UNIT III

1. **List the factors affecting choice of air pollution control equipment.**

Type of the industry:

- Cement factories release fugitive dust and sulphur oxide.
- Automobile industries release carbon monoxide and hydrocarbon.

Concentration and Characters of Pollutant:

- The particulate characters include particle size spectrum, effect shape, particle density, physical and chemical properties like stickiness, fluidity, corrosiveness and electrical conductivity.

Carrier Gas Characters:

- It includes the temperature, pressure, density, viscosity.

Process factors:

- It includes the flow variability, volumetric gas rate, particulate concentration rate and allowable pressure drop.

Control efficiency:

- It is the measure of emission reduction and it is a percentage value representing the amount of emission controlled by the device.

Operational factors:

- It includes the maintenance, continuity of operation, safety and health protection, ultimate use of collected material, etc.

Constructional Measures:

- It includes structural limitations such as floor space and head room and material limitations such as pressure, temperature and corrosion service requirements.

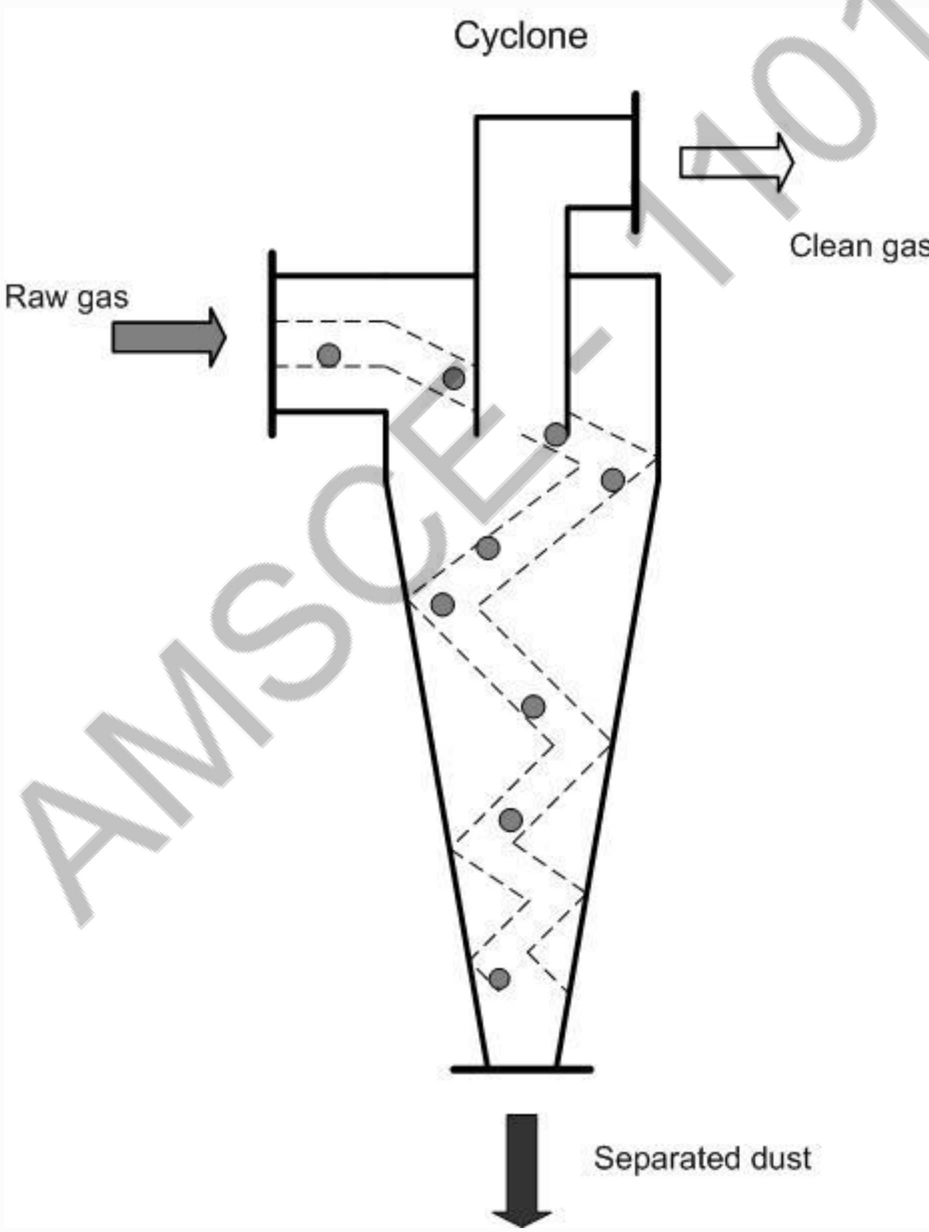
Other factors:

- Dust disposal, energy considerations, etc

2. Explain the working principle of cyclone separator.

Removed components

— Dust, particles: abrasive, corrosive, adhesive, explosive



Process description

Working principle

A cyclone is a centrifugal separator in which particles, due to their mass, are pushed to the outer edges as a result of centrifugal force. Incoming air is automatically forced to adopt a fast-revolving spiral movement - the so-called “ double vortex” . This double spiral movement consists of an outer stream, which flows downwards in a spiral, and an inner stream, which flows upwards in a spiral. At the interchange between both streams, air passes from one stream to the other. The particles which are present in the air are forced to the outer edges and leave the separator via a collection device fitted to the bottom of the separator.

The air speed of a cyclone lies between 10 and 20 m/s, and the most common speed is ca. 16 m/s. If there are fluctuations in speed (with lower speeds), separation yield falls quite drastically.

Design data

A cyclone is normally characterised by a cyclone diameter and a cut-off diameter.

The required geometrics are determined by the desired separation yield and the characteristics of the gas and particles.

The Lapple formula provides an indication of the separation yield:

$$d_{50} = \sqrt{\frac{9\mu b}{2\pi N v_i \Gamma_i}}$$

d_{50} = particle size which is separated with 50% yield (m);

b = inlet width for the cyclone inflow (m);

N = number of rotation cycles in the cyclone (? N=5, empirically determined);

v_i = inlet speed (m/s);

?i = specific density of particulate (kg/m^3);

μ^p = viscosity of gas (kg/ms).

Once the d_{50} has been determined, the separation yield for all other particle sizes can be graphically determined.

Materials

In the presence of substances and liquids with a strong corrosive or erosive nature, cyclones must be made of a suitable material or be coated with an appropriate substance. Cyclones are available in various materials such as stainless steel, aluminium, nickel, polystyrene (PS), polyvinylchloride (PVC) and polyvinylidenefluoride (PVDF).

Variants

" High throughput" cyclones have a diameter greater than 1.5 m and are suitable for separating particles that are 20 µm or larger.

"High efficiency" cyclones (pencil cyclones) have a diameter which lies between 0.4 and 1.5 m and can be used to separate particles that are10 µm or larger.

Cyclones with a diameter between 0.005 and 0.3 m are no longer used independently, but are constructed into **multi-cyclones**. In this case, the inflow of gas does not take place tangentially as in regular cyclones, but axially, after which the gas is made to spiral via splitter blades. A multi-cyclone requires gas to be well-distributed across the smaller cyclones. If there is insufficient distribution, this may lead to gas back-flow and blockages.

Other types of cyclones:

Electro-cyclones: By placing an electric field between the centre and the wall of the cyclone, the driving force pushing the particles to the wall is increased, which leads to a higher separation yield.

"*Secondary flow enhanced cyclone"*: In a cylindrical casing, the primary gas – the gas which is to be cleaned – is inputted from below in a swirling movement. Due to the tangential addition of secondary air from above, the centrifugal forces on particles are increased, whereby the removal efficiency is also increased.   Secondary air can be pure or purified air.

Combination of multi-cyclone and baghouse filter: This is a combination of two techniques; namely, a multi-cyclone for pre-cleaning, as described above, and a baghouse filter (see technique sheet 10) to further clean the waste gas.

Condensation cyclone: These cyclones are cooled via a cooling agent. At a particular temperature, under dew-point, substances like fats and water can be condensed and separated.

Wet cyclone: In order to increase the separation yield of fine particles (< 20 µm), water is sprayed into the cyclone's inlet pipe immediately prior to the cyclone. The water attaches itself to the fine particles and is removed as slurry.

Micronsep wringing separator: In addition to the vortex effect, the workings of this system are also based on the phenomenon of secondary flows in a boundary layer. The system consists of a spiral-shaped inside, which is placed in a sheath that resembles a cyclone. The system has a yield in excess of 99.5% for particles greater than 1 µm, whereby it excels compared to classic cyclones.

Efficiency

The separation yield of a cyclone is 99% at 50 µm. This is considerably higher than that of sedimentation chambers or impact separators. A guideline figure is: 90% yield for 10 µm particles. Cyclones are most efficient at high air speeds, small cyclone diameters and large cylinder lengths (pencil cyclones). This is in contrast to so-called " high output" cyclones, where large throughput, and thus large dimensions, negatively influence the yield.

Residual emissions: 100 mg/Nm^3

Boundary conditions

The physical and/or chemical properties of the to-be-separated pollutants are the main factors that influence the applicability of mechanical separators.

A major limiting factor for most cyclones is that to-be-separated substances may not lead to excessive pollution or cause obstructions.

The temperature of in-flowing air also sets a boundary condition for cyclones. Because there is a very wide range of material types, cyclones have the advantage of being applicable in extreme situations – low and high temperatures, for example.

— Flow rate: 1 – 100 000 Nm^3/h for a single cyclone

— Temperature: < 1.200 °C depending on construction material

— In-coming concentrations: 1 - 16 000 g/Nm^3

Auxiliary materials

Water for wet cyclones and coolant for condensation cyclones.

Environmental aspects

Separated dust disposed as waste product or re-used, if possible.

Slurry from wet cyclones must be processed via water purification or be disposed of.

Energy use

0.25 – 1.5 kWh/1 000 Nm^3/h

Advantages

— Simple construction

— No moving parts

— Little maintenance

— Low investment and operation costs

— Constant pressure loss

— Space efficient

— Dry collection, except for wet cyclones

Disadvantages

— High pressure loss (0.5 – 2.5 kPa), depending on set-up

— Low yield for low-diameter particles

— Poor performance for partial load

— Emission of waste water for wet cyclones

— Erosion-sensitive and risk of blockage at inlet

— Possible noise problems

Applications

Due to its relatively low yield and relatively high residual emissions, a cyclone is most commonly used as a pre-separator to remove larger particles before another dust abatement installation, such as a scrubber or baghouse filter, is implemented.

Pre-separation normally takes place on particles > 5µm and is mostly used in:

— Wood and furniture industry;

— The building sector;

— Glass industry;

— The transport sector for storage and transfer;

— The foodstuffs industry;

— Waste combustion installations;

— The chemicals industry;

— Melting processes in metallurgy;

— Sintering processes;

— Coffee roasting industry.

3. Explain the working principle of electrostatic precipitator.

Electrostatic Precipitator can be defined as a type of air cleaner or filter that utilizes electric energy for removing the impurities, dust particles from the air. This is a commonly used device for controlling air pollution. Most of the industries, power stations generate fossil fuels in the process of electricity generation or manufacturing process.

When these fuels burn, then the smoke will generate which includes the small soot particles that are balanced the air. The carbon particles which are not burned can pull out from the smoke with the help of electrical energy in the precipitator. It is essential for removing carbon particles from the burn because it can harm human health as well as properties like buildings.

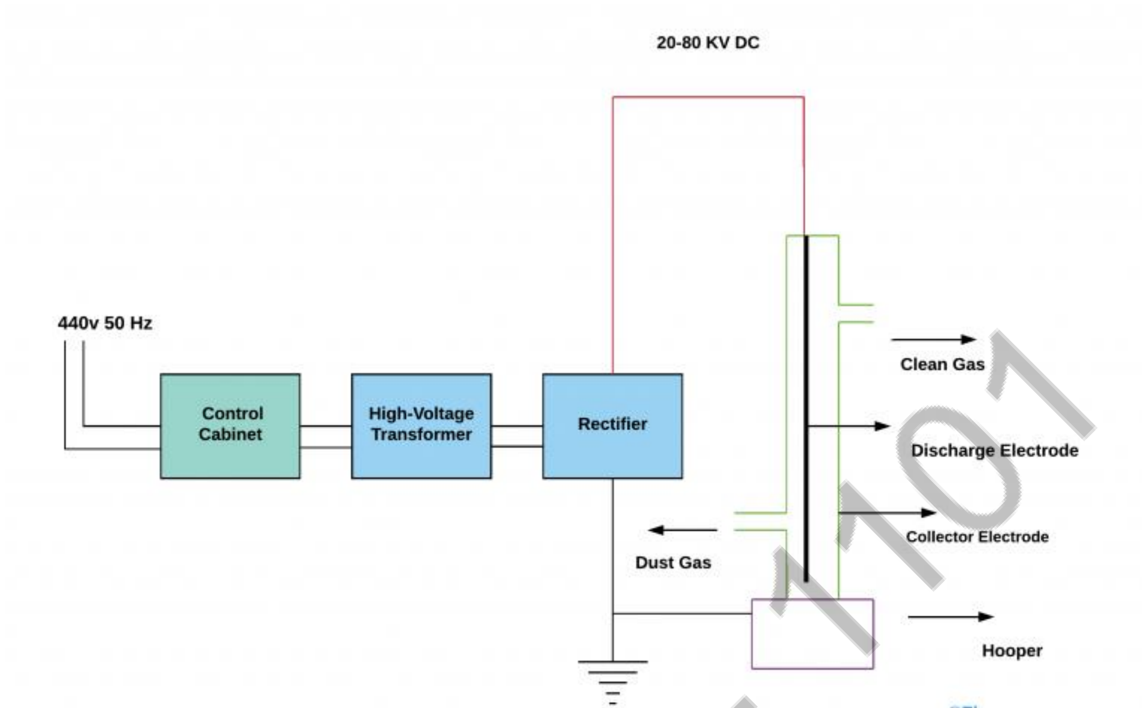
Electrostatic Precipitator Construction

This device includes two sets of electrodes namely positive as well as negative. The appearance of the positive electrodes is like plates whereas the negative electrodes are in the shape of a wire mesh or rod. These two electrodes are arranged vertically one after another in the precipitator. The connection of the two electrodes can be done by connecting the positive and negative electrodes to the two terminals of the DC source. The DC source positive terminal may be connected to GND for getting strong negativity to the negative terminals. The distance between the two electrodes and applied DC voltage are corrected.

The components of electrostatic precipitator include Electrodes, 3 phase supply 50 Hz 440v, control cabinet, High voltage transformer, Rectifier, Hooper and Insulators.

- The control cabinet is applicable for interconnecting the transformer & 3 phase ac supply using wires.
- The function of a transformer in an electrostatic precipitator is for step-up & step-down the voltage.
- The main function of a rectifier in an electrostatic precipitator is to alter the AC supply into DC supply.
- The hooper is useful for storing the particles of dust & content of ash from the electrostatic precipitator.

Electrostatic Precipitator Components



Electrostatic Precipitator Working

The **electrostatic precipitator working principle** is very simple. The unclean flue gas flowing through the tube is supplied by two electrodes. The shape of the two electrodes mainly depends on the type of precipitator employed like bars, plates, metal wires, etc.

One of the plates is charged by a high negative voltage, which causes particulates in the burn for getting a negative charge because they flow with this plate. The next plate carries a high positive voltage equally, due to the fact that opposed charges attract. The soot elements which are negatively charged are pulled in the direction of the positive electrode & fix to it. Irregularly these two plates should be cleaned for eliminating the collected dust.

Most of the electrostatic precipitator's works in the same method, and there are several dissimilarities as well as types that work well for different amounts of pollution, shaped particles, and smoke compositions

The efficiency of Electrostatic Precipitator

At present, the **applications of ESPs** have become very standard in several industries because of severe instruction as well as ever-growing air-pollution. Fixing one ESP has become a necessity in a power plant where chimney gases are out.

However whether ESPs execute the function estimated from them will be decided by calculating the device efficiency. The efficiency requirement can depend on the type of industry. The efficiency of an ESP can be affected by the factors like power ratio of a corona, the collected dust resistivity, and the size of a particle.

The **efficiency of ESP** can be calculated by the Deutsch Anderson equation.

$\eta = 1\text{-}e\ (-WA/Q)$

Where "η' is the efficiency of fractional collection.

"W' is the velocity of drift terminal in m/s.

'A' is the collection of the total region in m2.

'Q' is the volumetric rate of air flow in m3/s.

Advantages of Electrostatic Precipitator

The advantages of electrostatic precipitator include the following.

- The elimination of high-efficiency pollutants (or) particles
- Collection of dry & wet impurities
- Operating cost is low.

Disadvantages of Electrostatic Precipitator

The disadvantages of electrostatic precipitator include the following.

- Very expensive
- It requires huge space
- It is not supple once fixed
- They are not useful in collecting the gaseous pollutants

Electrostatic Precipitator Applications

The applications of electrostatic precipitator include the following.

- The most common application of Electrostatic precipitator is an industrial application for a smoke. It looks like a gas; however, it is basically an accumulation of hard elements floating in the atmosphere. These elements can be excited, letting them be composed of enormous, commercial precipitators.
- The dry electrostatic precipitators are used for collecting dry particles like cement, ash, etc.
- The wet electrostatic precipitators are used for removing the wet particles like oil, tar, resin, acid, etc.
- Electrostatic Precipitators are used in steam plants for removing the dust from flue gases.
- Electrostatic Precipitators are used in machine shops and chemical plants for removing oil mists and acid mists.
- These are used to clean the blast or metallurgical heating system gases
- ESPs are used to remove the bacteria & fungus in the medical field.
- ESPs are used in air conditioning systems for sanitizing air
- ESPs are used to recover the materials in the flow of gas
- ESPs are used in zirconium sand for detaching the rutile in plants like dry mills and rutile

4. Describe the working principle of scrubbers.

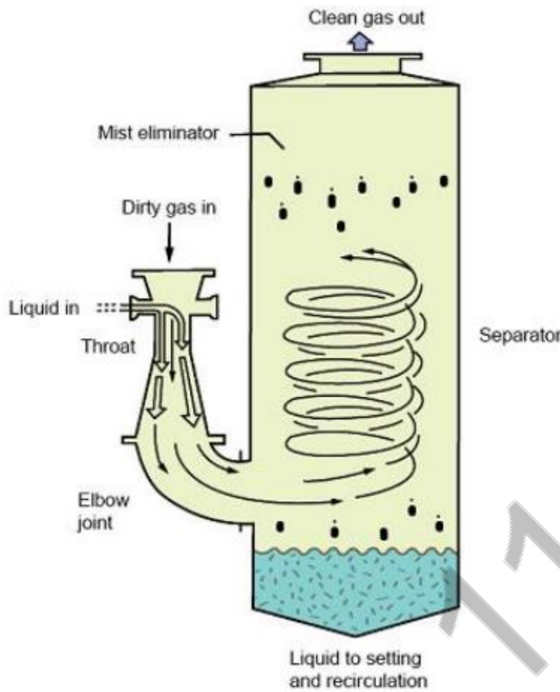
Scrubbers are most often used as an air pollution control device to remove particulate matters and chemicals from waste gas streams of stationary point source. They are also applied where the slurry is used in other parts of the process or where the mixture is in a slurry form. In some scrubbers are applied so that chemical reaction will be generated within the scrubbing action.

Orifice scrubbers

In an orifice scrubber also known as an impaction scrubber, the gas stream flows over the surface of a pool of scrubbing liquid. As the air impinges on the water surface, it entrains droplets of the liquid. The waste gas stream then flows upward and enters an orifice with a narrower opening than the duct. The orifice brings turbulence in the flow which atomizes the entrained droplets. The atomized droplets capture the particulate matters in the air stream. Air velocity in the orifice scrubbers can be controlled by using adjustable orifices. The main advantage of this type of scrubber is that it does not need the recirculation pump for the scrubbing liquid, which is the major contributor to operating costs for most of the scrubbers. The disadvantage is difficulty in removing the sludge generated during the scrubbing process. In most scrubber design waste continuously drains from the bottom. Orifice scrubber consists of a static pool for scrubbing liquids, so waste generated is removed with a sludge ejector, which operates like a conveyor belt.

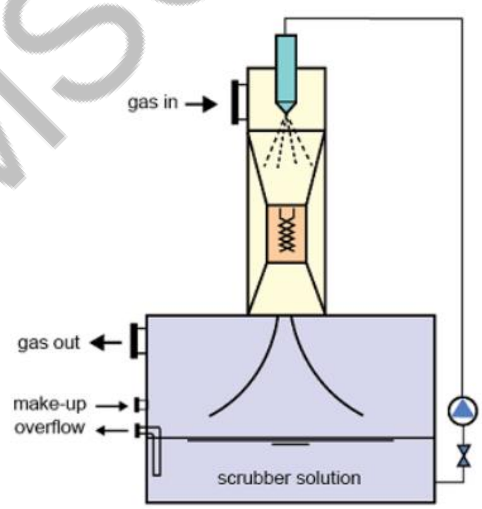
Venturi scrubbers

Venturi scrubber has a converging-diverging section, in this type of system the cross sectional area of the channel decreases then increases along the length of the channel. The narrowest area in the channel is referred as the throat. In venturi scrubber, liquid is introduced slightly upstream of the throat or directly into the throat section. In the converging section the decrease in area causes the waste gas stream velocity and turbulence to increase. The scrubbing liquid is atomized by high velocity air stream and improves the air –liquid contact. Further the air – liquid mixtures decelerate as it moves through the diverging section, which helps to creates particle droplet impacts and agglomeration of the droplets. The separation of the liquid droplets from the air stream takes place in the entrainment section. The entrainment section usually consists of cyclonic separator and mist eliminator. For venturi scrubber collection efficiency for the fine particulate matter is higher but the equipment is more expensive than spray tower, cyclonic or tray tower scrubber. High air velocity and turbulence in the venture scrubber throat result in high collection efficiencies ranging from 70 to 99% for particles larger than 1 µm in diameter and greater than 50% for submicron particles. Increasing the pressure drop increases the collection efficiency, but the system's energy demand also increases leading to higher operational cost.



Jet scrubber

In this scrubber, water flow is used in jet ejector to aspirate dusty air and to provide droplets for collecting particulates. Jet scrubber is used when it is not economical to used fan for a dust collection system . Also, it can be used as a gas absorber.



Dynamic scrubber

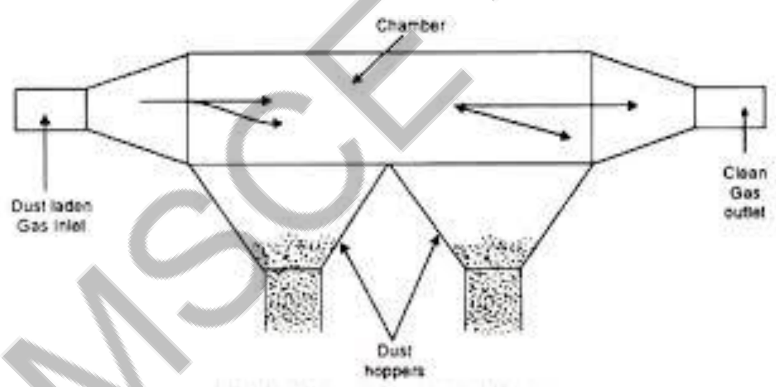
This type of scrubber is similar to spray towers, but only difference is that the dynamic scrubber uses power driven rotor that breaks the scrubbing liquids into finely dispersed droplets. Dynamic scrubbers are also known as mechanically –aided scrubbers or disintegrator. Liquid is sprayed into the suction of a fan and the wetted impeller and casing captures dust particles. Most dynamic scrubber systems humidify the waste air upstream of the rotor to reduce evaporation and particle deposition in the rotor area. This type of scrubber efficiently removes fine particulate matter, but the use of rotar in the system increases the maintenance cost. Pretreatment device, such as cyclone often used before dynamic scrubbers to remove the large particulate matter from the waste air stream. Collection efficiencies for dynamic scrubbers are similar to those for cyclonic spray towers.

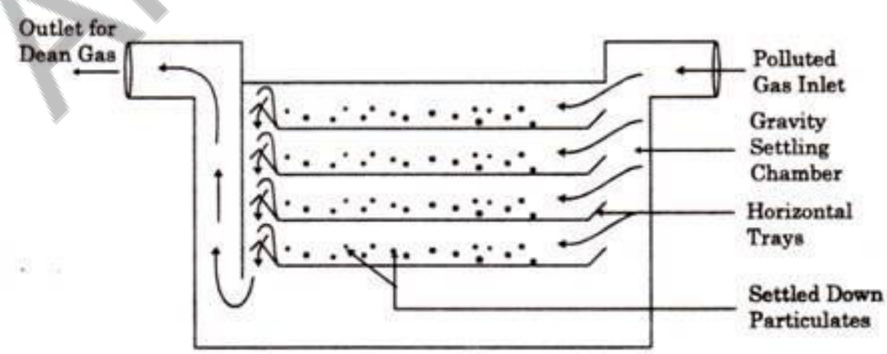
5. Explain the bag house filters with merits and demerits

A fabric filter unit consists of one or more isolated compartments containing rows of fabric bags in the form of round, flat, or shaped tubes, or pleated cartridges. Particle laden gas passes up (usually) along the surface of the bags then radially through the fabric. Particles are retained on the upstream face of the bags, and the cleaned gas stream is vented to the atmosphere. The filter is operated cyclically, alternating between relatively long periods of filtering and short periods of cleaning. During cleaning, dust that has accumulated on the bags is removed from the fabric surface and deposited in a hopper for subsequent disposal. Fabric filters collect particles with sizes ranging from submicron to several hundred microns in diameter at efficiencies generally in excess of 99 or 99.9 percent. The layer of dust, or dust cake, collected on the fabric is primarily responsible for such high efficiency. The cake is a barrier with tortuous pores that trap particles as they travel through the cake. Gas temperatures up to about 500F, with surges to about 550F can be accommodated routinely in some configurations. Most of the energy used to operate the system appears as pressure drop across the bags and associated hardware and ducting. Typical values of system pressure drop range from about 5 to 20 inches of water. Fabric filters are used where high efficiency particle collection is required. Limitations are imposed by gas characteristics (temperature and corrosivity) and particle characteristics (primarily stickiness) that affect the fabric or its operation and that cannot be economically accommodated.

6. Explain the working principle of settling chamber.

Separation of two immiscible liquids or slurry containing fine solids can also be carried out by making use of the density difference. In case of these two phase system the continuous phase is a liquid while the disperse phase is solid or other immiscible liquid. Solid-liquid separation processes are generally based on either one or a combination of gravity settling, filtration, and centrifugation principles. In gravity settling separation, solid particles will settle out of a liquid phase if the gravitational force acting on the droplet or particle is greater than the drag force of the fluid flowing around the particle (sedimentation).





The solid phase is assumed to having the higher density and its percentage should not be more than 25% by volume. Because upto the concentration of 1.0 -2.0% (vol.), hindered settling is negligible but above 10% (approx.), hindered settling becomes more dominant. The particle size or droplet to be separated should be less than 500 µm. In this separation, the sedimentation velocity or terminal settling velocity or sedimentation rate can be estimated using:

$$u_g = \frac{d_p^2(\rho_s - \rho_L)}{18\mu}$$

Above equation shows that if the density difference is negative. The particle will move upwards with a velocity u_g toward the surface of the liquid i.e. the particle will move in the opposite direction to that in which the force of gravity. The sedimentation rate depends upon the particle density, density of continuous phase and the viscosity of the continuous phase.

While in case of batch operation (i.e. separation by gravity) time required to achieve complete separation for the particle which is initially at the surface must be sufficient enough to travel through the entire depth of the liquid. Time required for the particle sedimentation can be reduced by decreasing the depth of the chamber. Decrease in depth can be achieved by increasing the length of the chamber and keeping same residence time, but with decrease in depth operation may become uncontrollable.

For continuous operation time provided for separation (by gravity) in the vessel is given by:

$$t = \frac{V}{Q} = \frac{W\,h\,L}{Q}$$

V - volume of tank $= W \times h \times L$

W - width of tank ; h- height of tank; L – length of tank

The desired particle size should be able to settle to the bottom of the tank

$$t = \frac{h}{u_{lim}}$$

$$t = \frac{W.\,h\,.L}{Q} = \frac{h}{u_{lim}}$$

$$\text{i.e.} \quad \frac{1}{u_{lim}} = \frac{W\,L}{Q} = \frac{A}{Q}$$

WL - surface area of the tank A.

Q - throughout rate

$Q = [u_{lim}\,.\,A]$

Above equation gives the maximum possible throughout for the desired particle size d_{lim} having a sediment velocity u_{lim}. From this it is observed that the height of the tank does not affect the throughput rate. Only alternative is throughput can be increased by increasing the surface area and it (surface area) can be increased by providing the horizontal or inclined plates in the tank.

$Q = u_{lim}.\ N.\ A$

Where N - number of separation channels of area A.

In the above equation u_{lim} is fixed by the particle size and density, thus the throughput is proportional to total area N A.

7. Explain the air pollution control methods.

Some of the effective methods to Control Air Pollution are as follows:

(a) Source Correction Methods

(b) Pollution Control equipment

(c) Diffusion of pollutant in air

(d) Vegetation

(e) Zoning.

<u>(a) Source Correction Methods:</u>

Industries make a major contribution towards causing air pollution. Formation of pollutants can be prevented and their emission can be minimised at the source itself.

By carefully investigating the early stages of design and development in industrial processes e.g., those methods which have minimum air pollution potential can be selected to accomplish air-pollution control at source itself.

These source correction methods are:

(i) Substitution of raw materials:

If the use of a particular raw material results in air pollution, then it should be substituted by another purer grade raw material which reduces the formation of pollutants. Thus,

(a) Low sulphur fuel which has less pollution potential can be used as an alternative to high Sulphur fuels, and,

(b) Comparatively more refined liquid petroleum gas (LPG) or liquefied natural gas (LNG) can be used instead of traditional high contaminant fuels such as coal.

(ii) Process Modification:

The existing process may be changed by using modified techniques to control emission at source. For example,

(a) If coal is washed before pulverization, then fly-ash emissions are considerably reduced.

(b) If air intake of boiler furnace is adjusted, then excess Fly-ash emissions at power plants can be reduced.

(iii) Modification of Existing Equipment:

Air pollution can be considerably minimised by making suitable modifications in the existing equipment:

(a) For example, smoke, carbon-monoxide and fumes can be reduced if open hearth furnaces are replaced with controlled basic oxygen furnaces or electric furnaces.

(b) In petroleum refineries, loss of hydrocarbon vapours from storage tanks due to evaporation, temperature changes or displacement during filling etc. can be reduced by designing the storage tanks with floating roof covers.

(c) Pressurising the storage tanks in the above case can also give similar results.

(iv) Maintenance of Equipment:

An appreciable amount of pollution is caused due to poor maintenance of the equipment which includes the leakage around ducts, pipes, valves and pumps etc. Emission of pollutants due to negligence can be minimised by a routine checkup of the seals and gaskets.

<u>(b) Pollution Control Equipment:</u>

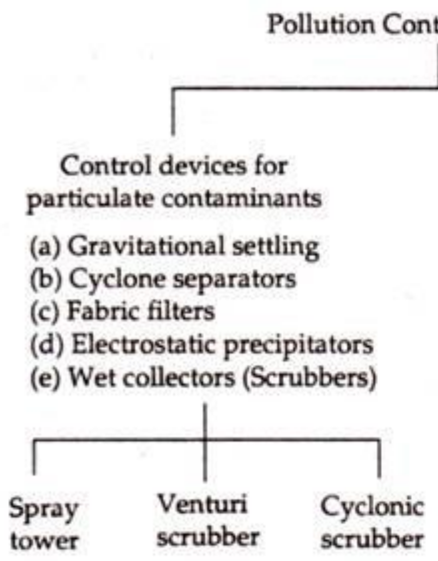
Sometimes pollution control at source is not possible by preventing the emission of pollutants. Then it becomes necessary to install pollution control equipment to remove the gaseous pollutants from the main gas stream.

The pollutants are present in high concentration at the source and as their distance from the source increases they become diluted by diffusing with environmental air.

Pollution control equipment's are generally classified into two types:

(a) Control devices for particulate contaminants.

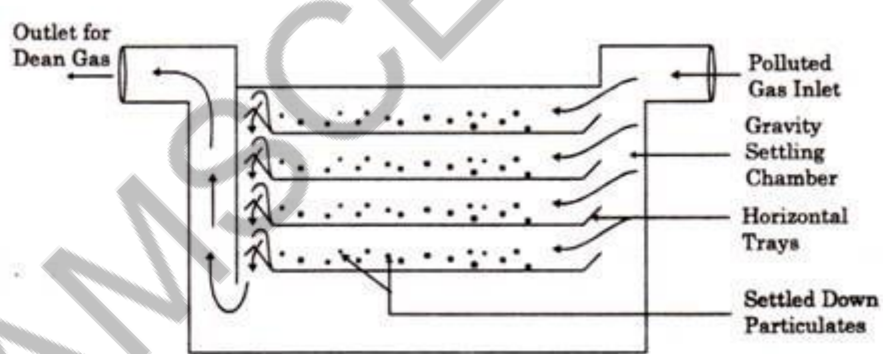
(b) Control devices for gaseous contaminants.



Control Devices for Particulate Contaminants:

(1) Gravitational Settling Chamber:

For removal of particles exceeding 50 µm in size from polluted gas streams, gravitational settling chambers (Fig 5.1) are put to use.



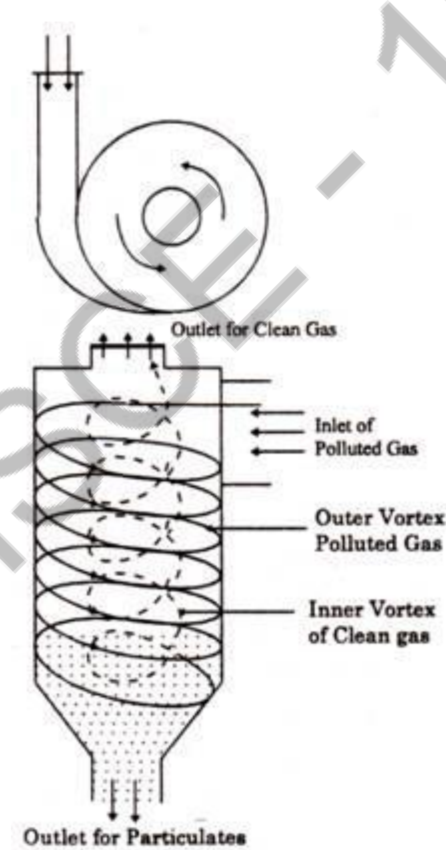
This device consists of huge rectangular chambers. The gas stream polluted with particulates is allowed to enter from one end. The horizontal velocity of the gas stream is kept low (less than 0.3 m/s) in order to give sufficient time for the particles to settle by gravity.

The particulates having higher density obey Stoke's law and settle at the bottom of the chamber from where they are removed ultimately. The several horizontal shelves or trays improve the collection efficiency by shortening the settling path of the particles.

(2) Cyclone Separators (Reverse flow Cyclone):

Instead of gravitational force, centrifugal force is utilized by cyclone separators, to separate the particulate matter from the polluted gas. Centrifugal force, several times greater than gravitational force, can be generated by a spinning gas stream and this quality makes cyclone separators more effective in removing much smaller particulates than can possibly be removed by gravitational settling chambers.

A simple cyclone separator consists of a cylinder with a conical base. A tangential inlet discharging near the top and an outlet for discharging the particulates is present at the base of the cone.



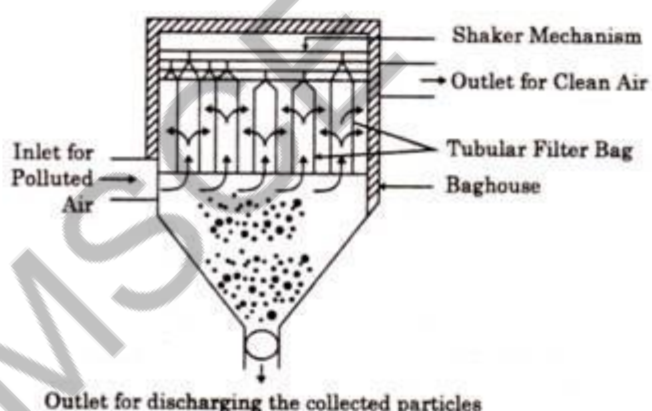
Mechanism of Action:

The dust laden gas enters tangentially, receives a rotating motion and generates a centrifugal force due to which the particulates are thrown to the cyclone walls as the gas spirals upwards inside the cone (i.e. flow reverses to form an inner vortex which leaves flow through the outlet). The particulates slide down the .walls of the cone and are discharged from the outlet.

(3) Fabric Filters (Baghouse Filters):

In a fabric filter system, a stream of the polluted gas is made to pass through a fabric that filters out the particulate pollutant and allows the clear gas to pass through. The particulate matter is left in the form of a thin dust mat on the insides of the bag. This dust mat acts as a filtering medium for further removal of particulates increasing the efficiency of the filter bag to sieve more sub micron particles (0.5 µm).

A typical filter is a tubular bag which is closed at the upper end and has a hopper attached at the lower end to collect the particles when they are dislodged from the fabric. Many such bags are hung in a baghouse. For efficient filtration and a longer life the filter bags must be cleaned occasionally by a mechanical shaker to prevent too many particulate layers from building up on the inside surfaces of the bag.



(4) Electrostatic Precipitators:

The electrostatic precipitator works on the principle of electrostatic precipitation i.e. electrically charged particulates present in the polluted gas are separated from the gas stream under the influence of the electrical field.

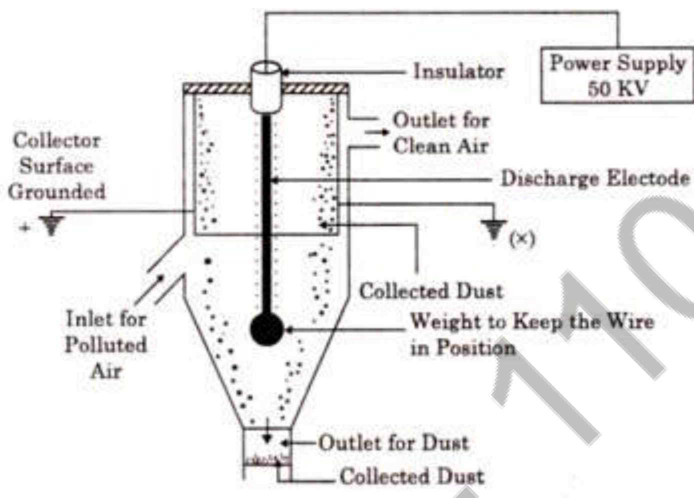
A typical wire and pipe precipitator consists of:

(a) A positively charged collecting surface (grounded).

(b) A high voltage (50 KV) discharge electrode wire.

(c) Insulator to suspend the electrode wire from the top.

(d) A weight at the bottom of the electrode wire to keep the wire in position.



Mechanism of Action:

The polluted gas enters from the bottom, flows upwards (i.e. between the high voltage wire and grounded collecting surface). The high voltage in the wire ionises the gas. The negative ions migrate towards the grounded surface and pass on their negative charge to the dust particles also. Then these negatively charged dust particles are electrostatically drawn towards the positively charged collector surface, where they finally get deposited.

The collecting surface is rapped or vibrated to periodically remove the collected dust-particles so that the thickness of the dust layer deposited does not exceed 6 mm, otherwise the electrical attraction becomes weak and efficiency of the electrostatic precipitator gets reduced.

As the electrostatic precipitation has 99 + percent efficiency and can be operated at high temperatures (600°C) and pressure at less power requirement, therefore, it is economical and simple to operate compared to other devices.

(5) Wet Collectors (Scrubbers):

In wet collectors or scrubbers, the particulate contaminants are removed from the polluted gas stream by incorporating the particulates into liquid droplets.

Common wet scrubbers are:

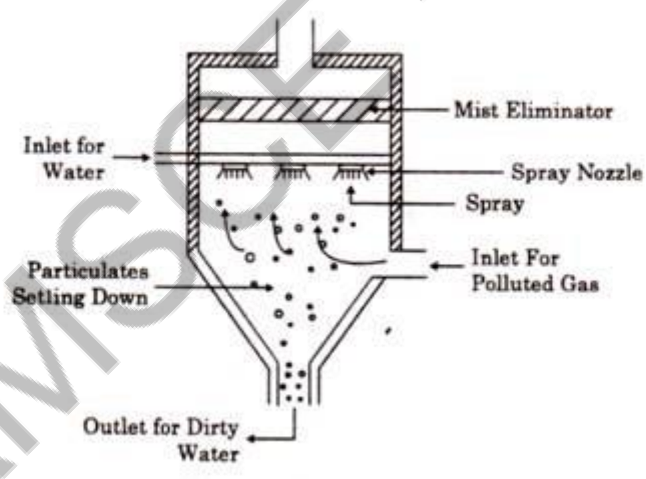
(i) Spray Tower

(ii) Venturi Scrubber

(iii) Cyclone Scrubber

(i) Spray Tower:

Water is introduced into a spray tower by means of a spray nozzle (i.e. there is downward flow of water). As the polluted gas flows upwards, the particulates (size exceeding 10 µm) present collide with the water droplets being sprayed downward from the spray nozzles. Under the influence of gravitational force, the liquid droplets containing the particulates settle to the bottom of the spray tower.

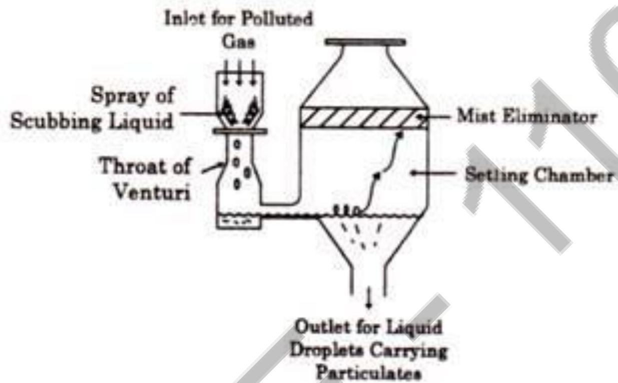


(ii) Venturi Scrubber:

Submicron particulates (size 0.5 to 5 µn) associated with smoke and fumes are very effectively removed by the highly efficient Venturi Scrubbers. As shown in Fig 5.6 a Venturi Scrubber has a Venturi shaped throat section. The polluted gas passes downwards through the throat at the velocity of 60 to 180 m/sec.

A coarse water stream is injected upwards into the throat where it gets atomised (i.e. breaks the water into droplets) due to the impact of high velocity of the gas. The liquid droplets collide with the particulates in the polluted gas stream.

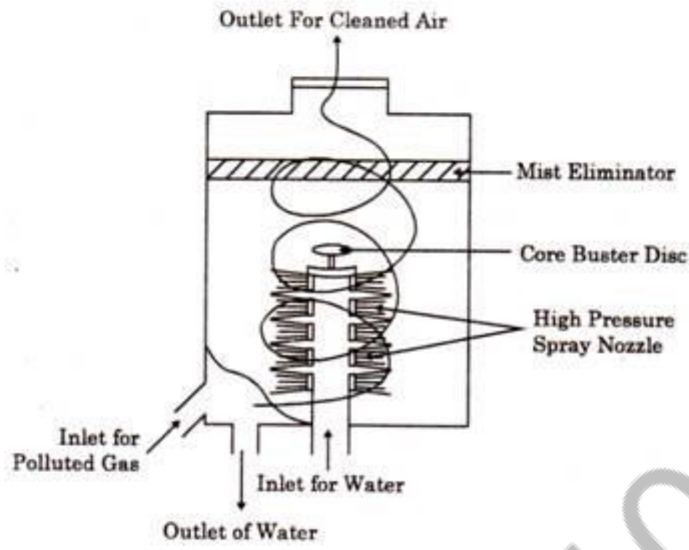
The particles get entrained in the droplets and fall down to be removed later on. Venturi Scrubbers can also remove soluble gaseous contaminants. Due to the atomisation of water there is proper contact between the liquid and the gas increasing the efficiency of the Venturi Scrubber (their power cost is high because of the high inlet gas velocity).



To separate the droplets carrying the particulate matter from the gas stream, this gas-liquid mixture in the Venturi Scrubber is then directed into a separation device such as a cyclone separator.

iii) Cyclone Scrubber:

The dry cyclone chamber can be converted into a wet cyclone scrubber by inserting high pressure spray nozzles at various places within the dry chamber (Fig. 5.7).



The high pressure spray nozzles generate a fine spray that intercepts the small particles in the polluted gas. The centrifugal force throws these particles towards the wall from where they are drained downwards to the bottom of the scrubber.

(c) Diffusion of Pollutants in Air:

Dilution of the contaminants in the atmosphere is another approach to the control of air pollution. If the pollution source releases only a small quantity of the contaminants then pollution is not noticeable as these pollutants easily diffuse into the atmosphere but if the quantity of air contaminants is beyond the limited capacity of the environment to absorb the contaminants then pollution is caused.

However, dilution of the contaminants in the atmosphere can be accomplished through the use of tall stacks which penetrate the upper atmospheric layers and disperse the contaminants so that the ground level pollution is greatly reduced. The height of the stacks is usually kept 2 to $2^1/_2$ times the height of nearby structures.

Dilution of pollutants in air depend on atmospheric temperature, speed and direction of the wind. The disadvantage of the method is that it is a short term contact measure which in reality brings about highly undesirable long range effects.

This is so because dilution only dilutes the contaminants to levels at which their harmful effects are less noticeable near their original source whereas at a considerable distance from the source these very contaminants eventually come down in some form or another.

(d) Vegetation:

Plants contribute towards controlling air-pollution by utilizing carbon dioxide and releasing oxygen in the process of photosynthesis. This purifies the air (removal of gaseous pollutant—CO_2) for the respiration of men and animals.

Gaseous pollutants like carbon monoxide are fixed by some plants, namely, Coleus Blumeri, Ficus variegata and Phascolus Vulgaris. Species of Pinus, Quercus, Pyrus, Juniperus and Vitis depollute the air by metabolising nitrogen oxides. Plenty of trees should be planted especially around those areas which are declared as high-risk areas of pollution.

(e) Zoning:

This method of controlling air pollution can be adopted at the planning stages of the city. Zoning advocates setting aside of separate areas for industries so that they are far removed from the residential areas. The heavy industries should not be located too close to each other.

New industries, as far as possible, should be established away from larger cities (this will also keep a check on increasing concentration of urban population in a few larger cities only) and the locational decisions of large industries should be guided by regional planning. The industrial estate of Bangalore is divided into three zones namely light, medium and large industries. In Bangalore and Delhi very large industries are not permitted.