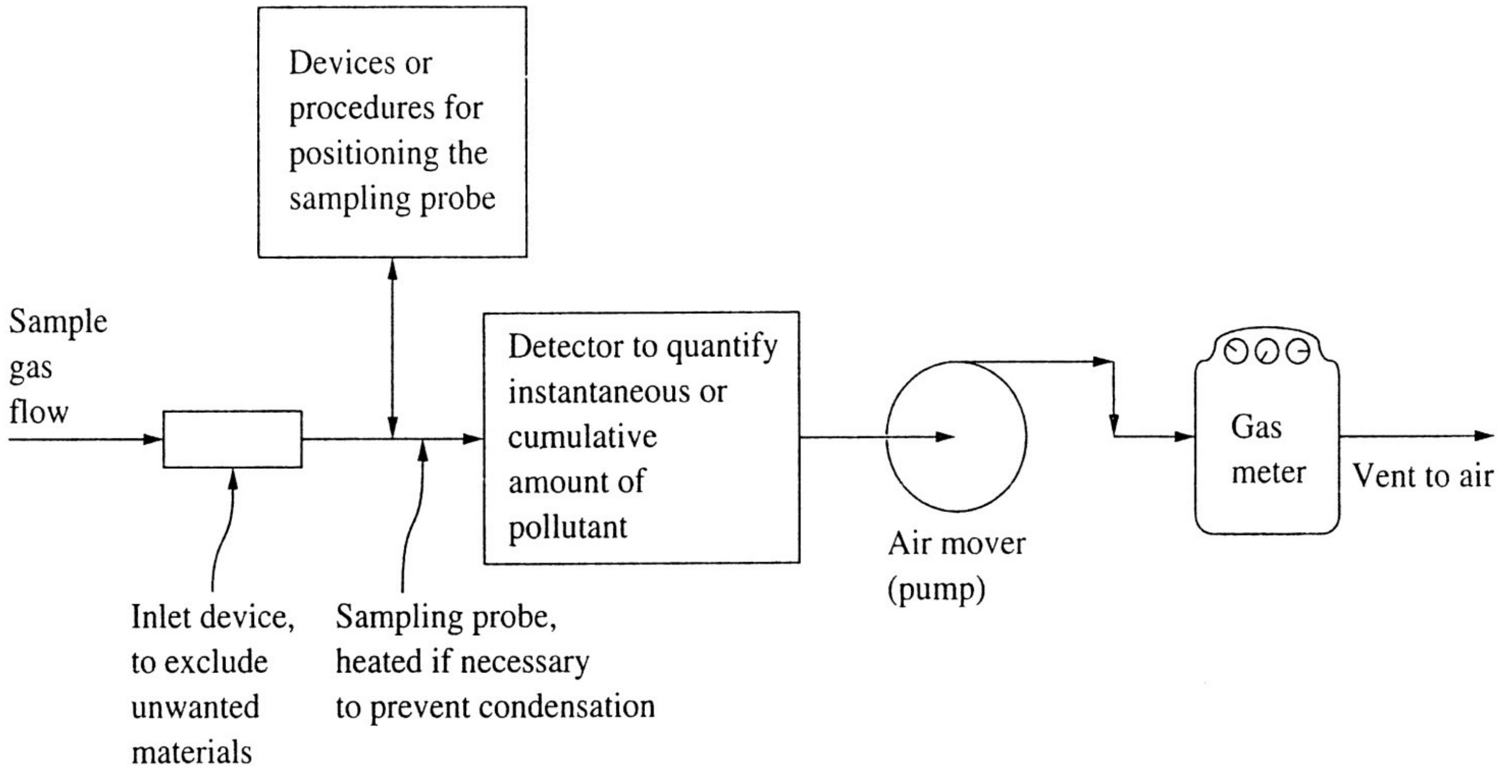


FIGURE 4.1
The components of any ambient-monitoring or source-sampling device. If the detector functions in real time (not cumulative), then the gas meter is not needed, but some kind of signal integrator or recorder is.

Site Selection

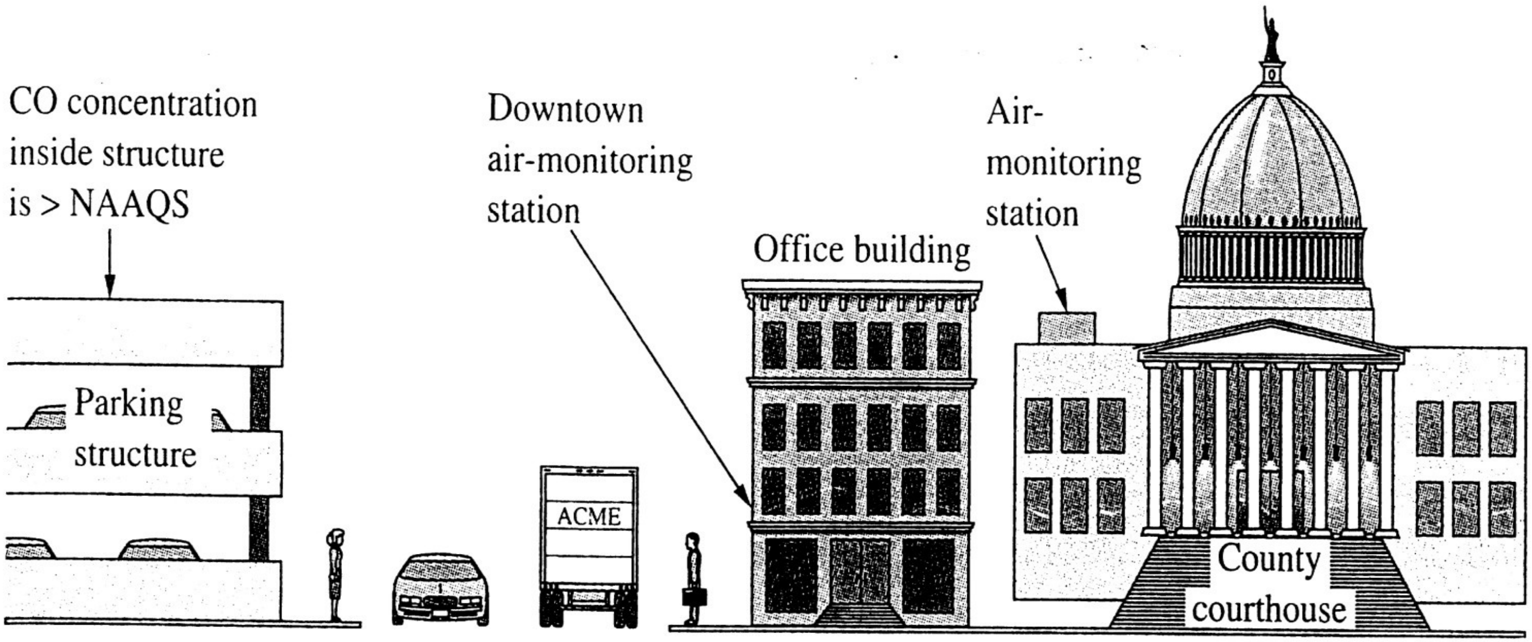


FIGURE 4.2
Illustration of some of the problems of choosing a sampler site to measure ambient CO in a city.

Site Selection..

- In Place:

  1- has the power

  2- shelter from rain and snow

  3- constant temp. and pressure

  4- easy access from monitoring personnel

  5- protection from vandalism

  6- if possible free rent place

Sampling of Gaseous Air Pollutants

- Several methods are available for the collection of gaseous air pollutants form ambient atmosphere.
- The most commonly used methods are

  The Gram Sampling

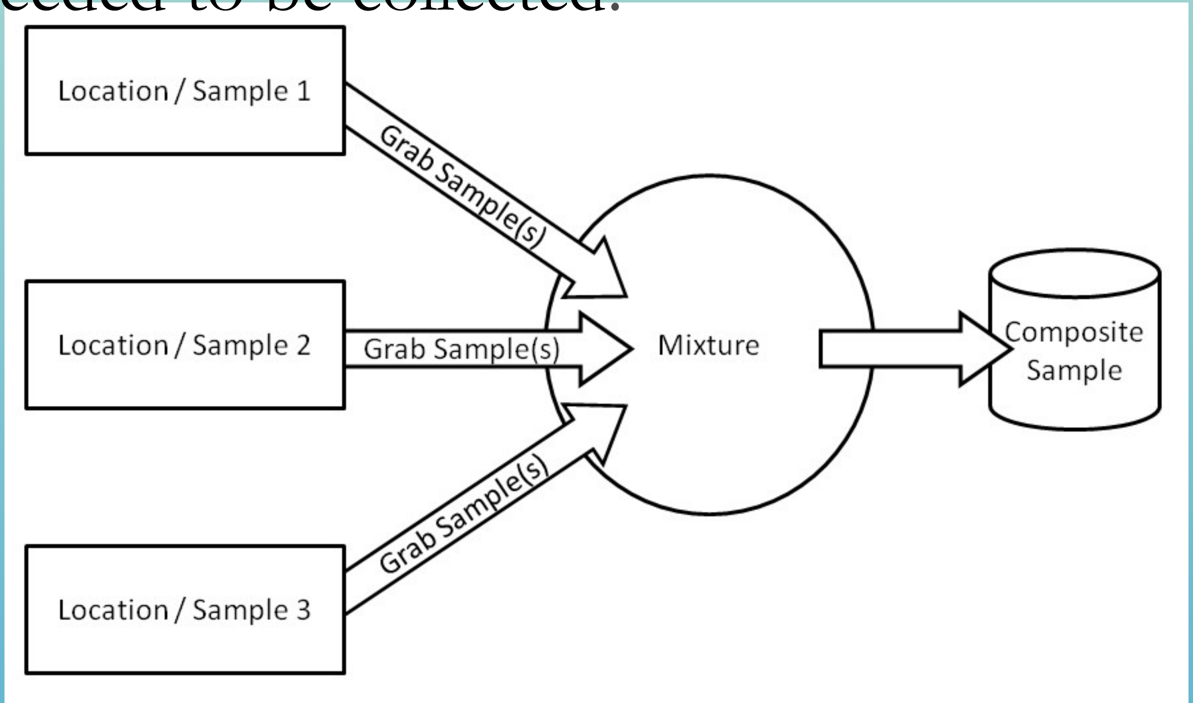
  Absorption in Liquids

  Adsorption on Solid Materials

  Freeze out Sampling/Condensation

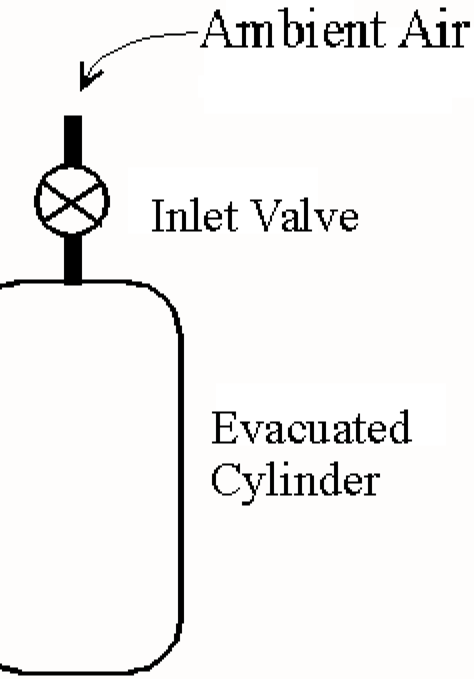
The Grab Sampling (Sampler)

The grab sample is a discrete sample which is collected at specific location at a certain period of time. If the environment medium varies then a single grab sample is not representative and more samples are needed to be collected.



The Grab Sampling (Sampler)

The sample is collected by filling an evacuated flask or an inflatable bag. Plastic bags have been widely used for garb sampling and for storage before analysis. Bag sampling may result in loss of collected sample from the bag because of moisture condensation or diffusion through the walls of the bag.



Principle of
Grab Sampling Method

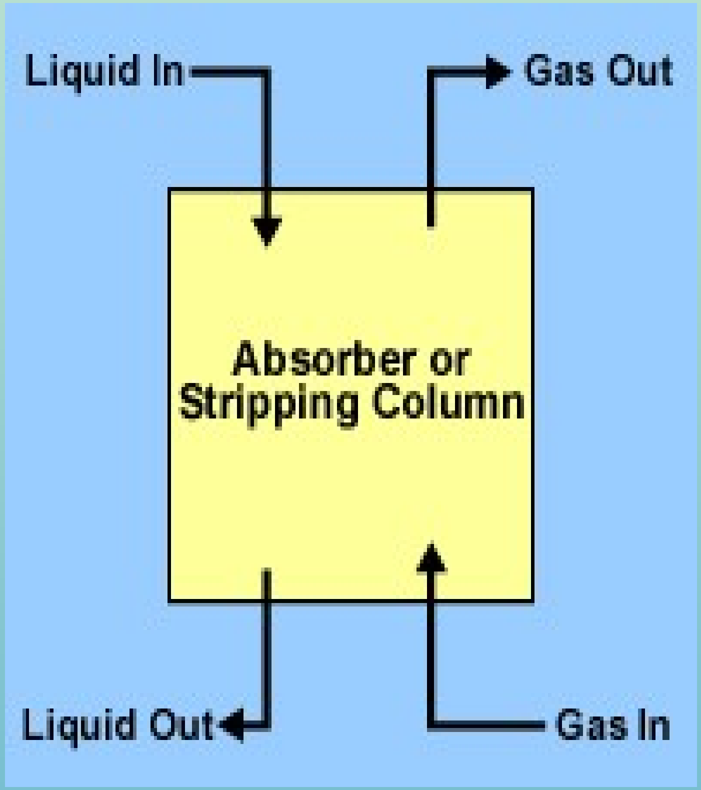
The Grab Sampling (Sampler)

Grab samples may be taken using rigid wall containers made from glass or stainless steel. These containers are first evacuated and then filled by allowing air to enter. Alternatively the container may be filled with water and then used as a collector by simply draining the water and allowing the air to enter.

Absorption in Liquid

Absorption is defined as the process of separation of soluble gaseous impurities by dissolving in liquid solvent (Water).

- As the gas stream passes through the liquid, the liquid absorbs the gas, in much the same way that sugar is absorbed in a glass of water when stirred.



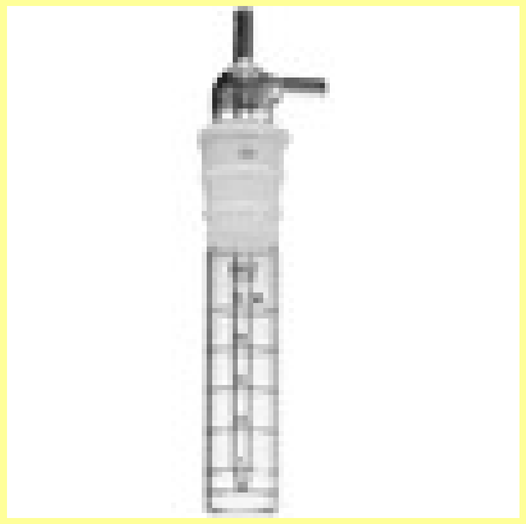
Absorption in Liquid

The principal types of gas absorption equipment include spray towers, packed columns, spray chambers, and venture scrubbers.

- In general, absorbers can achieve removal efficiencies grater than 95 percent. One potential problem with absorption is the generation of waste-water, which converts an air pollution problem to a water pollution problem.

Absorption in Liquid

- The most widely used absorber is the **Impinger**, wherein the gas stream is impinged at high velocity onto a flat surface providing a good contact between the gas and the liquid. The flat surface can either be the bottom on the container or a specially designed plate. The common impinger are Greenburg Smith Type, Midget Type impinger.



Impinger

Adsorption on Solid

Adsorption is the process of removal of gaseous impurities by adsorbing on solid adsorbent.

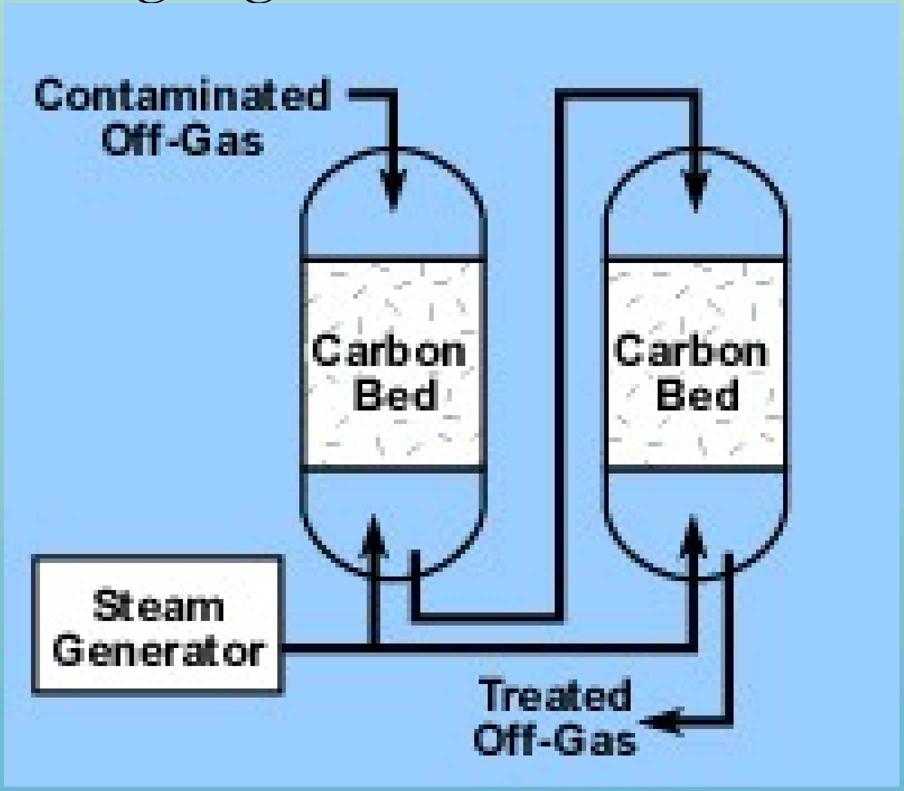
- When a gas or vapor is brought into contact with a solid, part of it is taken up by the solid. The molecules that disappear from the gas either enter the inside of the solid, or remain on the outside attached to the surface. The former phenomenon is termed absorption (or dissolution) and the latter adsorption.

Adsorption on Solid

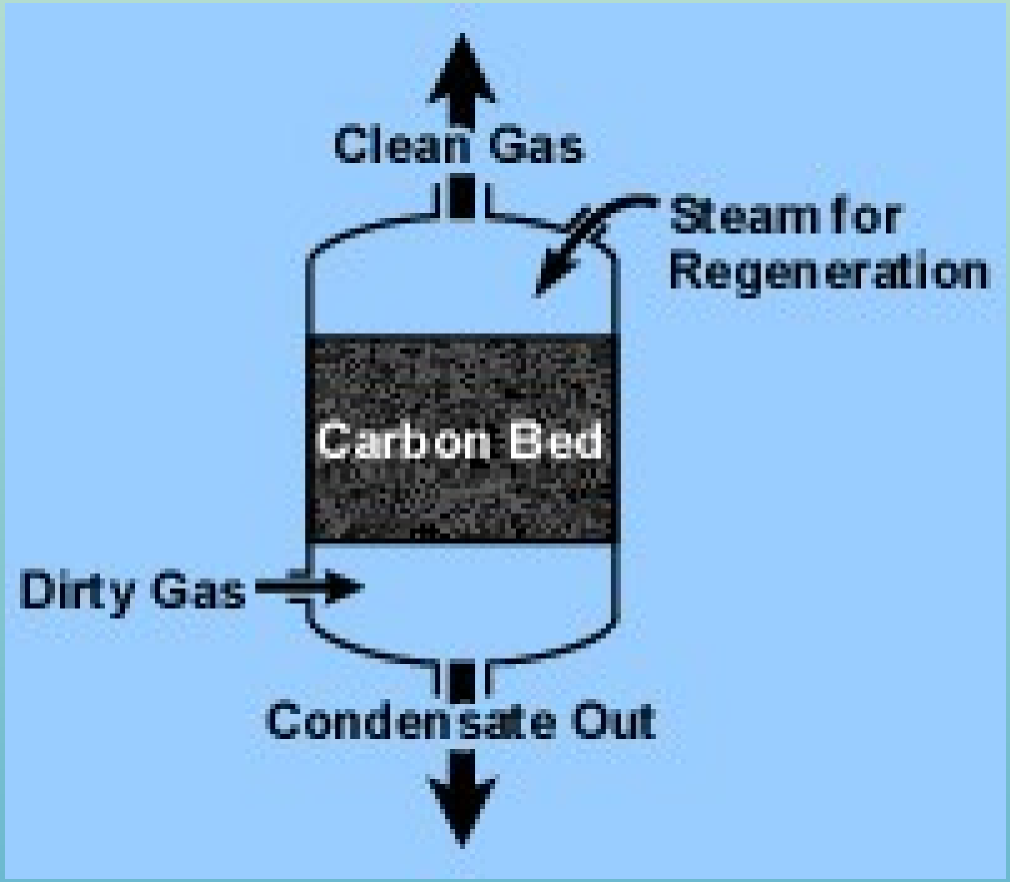
- The most common industrial adsorbents are activated carbon, silica gel, and alumina, because they have enormous surface areas per unit weight.

- Activated carbon is the universal standard for purification and removal of trace organic contaminants from liquid and vapor streams.

- Carbon adsorption systems are either regenerative or non-regenerative.
- **Regenerative system** usually contains more than one carbon bed. As one bed actively removes pollutants, another bed is being regenerated for future use.



Non-regenerative systems have thinner beds of activated carbon. In a non-regenerative adsorber, the spent carbon is disposed of when it becomes saturated with the pollutant.

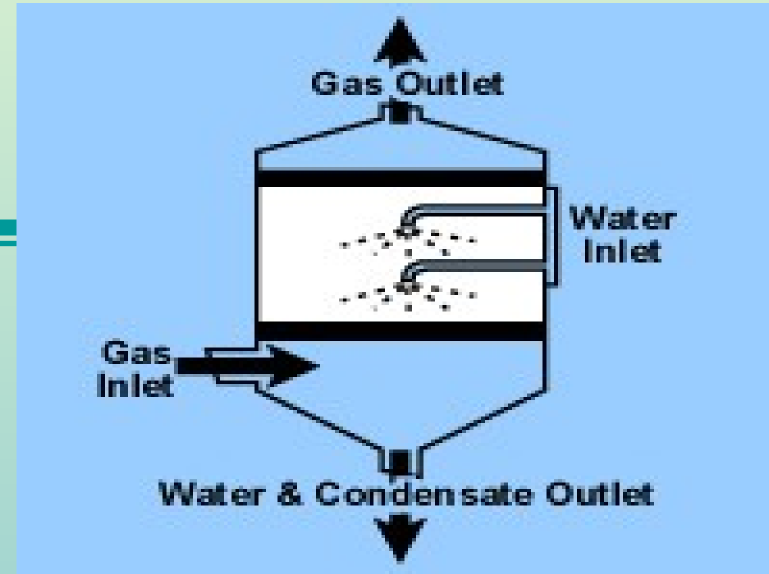


Freeze out Sampling/Condensation

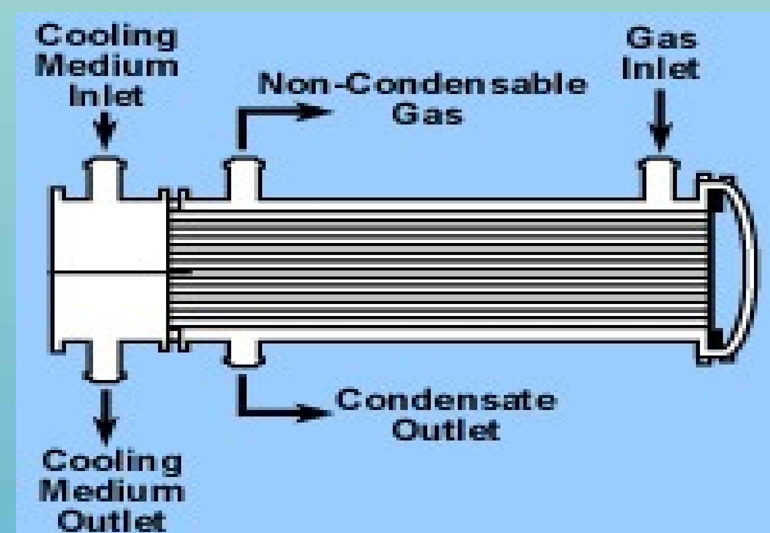
- Condensation is the process of converting a gas or vapor to liquid. Any gas can be reduced to a liquid by lowering its temperature and/or increasing its pressure.
- Condensers are typically used as pretreatment devices. They can be used ahead of absorbers, absorbers, and incinerators to reduce the total gas volume to be treated by more expensive control equipment. **Condensers used for pollution control are contact condensers and surface condensers.**
- The most commonly used coolants are Ice-water, Ice-salt, Dry ice and acetone, Liquid air, Liquid oxygen, Liquid nitrogen.

- In a **Contact Condenser**, the gas comes into contact with cold liquid.

- In a **Surface Condenser**, the gas contacts a cooled surface in which cooled liquid or gas is circulated, such as the outside of the tube.
- Removal efficiencies of condensers typically range from 50% to more than 95%, depending on design and applications.



Contact condenser



Surface condenser

Sampling of Particulate Air Pollutants

- Particulate pollutants in the atmosphere are grouped generally into those that settle out due to the force of gravity and those remain suspended as aerosols. Those particles which remain suspended in air as aerosols can be collected using techniques like filtration, impingement and electrostatic precipitator.

Particulate Control Equipment

- Sedimentation (Dust Fall Jar)
- Gravity Settling
- Cyclone Separator
- Fabric Filter
- High Volume Sampler
- Wet Scrubber
- Spray Tower
- Plate Tower
- Electrostatic Precipitator (ESP)

Sedimentation (Dust Fall Jar)

- Use the **force of gravity** to remove solid particles The simplest device used for sampling **particles larger than 10µm in diameter** is the dust fall collector.
- It consists of a plastic jar of about 20 to 35 cm height and 10 to 15cm diameter at the base with inward tapering of the walls from top to bottom.
- Since particles larger than 10µm are seldom carried away from distance of 1km the collector **must be kept as close as possible to the source**.
- It is inexpensive, cheap; easy to use, requires no electrical and/or moving parts.

Sedimentation (Dust Fall Jar)

- Reading are taken generally over a period of 30 days - 1 data point per month.
- It suffer from many problems (uncooperative birds like pigeons etc and drunkards)

High Volume Sampler

- Most commonly used particle sampling method
- Analysis is gravimetric i.e. Filter is **weighed before and after the analysis** on an analytical balance, and difference is particulates collected
- A standard high volume sampler collects particles in the **size range from 0.1 - 100µm**

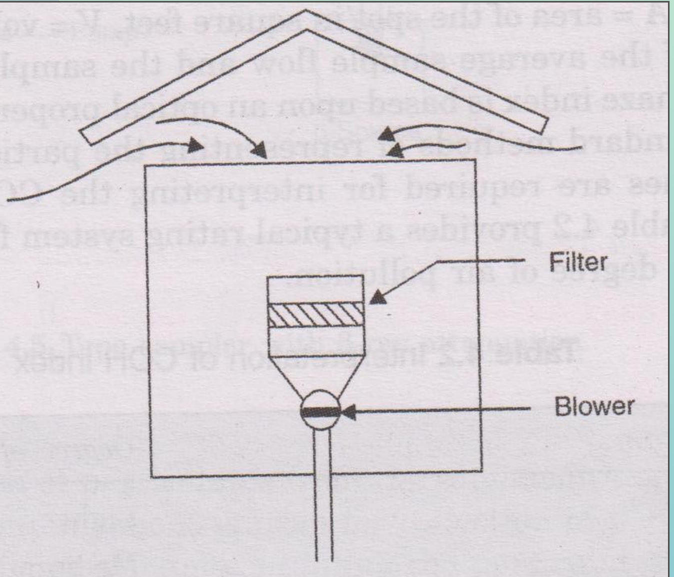


Fig. 4.4 Hi-vol sampler

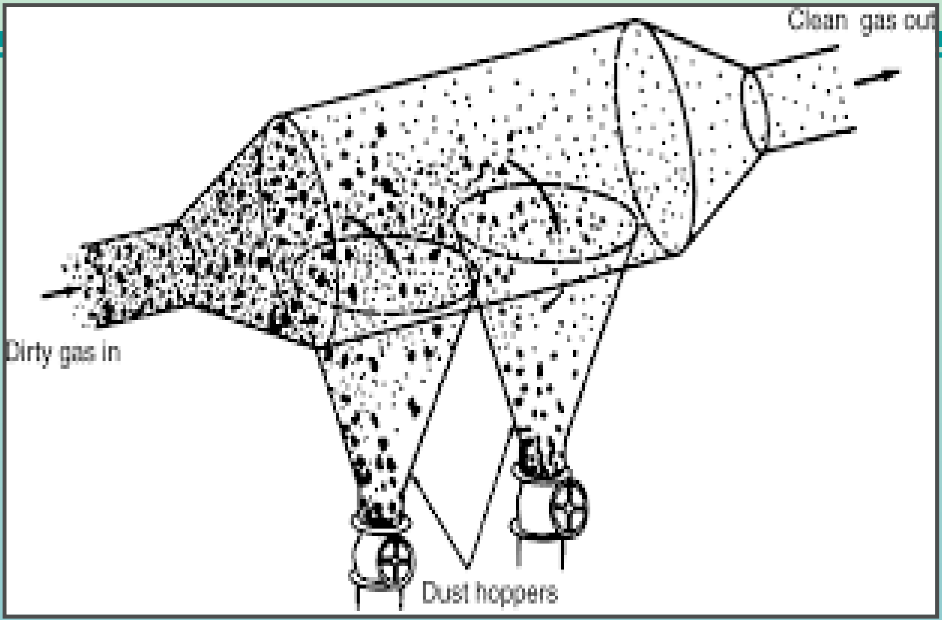
High Volume Sampler

- A known/fixed amount of air is sucked by a high speed blower through a fine filter and the increase in weight due to deposited particles is measured.
- The filter is **made of fibrous or granular particles** and provides a dense porous medium through which the air stream must change direction in random fashion allowing the entrained particles to impact on filter medium.
- Glass fibre filter is used as a filter medium for particles of size 0.3μm.

High Volume Sampler

- Airflow is measured by a small flow meter (calibrated in m^3 air/minute)
- Particulate concentration measured is referred to as the **Total Suspended Particles (TSP)** = combination of **Settle-able particles** and **Suspended Particles** expressed as $\mu g/m^3$ for a 24hour period.

Gravity Settling Chamber



- **Settling chambers use the force of gravity to remove solid particles.**
- The gas stream enters a chamber where the **velocity of the gas is reduced**. Large particles drop out of the gas and are recollected in hoppers. **Because settling chambers are effective in removing only larger particles, they are used in conjunction with a more efficient control device**.

Gravity Settling Chamber

- Used to remove **large, abrasive particles (usually >50 μm)** from the gas streams.
- Low pressure drop and require simple maintenance.
- Low efficiency for particles with size <<50 μm.
- Used when the mass of particles is large.
- As most of the particulate matters have size much less than 50μm these are **Normally Used As Pre-cleaners** prior to passing the gas stream through high efficiency collecting devices.

Horward Settling Chamber

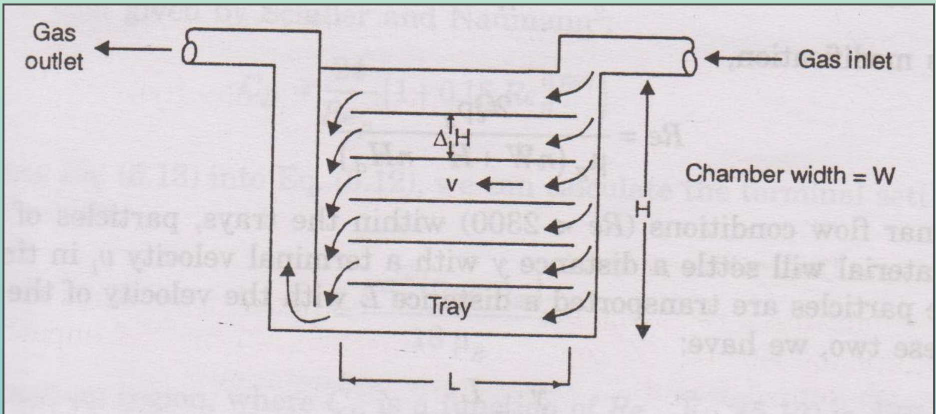
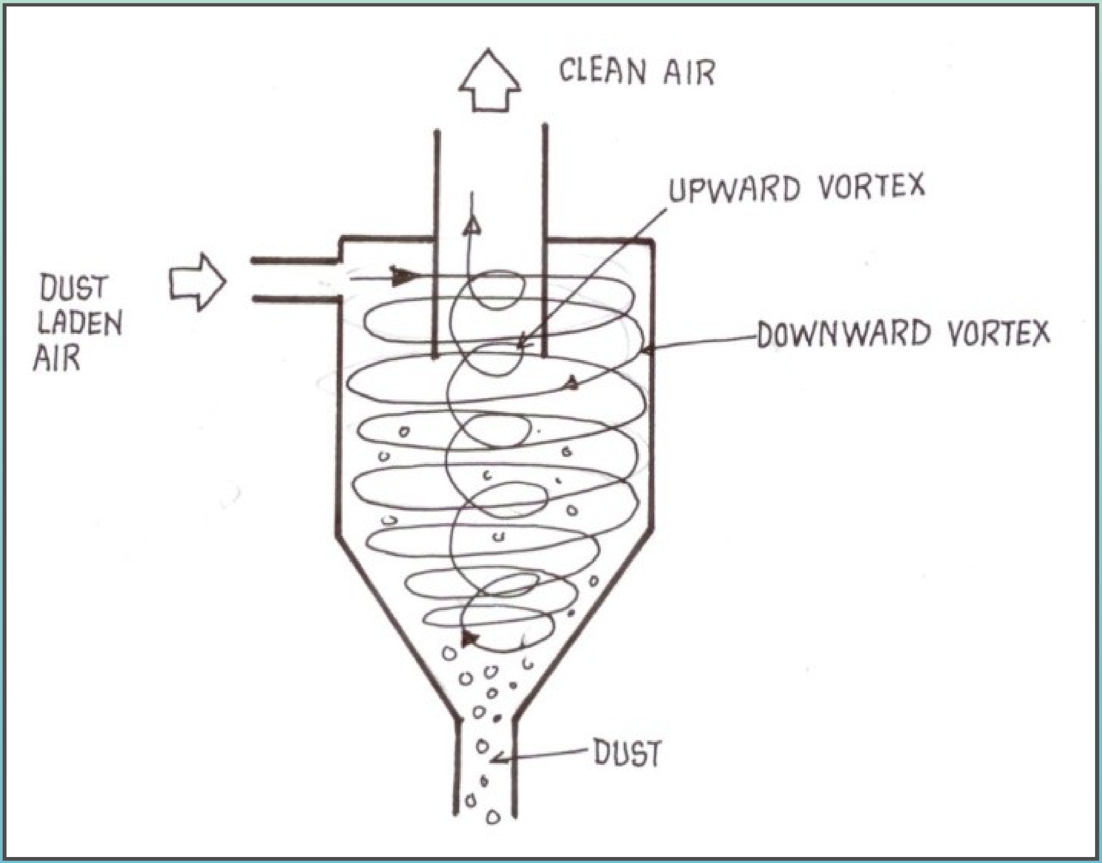


Fig. 5.3 Howard settling chamber

In the settling chamber the gas stream, with its entrained particles is allowed to **flow at a very low velocity** providing **sufficient time for the particles to settle down.**

By providing vertical trays the collection efficiency increases as the gas flow velocity in the chamber remains the same throughout and each particles has to travel a much shorter distance to fall before reaching the bottom of passages between the trays.

Cyclone Separator

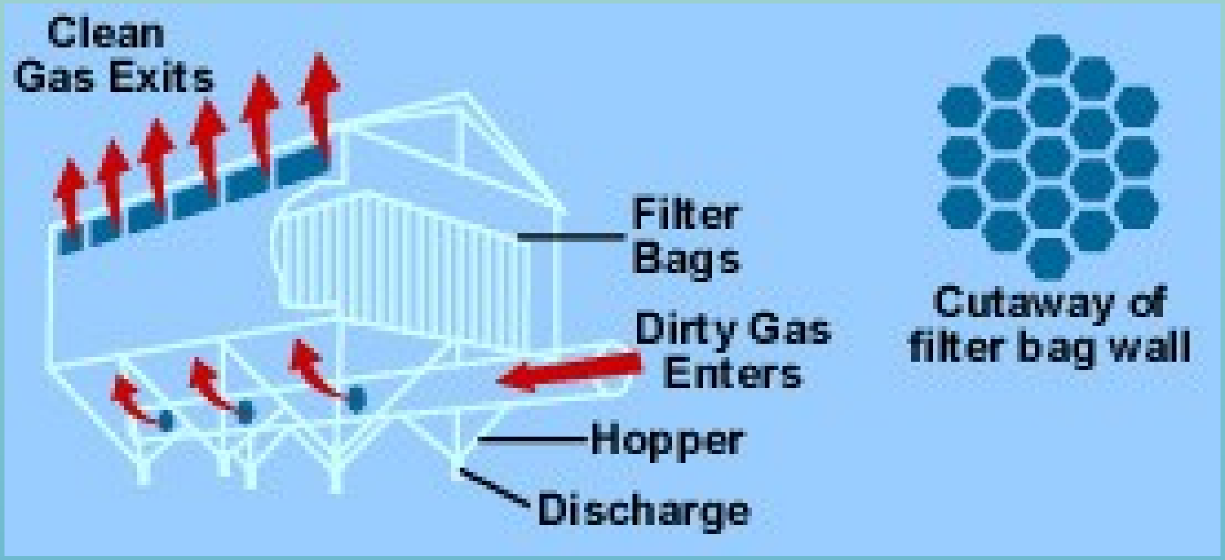


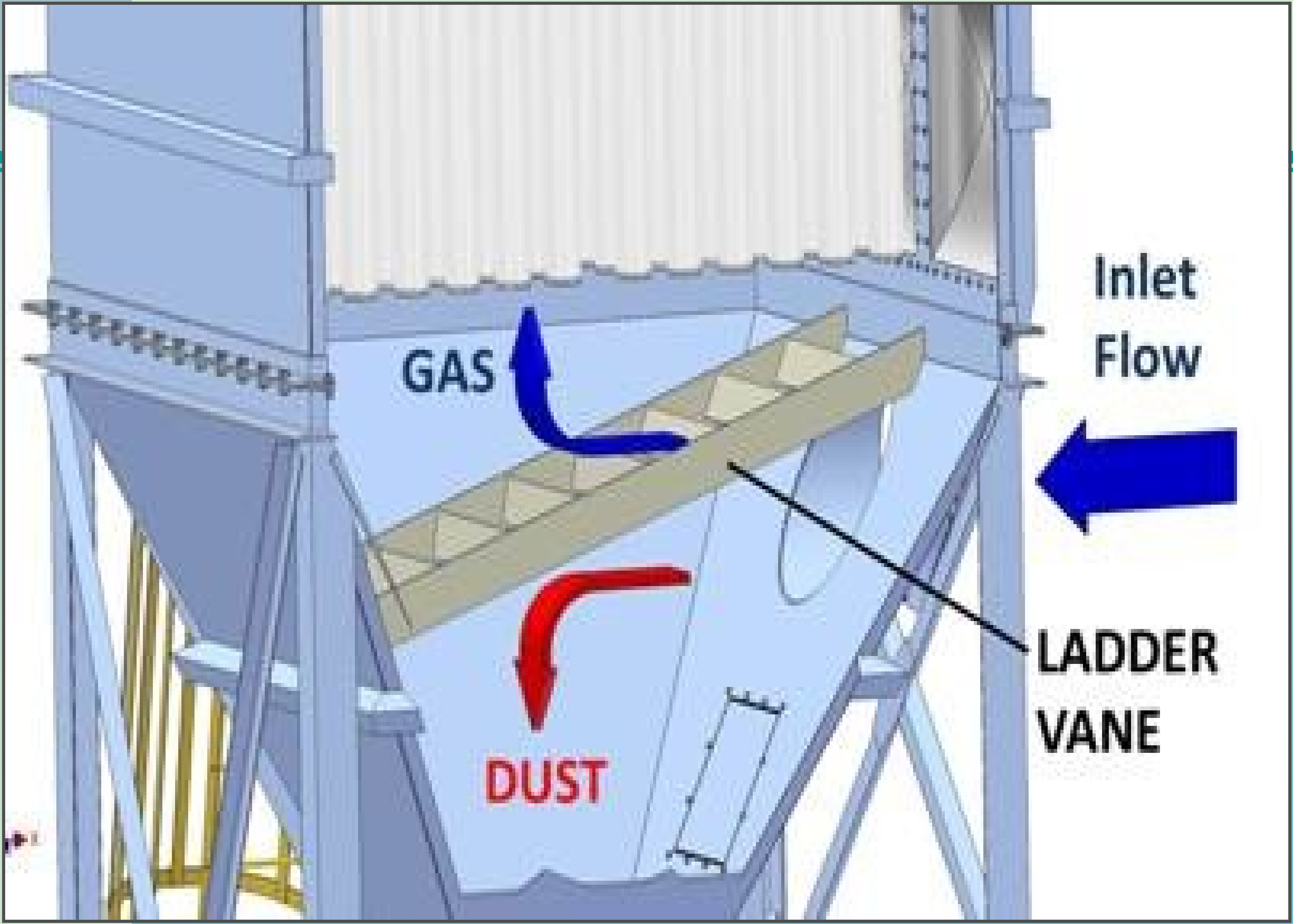
Cyclone Separator

- Cyclone separators use a **centrifugal force** generated by spinning the gas stream to separate the particulate matter from the gas.
- The centrifugal force on particles in a spinning gas stream is much greater than gravity; therefore cyclones are **effective in the removal of much smaller particles than gravitational settling chambers**, and **require much less space** to handle the same gas volumes.
- Cyclones are **efficient in removing large particles** but are not as efficient with smaller particles. For this reason, they are used with other particulate control devices.

Fabric Filter (Dry Particle Removal)

- Fabric filters, or baghouses, remove dust from a gas stream by passing the stream through a porous fabric. The fabric filter is efficient at removing fine particles and can exceed efficiencies of 99% in most applications




Inlet
Flow
GAS
DUST
LADDER
VANE

Fabric Filter

- Consists of a long tubular bag or an envelope, suspended or mounted in a manner such that the collected particles fall into a hopper when removed from the fabric. The assembly is called **Bag house**.
- The pores in fabrics are usually many times more than the size of the individual particle. As a result of which the **collection efficiency is much less in the beginning**. After a short period of operation the particles get captured into the pores of the fabric and thereby form an additional filter medium which helps in increasing the efficiency of the fabric filter.

Types and Selection of Fabric Filter

- **Woven Fabric** has a specific long range repeating pattern and has considerable porosity in the direction of gas flow.
- **Felted cloth** consists of randomly oriented fibres, compressed into a mat and needled to some loosely woven backing material to improve mechanical strength. The felt cloth type filter requires lesser cloth area than woven fabric type filter. The felt type filter is **more expensive** and **cannot be used in high humidity service because of tendency to choke.**

Choice of Fabric Filter

- The choice of fabric filter depends primarily on **Operating Temperature, Pressure, Gas flow rate, Size and Shape of Particles** and the **corrosiveness or abrasiveness of the particles**.
- **COST** is **Obvious** to be considered.
- **Cotton** is the least expensive fibre and is used at low temperature conditions.
- **Silicon coated glass fibre** cloth is commonly used in high temperature conditions.
- **The glass fibre** needs to be well lubricated to prevent abrasion.

Cleaning of Fabric Filter

- There are 3 common types of baghouse based on cleaning method
  - Reverse-air
  - Shaker
  - Pulse-jet

Absorption Equipment(s)

Terminologies:

Absorbent	The liquid, usually water, into which contaminant is absorbed.
Absorbate or solute	The gaseous contaminant being absorbed, such as SO_2, H_2S, etc.
Carrier gas	The inert portion of gas stream, usually air, from which the contaminant is to be removed.
Interface	The area where the gas phase and the absorbent contact each other.
Solubility	The capability of the gas to be dissolved in a liquid.

Wet Scrubber

Work on the principle of Gas Absorption.

- **Spray Chamber, Venturi Scrubber, Plate or Tray Tower, Packed Tower**

3 Step Mechanism :

- The pollutant diffuses from bulk area of the gas phases to the gas liquid interface.
- Gaseous pollutant transfer across the interface to the liquid phase. The second step is extremely rapid.
- The pollutant diffuses bulk area of the liquid, making room for additional gas molecule to absorb.

Wet Scrubber

Mechanism :

- The rate of mass transfer (absorption) is dependent on the **diffusion rate in either the gas phase or liquid phase.** The diffusion rate of gaseous pollutant molecule through a gas is always faster than its diffusion rate through the liquid **because molecules in the gas are further apart than are molecules in the liquid**. However the mass transfer rate depends primarily upon the solubility of the pollutant in the liquid.

Spray Tower

- Useful for large volume handling with relatively **low pressure drop**. In general smaller the droplet size the greater the turbulence, the more chance for absorption of the gas. Spray tower has **less gas liquid interfacial area so they are less effective in removal of gaseous contaminant.**

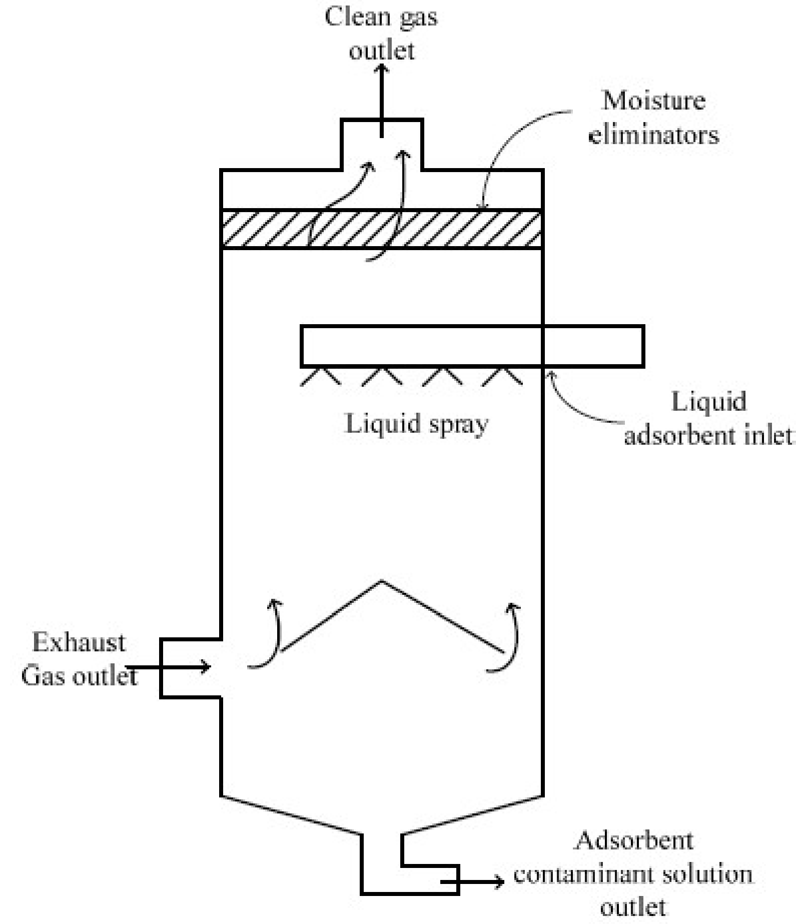


Figure Spray Tower

Plate Tower

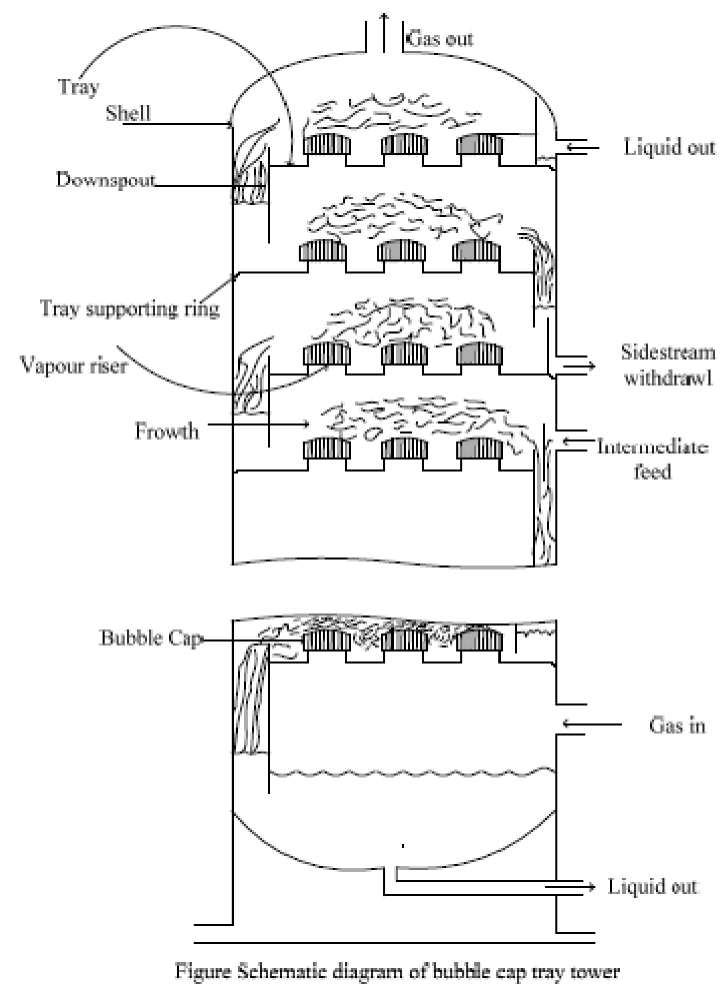


Figure 2.8.2. Schematic diagram of bubble cap tray tower

Plate Tower

- This type of tray contains horizontal trays or plate that **provides large gas liquid interfacial areas**.
- The polluted air is introduced from one side of the bottom of the column, rise up through the opening in each tray, and the rising gas prevents the liquid from draining through the opening.
- Due to repeated contact of gas and liquid the contaminant are removed and the clean air emerges from the top.

Packed Tower

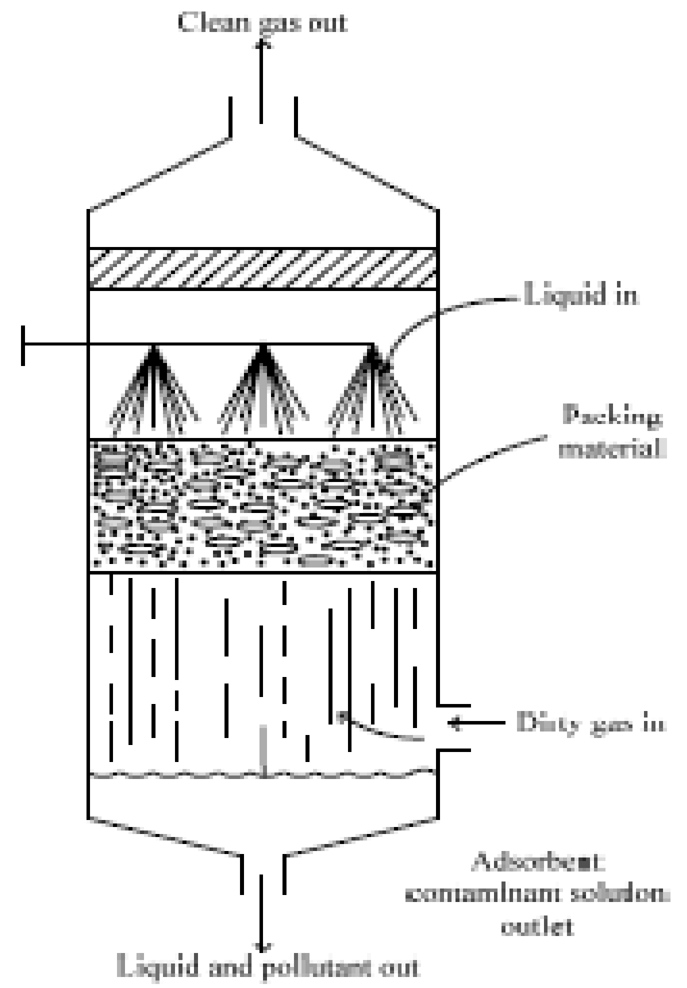


Figure Counter current flow Packed tower

Packed Tower

- In packed tower the **contact time between vapour and liquid is increased by introducing packing**. The packing material has a large surface to volume ratio and a large void ratio that offers minimum resistance to gas flow.
- Liquid flows over the surface of the packing in a thin film causing continuous contact with the gases.
- Packed towers are **highly efficient** but they become easily clogged when gas with high particulate loads are introduced.

Electrostatic Precipitator

- **Principle:**

  The basic force which acts to separate the particles from the gas is **Electrostatic Attraction**.

  The particles are given an electrical charge by forcing them to pass through a **Corona (a region in which gaseous ions flow)**.

  The electrical field that forces the charged particles to the walls comes from electrodes maintained at high voltage in the centre of the flow lane.

Electrostatic Precipitator

- Second most widely used collection devices for particulates.
- Used to collect particulates emitted from Cement, Power Plants, Paper Mills, Byproduct of combustion (ash, dust matter etc)

Electrostatic Precipitator

Requirements of ESP:

- Source of high voltage
- Discharge and collecting electrode
- Inlet and outlet for gas
- A means for disposal of collected material
- Cleaning system, Outer casing.

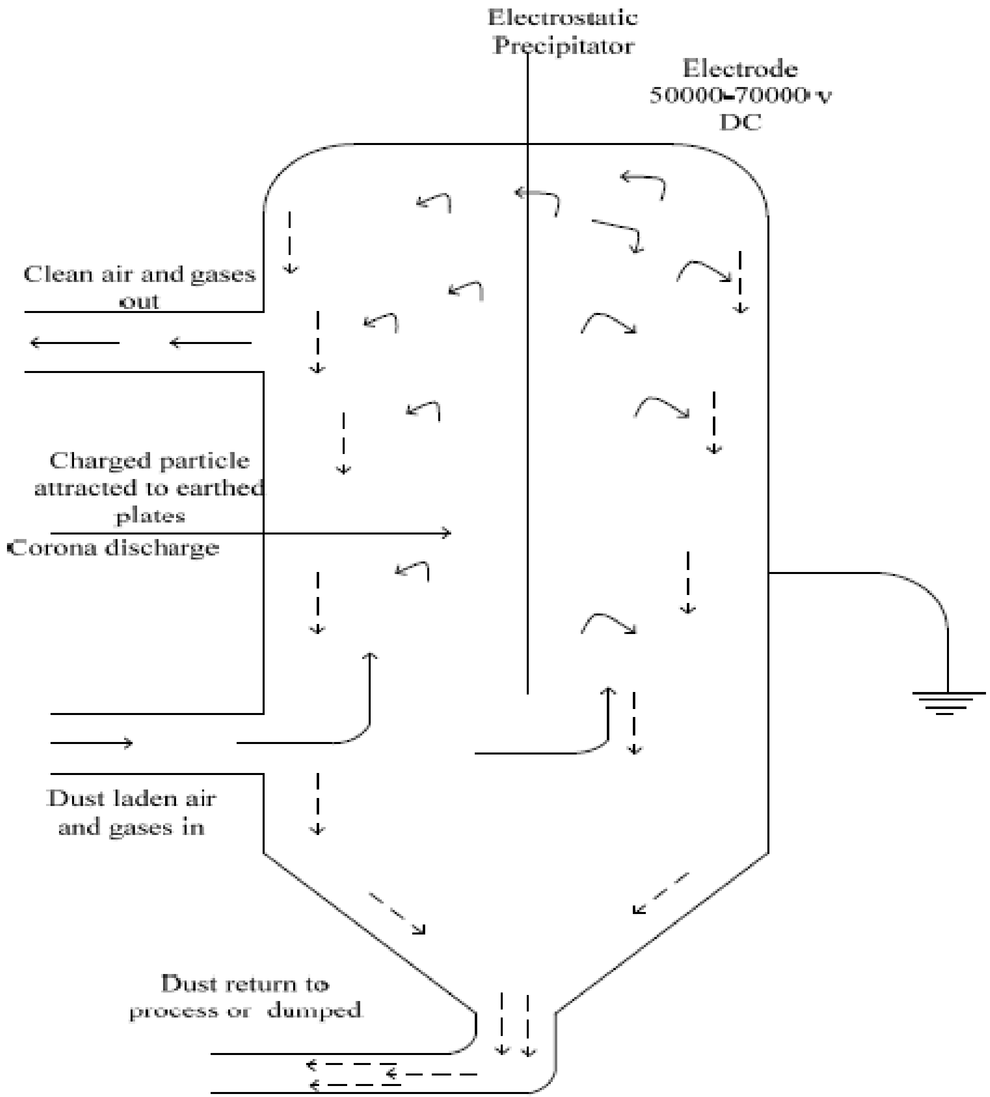
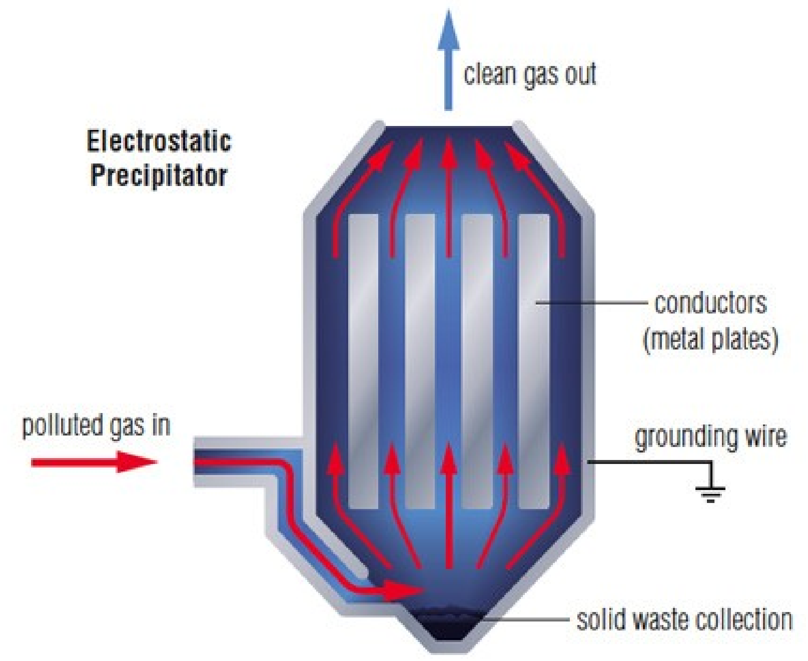


Figure 2.5.2. Movement of dust and air in ESP



Steps in ESP

Steps in ESP:

- Ionization or corona generation
- Charging of Particles
- Migration and precipitation of particle
- Removal of deposited dust

Working of ESP

Ionization or corona generation:

- When the potential difference between the wire and electrode increases, a voltage is reached where an **electrical breakdown of the gas occurs near the wire. This electrical break down or ion discharge is known as** Corona Formation and thereby gas is transformed from insulating to conducting state.
- Two types of corona discharge can be generated which are **Negative Corona and Positive Corona**

Working of ESP

Charging of Particles:

Particle charging takes place in region between the boundary of corona glow and the collection electrode, where particles are subjected to the rain of negative ions from the corona process.

Working of ESP

Migration and precipitation of particle:

- The precipitation system consist of a positively charges collecting surface and a high voltage discharge electrode wire suspended from an insulator at the top and held in position by a weight at the bottom.
- At very high DC voltage, of the order of 50kV a corona discharge occurs close to the negative electrode, setting up an electric filed between the emitter and the grounded surface.
- The gas enters through the bottom and flows upwards.

Working of ESP

Migration and precipitation of particle:

- The gas close to the negative electrode is ionized.
- As the negative ions and electrons migrate towards the grounded surface, they charge the passing particles.
- The electrostatic field draws the particles to the collector surface where they are deposited.

Working of ESP

Removal of deposited dust:

- Once collected, particle can be removed by **Coalescing and Draining** in the case of **liquid aerosols** and by periodic **Impact or Rapping** in case of **solid material.**
- In case of solid material, a sufficiently thick layer of dust must be collected so that it falls into the hopper or bin in coherent masses to prevent excessive re-entrainment of the material into the gas system

Working of ESP

Thermal Incineration

- Many industrial process produce gas streams **which are of no value** thus absorption or adsorption methods **may not be economically feasible**.
- When the conc. Of combustible pollutant is below lower explosive limits, thermal incineration is used.
- If the waste gas contains large amount of **combustible materials** then incineration is the simple route to prevent air pollution.
- The combustion processes comprises of **Destruction of Odours**, **Toxic Substances**, **Reactive Materials**, **Prevention of Hazards**, and **Finally reduction of atmospheric pollutants.**

Thermal Incineration

- When a pollutant is to be destroyed, the **combustion must be complete** or else intermediate products shall be formed.
- In order to have complete combustion there must be sufficient amount of Oxygen to come in contact with the combustible materials at **High Temperatures, Long Residence Time, and Adequate Turbulence (3T's)**.

Thermal Incinerator

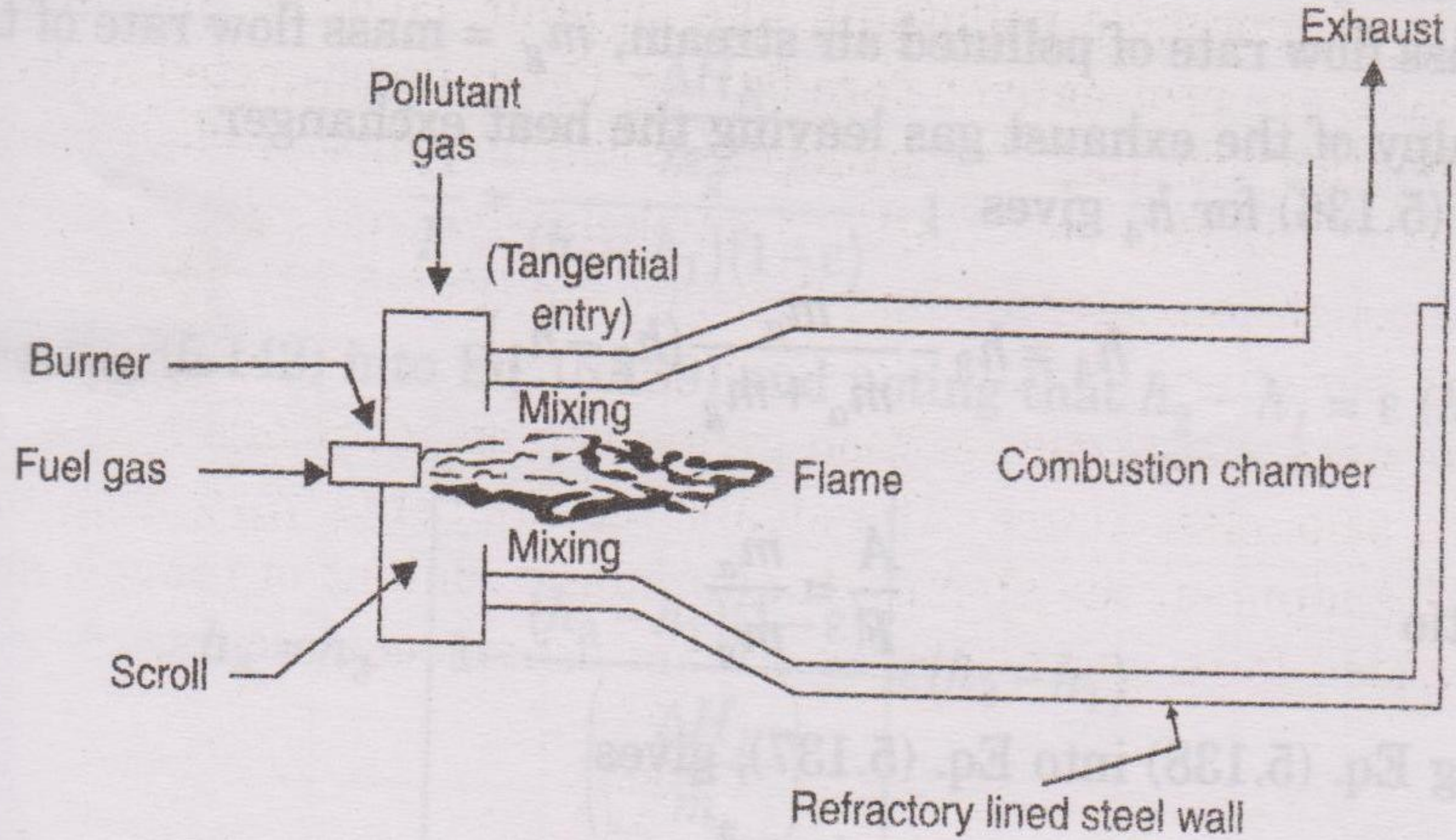
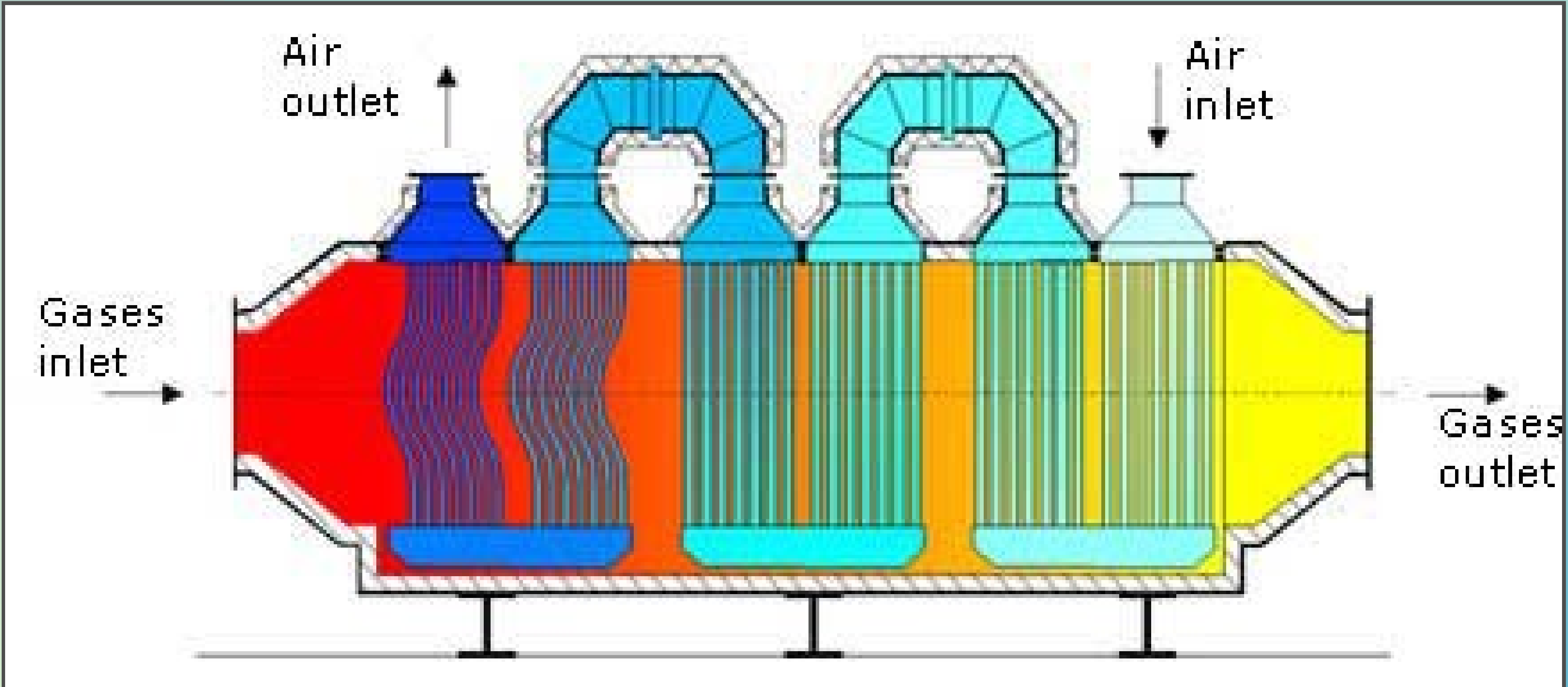


Fig. 5.36 Thermal incinerator

Thermal Incinerator with Recuperator

Counter-flow energy recovery heat exchanger positioned within the supply and exhaust air streams of an air handling system, or in the exhaust gases of an industrial process, in order to recover the waste heat.



Thermal Incineration

- The waste gas is **Preheated** on an **Auxiliary Fuel Fired Burner** and passed into combustion chamber which is maintained at **500°C to 800°C**.
- The gas stream is kept for a sufficient time (i.e 0.3 to 0.7 sec residence time) to allow complete oxidation.
- The gas steam in introduced into the chamber **through a special mechanism (jet or nozzle type)** which creates turbulence and promotes proper mixing with the burning fuel.

Pollutant to be Oxidized	Avg. Temperature Range (°C)
Hydrocarbon	500-750
Carbon monoxide	680-800
Odours	680-700