

* Pollutant:

→ Air Pollution is defined as the presence of contaminants in air such as dust, fumes, gases, mist, odour, smoke or vapour in such quantities and characteristics for a particular duration which may be injurious to human plant or animal life or to the property or which unreasonably interfere with comfortable environment of life and the property.

→ Air Pollutant Unit (Conc.) → $\mu\text{g}/\text{Nm}^3$

→ Water Pollutant → PPM or mg/l or $\mu\text{g/l}$

* NAAQS - National Ambient Air Quality Standard

Common types of Air Pollutant by Air are:

1. Primary Air Pollutant (Directly emitted from sources)

1. Particulate Matter (PM)

* PM_{10} → Particle with diameter $\leq 10\text{mm}$

(e.g. $\text{PM}_{2.5}$ → Particle with diameter $\leq 2.5\text{mm}$)

Sources → Combustion, Industrial process, dust, construction.

→ Permissible limit (concentration) →

$$\text{PM}_{10} = 100 \mu\text{g}/\text{m}^3$$

$$\text{PM}_{2.5} = 60 \mu\text{g}/\text{m}^3$$

2. Sulphur Dioxide (SO_2)

Sources → Burning of fossil fuel containing sulphur, smelting of mineral ore.

Effect → Acid rain, respiratory issue.

* Permissible limit (concentration) - 80 ug/m^3

* Convert to PPM (Parts Per million)

Formula : $\boxed{\text{PPM} = \frac{\text{ug/m}^3 \times 24.45}{\text{Molecular wt} \times 1000}}$

Note: Mass conc. (ug/m^3) to Volume conc. (PPM)

Q → Why we divide 1000 (Basic)

Ans → Molecular wt is gm/mole so we convert

ug/m^3 to match units (we divide 1000)

$\rightarrow 24.45$ - litres per mole (at STP 25°C 1 atm).

* $\text{SO}_2 \rightarrow 80 \text{ ug/m}^3$

M.Wt. $\rightarrow 64.07 \text{ gm/mol}$

$$\text{PPM} = \frac{80 \times 24.45}{64.07 \times 1000}$$

$$\boxed{\text{PPM} = 0.0305 \text{ PPM}}$$

Ans

3. Nitrogen Oxides (NO_2) (Mw. 46.01)

Sources \rightarrow Vehicle Exhaust, Power Plant, Industrial Combustion

Effects \rightarrow Smog Formation, Acid rain.

* Permissible limit (Conc) - 80 ug/m^3

$$\text{PPM} = \frac{80 \times 24.45}{46.01 \times 1000}$$

$$\boxed{\text{PPM} = 0.0425 \text{ PPM}}$$

4. Carbon Monoxide (CO) -

Mw: 28.019/mol

Sources → Incomplete combustion of carbon-containing fuels.

Effects → Reduces oxygen delivery in the body.

Permissible limit → $2 \text{ mg/m}^3 = 2000 \text{ } \mu\text{g/m}^3$

$$\text{PPM} = \frac{2000 \times 24.45}{28.01 \times 1000} = 1.746 \text{ PPM}$$

5. Volatile Organic Compounds:

→ Sources → Solvents, Paints, Petrochemicals Industries.

→ Effects → From ground level smog, health issue.

Secondary Air Pollutants (Formed by reaction in Atmosphere).

1. Ozone (O₃) :-

Mw: 48.009/mol

→ Formed from NO_x and VOCs in sunlight.

→ Effect - Respiratory issue Smog.

Permissible limit = $180 \mu\text{g/m}^3$

$$\text{PPM} = \frac{180 \times 24.45}{48 \times 1000} = 0.0917 \text{ ppm}$$

2. Ammonia (NH₃)

Source - Fertilizer Industry, biomass burning.

Permissible limit = $400 \mu\text{g/m}^3$

$$\text{PPM} = \frac{400 \times 24.45}{17.03 \times 1000} = 0.5746 \text{ ppm}$$

Sir Notes (Chm-1)

- A substance is normally consider as a pollutant if it adversely pollutes the environment by changing the growth rate of a species Interfer with food chain toxic or interfere with health, comfort, amenities for property value of the people. A Polluting substance will solid, Semisolid, liquid gas or some micron compound.
- Any material which are present in environment in sufficient quantity and sufficient time which cause adverse effects in enjoyment of property and
- The WHO thinks of air pollutions as any things which are harmful for human being.

4 Level of Air Pollution

- * Level 1 Concentration and exposure time at and above which according to present knowledge there is no direct and indirect effect.
- * Level 2 Concentration and exposure time at and above which there is lightly to be irritation of sensing organs harmful effect of vegetation visibility reduction and adverse effect on environment.
- * Level 3 Concentration and exposure time at and above which there changes that lead to chronic disease and the shortening of the life period.

* Level 4: Concentration and exposure time at and above which there will be severe diseases and death.

* Types of Air Pollutants

1. Solid
2. Semi-Solid
3. Liquid.

Gases - SO_2 , SO_3
 NH_3 , H_2S , CO , NO_x
Absorbed on solid surface.

* Ash content (Thermal Power Plant) = 35-40%
Sulphur content of Indian coal: > 2-1%
Assam side

* Particulate Matter

↳ Dust

↳ Fume

↳ Mist

↳ Smoke

↳ Spray.

→ Source → Point Source → Industrial waste
Line Source → traffic or vehicle
Area Source.

* Pollution load to calculate.

⇒ According to the pollution load Polluted Area known. are:

PA → Polluted Area

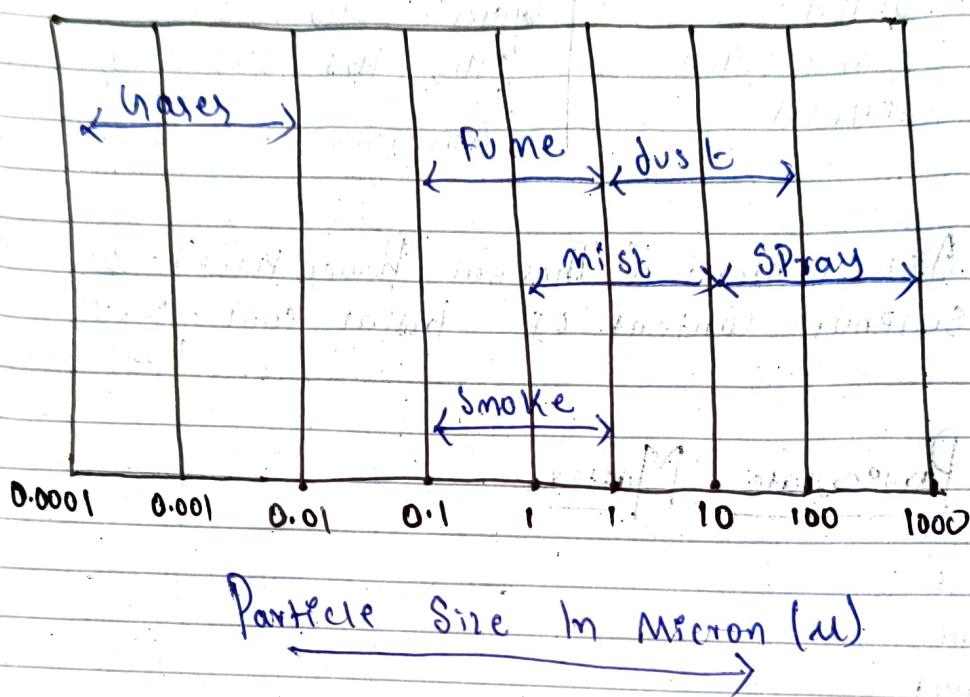
HPA → Highly Polluted Area.

CPA → Critically Polluted Area.

Note - CEPI - Comprehensive Environmental Pollution Index.

- * Primary Pollutant \rightarrow SO_2 , CO , NO_x , PM_{10} , $\text{PM}_{2.5}$
- * Secondary Pollutant \rightarrow Carbon + Air \rightarrow free radical

Particulates



Just - Solid Particle that.

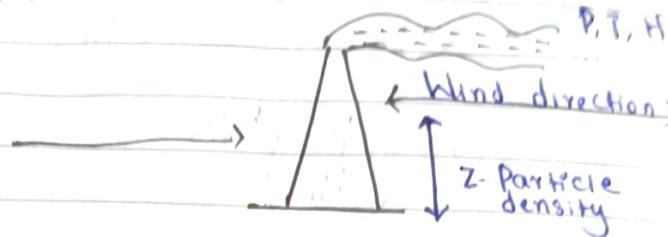
- a) Entrained by Process (haze directly from material handling or processing)
- b) direct off spring of parent material undergoes a mechanical operation.

L-3

* 1) Dispersion of Air Pollutants

⇒ dispersion of Air Pollutants refer to the process by which pollutants emitted into the atmosphere spread out or dilute over time and distance, reducing their concentration as they move away from the source.

Industrial / Commercial



* ~~Imp.~~ Adiabatic Lapse Rate $\left(\frac{dT}{dh} \right)$

$$\Rightarrow \frac{dT}{dh} = \frac{dT}{dp} \times \frac{dp}{dh} \quad \text{--- (1)}$$

$$\Rightarrow P = f \times g \times h$$

As we go up $T \downarrow$ (decrease)

$$\frac{dp}{dh} = -fg \quad \text{--- (2)}$$

Eqn

$$P = \frac{PM}{RT} \quad (\text{For gases}) \quad \text{--- (3)}$$

$$PV = nRT$$

$$\frac{P}{RT} = \frac{n}{V} \quad \text{--- (4)}$$

From Eqn (2) and (3)

$$\frac{dp}{dn} = -\frac{PM}{RT} g \quad \text{--- (5)}$$

From Equation (4) and (5)

$$\frac{dp}{dh} = -\frac{ngM}{V}$$

* Under Adiabatic Condition

$$Pv^{\gamma} = \text{constant}$$

$$\gamma = \frac{C_P}{C_V}$$

$$\frac{T}{T_0} = \left(\frac{P}{P_0} \right)^{\gamma-1/\gamma} = \left(\frac{P}{P_0} \right)^{R/C_P}$$

$$T = T_0 \left(\frac{P}{P_0} \right)^{R/C_P}$$

$$\frac{dT}{dP} = \frac{RT}{PC_P}$$

$$\frac{dp}{dh} = \frac{dT}{dp} \times \frac{dp}{dh} = \frac{RT}{PC_P} \times -\frac{mgM}{V}$$

For Air

$$\gamma = 1.4$$

$$C_P = 3.5$$

$$R = 9.814 \text{ J/mol.K}$$

$$M = 28.9$$

$$g = 9.81$$

$$\frac{dT}{dh} = -9.816 \text{ } ^\circ\text{C/KM}$$

Calculation value.

$$\frac{dT}{dh} = -6.5 \text{ } ^\circ\text{C/KM} \rightarrow \text{Environmental Lab Scale value.}$$

$$\Rightarrow T_1 = 65^{\circ}\text{C} \quad R_2 = \frac{P_2}{R_1(T_2 - 65)} \quad \text{Cold Air}$$



* Inversion (Ind)

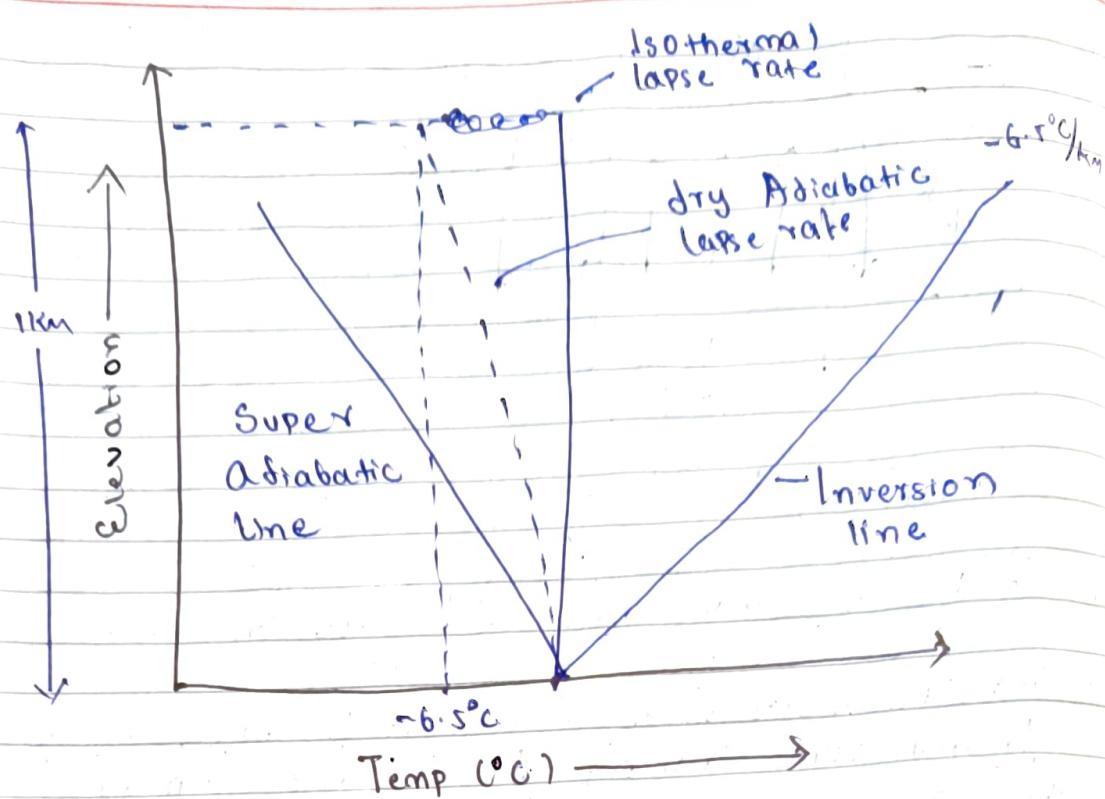
1. Radiation Inversion (Surface Inversion)

→ Radiation Inversion occurs at Night when the ground cools rapidly due to radiation, making the air near the surface cooler than the air above it.

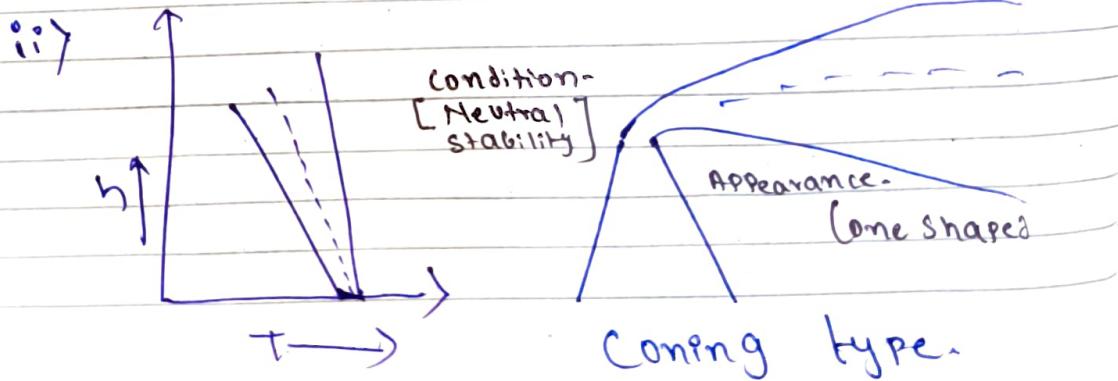
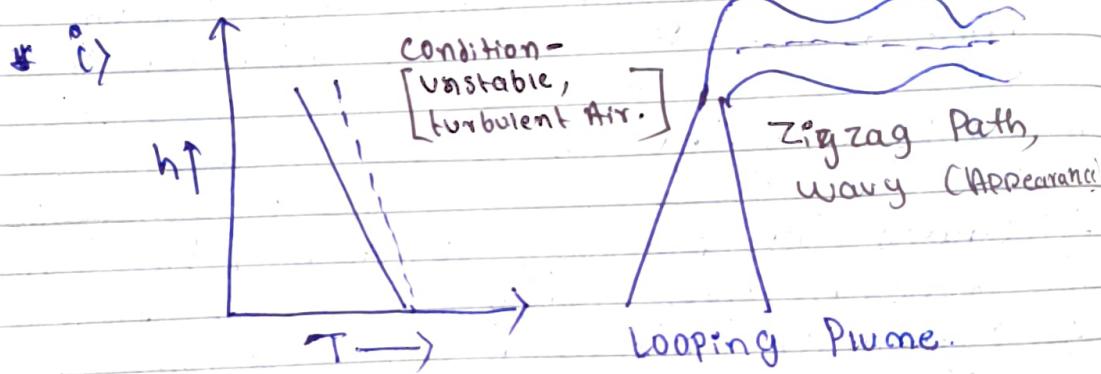
→ This creates a temperature inversion near the ground (short term). Traps Pollutants near ground. It due to Temperature inversion.

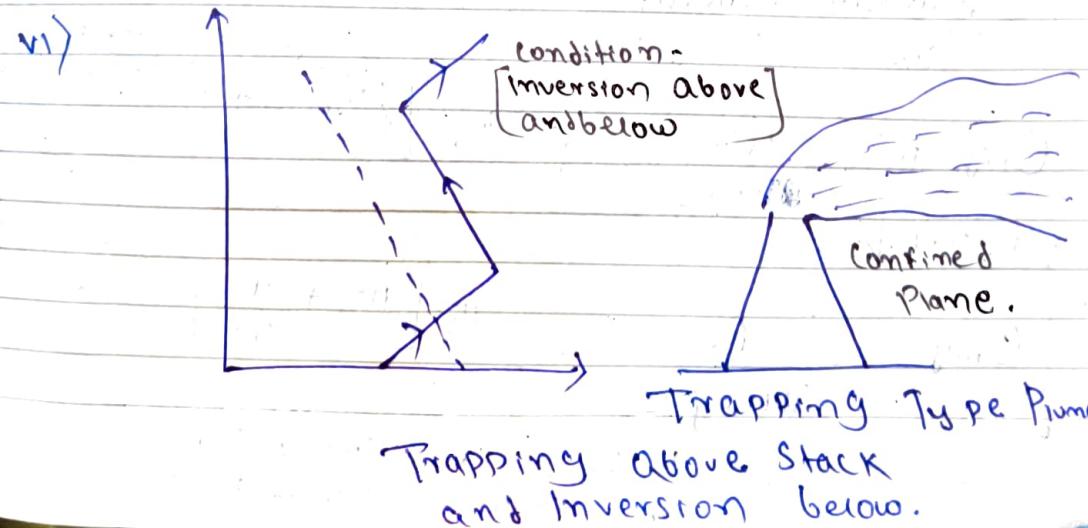
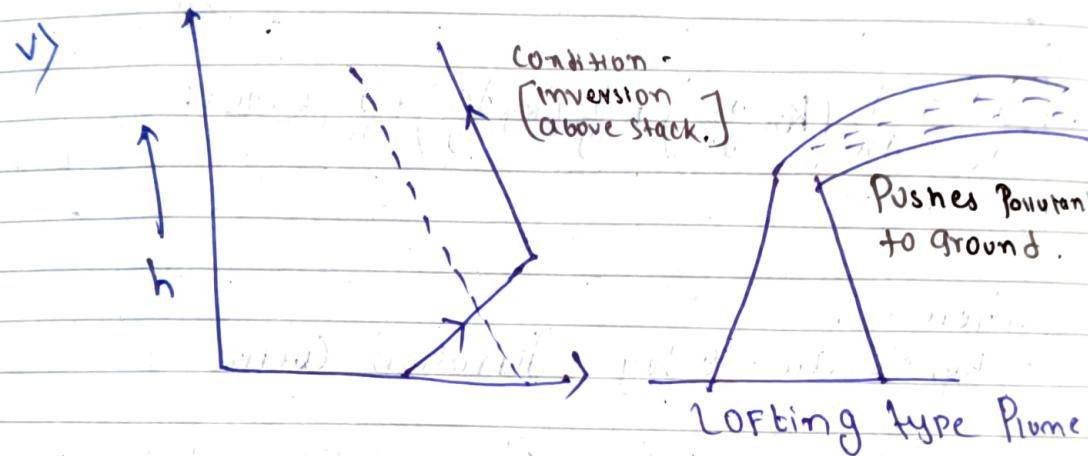
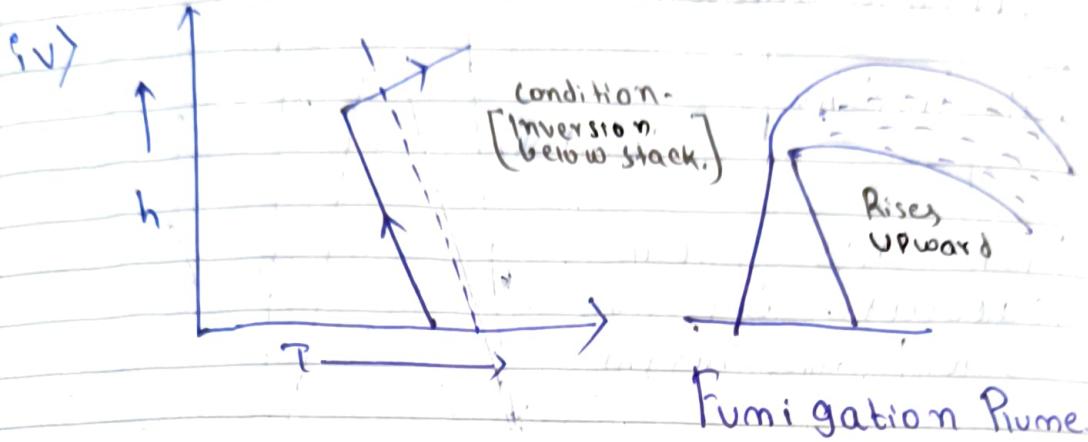
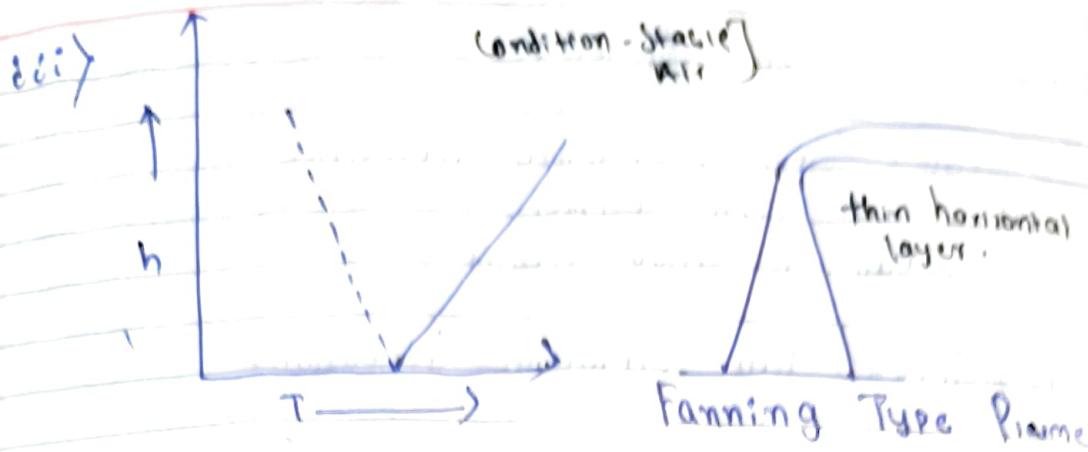
a. Subsidence Inversion:

→ Caused by descending air in high pressure system
→ It occurs over large geographical area
→ Common in valleys or coastal regions (long lasting) prevent vertical dispersion



* Types of Plume Behaviour:





Dt-04/08/2025

* 1) Dispersion Model:

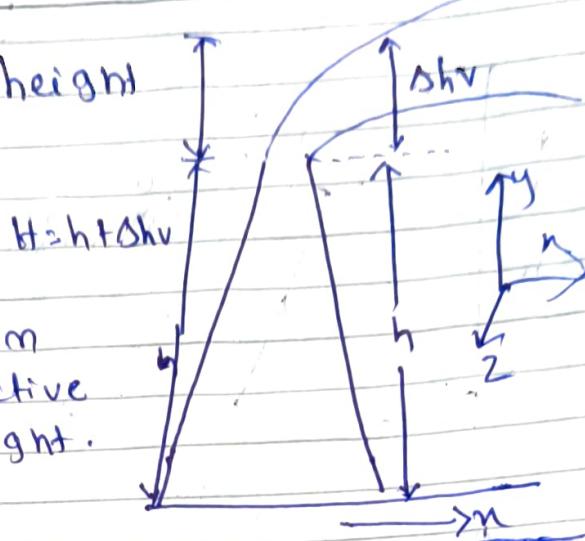
- Fick's Law Turbulence diffusions
- Gaussian Plume Model
- Gaussian dispersion Model.

* i) Fick's Law Turbulence diffusions.

* Effective Stack height

$$H = h + \Delta h_{rv}$$

From this form calculate Effective Stack/chimney height.



$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial n} \left(k_n \frac{\partial C}{\partial n} \right) + \frac{\partial}{\partial y} \left(k_y \frac{\partial C}{\partial y} \right) + \frac{\partial}{\partial z} \left(k_z \frac{\partial C}{\partial z} \right) + Q u y z^2$$

Where:

k_n, k_y, k_z are Eddy diffusion coefficient.

- Gaussian developed the solution of Model Equation

$$C_{n,y,z,H} = \frac{Q}{\pi U \sigma_y \sigma_z} e^{-\frac{y^2}{2\sigma_y^2}} \left[e^{-\frac{(z-H)^2}{2\sigma_z^2}} + e^{-\frac{(z+H)^2}{2\sigma_z^2}} \right]$$

with $z=0$:

$$C_{n,y} = \frac{Q}{\pi U \sigma_y \sigma_z} e^{-\frac{y^2}{2\sigma_y^2}} \left[\frac{H^2}{\sigma_z^2} + \frac{Y^2}{\sigma_z^2} \right]$$

↳ Ground level concentration plume at Height H.

$$C_{n,y} = \frac{Q}{\pi U \sigma_y \sigma_z} e^{-\frac{y^2}{\sigma_z^2}} \cdot e^{-\frac{H^2}{\sigma_z^2}}$$

Where :-

C = Concentration of Pollutant in (mg/m^3)

Q = Emission rate of Pollutant (g/ls)

U = mean wind Velocity (m/ls)

x, y = Downwind and cross wind distance (m)

σ_y = Plume Standard Variation in cross wind direction

σ_z = Plume Standard Deviation in down wind direction (m)

H = $ht + dhv$ - Effective Stack height.

* When Concentration at the Central Line of Plume needed. ($y=0$) Plume at height H

$$C_{n,0} = \frac{Q}{\pi U \sigma_y \sigma_z} e^{-\frac{H^2}{\sigma_z^2}}$$

* When at ground level (Ground level Centreline) ($y=0, H=0$)

$$C_{n,0} = \frac{Q}{\pi U \sigma_y \sigma_z}$$

* Maximum Ground level Concentration (C_{\max})

$$C_{\max} \Rightarrow \sigma_z = 0.707 H$$

Provided $\rightarrow \frac{\sigma_y}{\sigma_z} = \text{constant}$.

* Wind typically increases with height and depends on the amount of solar radiation.

$$\frac{U_2}{U_1} = \left(\frac{Z_2}{Z_1} \right)^P \quad (z < 200m)$$

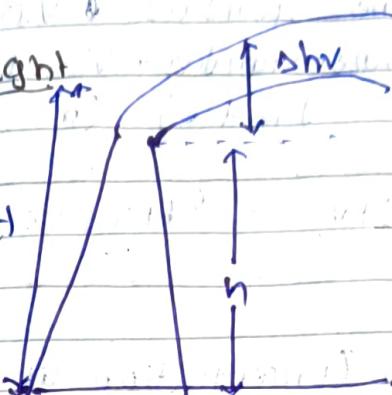
P depend on Stability Class (rural or Urban) and Surface roughness.

Effective Stack height

$$\Rightarrow H = h + \Delta h_{vr}$$

where
H: Effective stack height.
h: Stack height or chimney height

Δh_{vr} : Plume rise



* Plume rise (by Holland's equation)

$$\Delta h_{vr} = \frac{V_s \times D}{U} \left[1.5 \times 2.68 \times 10^3 \times P \times D \times \left[\frac{(T_s - T_a)}{T_s} \right] \right]$$

Where:-

↳ For Neutral flow / Plume

$V_s \rightarrow$ Stack gas Velocity (m/s)

D → Inside dia of stack at Exit Period (m)

U → Wind speed at top of stack (chimney) (m/s)

P = Atmosphere Pressure m (millibar)

T_s = Stack gas Exit temp (k)

T_a = Air Ambient temp (k)

* BIS NO. 8829 - 1978

Note:-

- ① For Unstable Plume Δh_v is increase by 10%.
- ② For stable Plume Δh_v decrease by 10%.

a) For hot fine gasses with heat release rate $> 10^6 \text{ cal/s}$.

$$\Delta h_v = 0.84 (12.4 + 0.09h) \times \frac{Q_H^{0.25}}{u}$$

b) For not very high Δh_v heat release rate

$$\Delta h_v = \frac{3V_s \times D}{u}$$

D = dia of stack

V_s = Stack gas velocity (m/s)

u = Wind speed.

* For the Physical stack height its should be minimum 30m it would 2.5 times to a near by Structure.

* To get height of chimney :-

$$① h = 74 (Q_p)^{0.27}$$

$$② h = 14 (Q_s)^{0.33}$$

Where:-

Q_p = Particulate Emission ~~ton/h~~ rate (ton/hr)

Q_s = SO₂ Emission rate (kg/hr)

→ If the value is $h = 30m$ as per standard height
give minimum stack height as $30m$.

* Minimum height:

a) Except thermal power plant, for rest
of industries $< 30m$

b) For thermal Power plant height
i) $> 200MW$ and $< 500MW$ - $200m$
 $> 500MW$ - $275m$ - height.

* Wind varies with height

$$\frac{U_2}{U_1} = \left(\frac{z_2}{z_1}\right)^P$$

($z < 200m$)

P is a constant which depends on atmospheric stability and on surface roughness

Ques A coal-burning power plant burns 50,000 tonnes of coal per day and an ESP is used to collect the fly-ash from power plant with an working efficiency of 99.3%. The coal has a sulfur content 0.6% and total amount of fly ash generated is 5kg/ton of coal burnt. The physical stack height is 150m and inside diameter of 1.5m. The gas leaves at 130°C. The ambient temperature 30°C and barometric pressure of gas milibars. A moderately unstable plume is found at the exit of the chimney. The wind velocity measured at 6 meter height from the ground and the average wind velocity recorded as 3.0 m/s. The value of exponent p for various stability class is given below.

Stability Class	A	B	C	D	E	F
Rural	0.07	0.09	0.10	0.15	0.35	0.50
Urban	0.15	0.17	0.20	0.25	0.30	0.35

Calculate

- 1) Effective Stack height
- 2) The Maximum concentration of SO₂ and how far is this from the plant does this plant by itself causes concentration in excess of the annual ambient air quality standards.
- 3) The maximum concentration of fly ash and how far is it from the point.
- 4) Fly ash concentration profile upto a distance of 10km from the stack.

Answer:-

Given:-

- * Coal burned = 30,000 ton $\frac{1}{2}$ /day
- * Sulphur content in coal = 0.6%.
- * Fly ash generated = 5 kg/lton of coal
- * ESP efficiency = 99.5%.
- * Physical Stack height (h) = 150m
- * Inside diameter = 1.5m
- * Stack gas exit temp = $130^{\circ}\text{C} = 403.15\text{K}$
- * Ambient temp $= 30^{\circ}\text{C} \approx 303.15\text{K}$
- * Barometric pressure = 925 mbars
- * Stability class $\geq B$ (Moderately unstable)
- * Area type = Urban
- * Wind Velocity at 6m = 3.0 m/s.
- * For urban & class B, ($\rho = 0.17$):

Q) Effective Stack height (H)

$$H = h + \Delta h_v$$

where

h : Physical Stack height (150m)

Δh_v : plume rise.

Assume stack gas exit velocity

$$V_s = 15 \text{ m/s}$$

(Note \rightarrow BIS CIS: 8829 - 1979 Standard guideline according Humphson)

$h \rightarrow$ we have 150m
 $\Delta h_v \rightarrow$ calculate.
 from Holland's equation

$$\Delta h_v = \frac{V_s \times D}{V} \left[1.5 + 2.63 \times 10^{-3} \times \rho \times D \times T_s - T_a \right]$$

Now

Find U_2 (wind speed at top of stack
(150m))

By formula. (wind varies with height)

$$\frac{U_2}{U_1} = \left(\frac{z_2}{z_1}\right)^p$$

$$U_2 = U_1 \times \left(\frac{z_2}{z_1}\right)^p$$

$$U_2 = 3.0 \times \left(\frac{150}{6}\right)^{0.17}$$

$$U_2 = 5.18 \text{ m/s}$$

Now ~~for~~ substitute U_2 in honora's eqn.

$$\Delta h_{vr} = \frac{V_s \times D}{U} \left[1.5 + 2.63 \times 10^{-3} \times \rho \times D \times \left(\frac{T_d - T_a}{T_s} \right) \right]$$

$$\Delta h_{vr} = \frac{15 \times 1.5}{5.18} \times \left[1.5 + 2.63 \times 10^{-3} \times 0.25 \times 1.5 \times \left(\frac{403.15 - 303}{403.15} \right) \right]$$

$$\Delta h_{vr} = 4.34 \times [2.42236]$$

$$\Delta h_{vr} = 10.51 \text{ m.}$$

∴ Effective Stack height

$$H = h + \Delta h_{vr}$$

$$H = 150 + 10.51$$

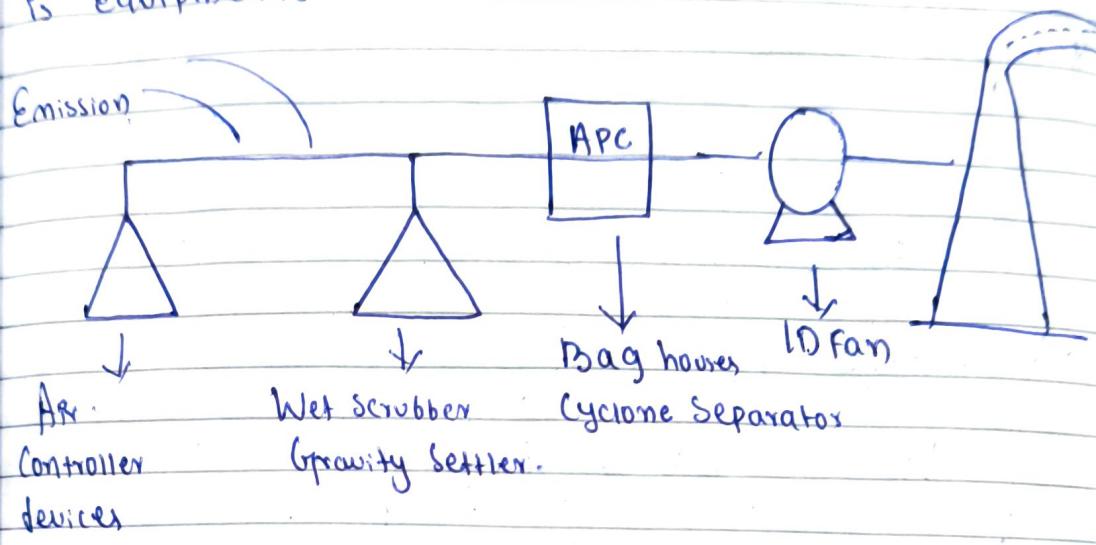
$$H = 160.51 \text{ m.}$$

Ans

$$H = 160.51 \text{ m}$$

* ~~Reles~~ Fugitive Emission

→ Fugitive Emission are Unintentional releases of gases or vapors from Industrial processes often due to leaks or other Malfunctions in equipments.



* Two types of Pollutant limit :-

- 1) Ambient Air Quality
- 2) Stack Emission quality.

* Terminal Settling Velocity :- It is constant speed that a freely falling object eventually reaches when the force of gravity is balanced by force of drag.

$$V_t = \frac{D_p^2 (f_p - f_g)}{18 \mu g}$$

Where:-

V_t = Terminal settling velocity

D_p = Particle size (diameter)

f_p = Particle density

f_g = Gas density

μ = Viscosity

$g = 9.81$ (Acceleration due to gravity).

* Capture Velocity :-

$$V_{capture} = 2.5 \times U_t$$

Where U_t = terminal settling velocity.

Hoods

20

Volumetric Flow rate

$$Q_m = \frac{\pi}{4} \times D^2 \times V_{capture}$$

For rectangle hoods =

$$Q_m = (L \times b) \times D^2 \times V_{capture}$$

Note:-

- For different shape (Area will change).
- For different type of suction line (duct) Area will be vary.

So calculate pressure drop.

Total Volumetric Flow

$$Q' = \sum_{n=1}^{n=20} Q_m$$

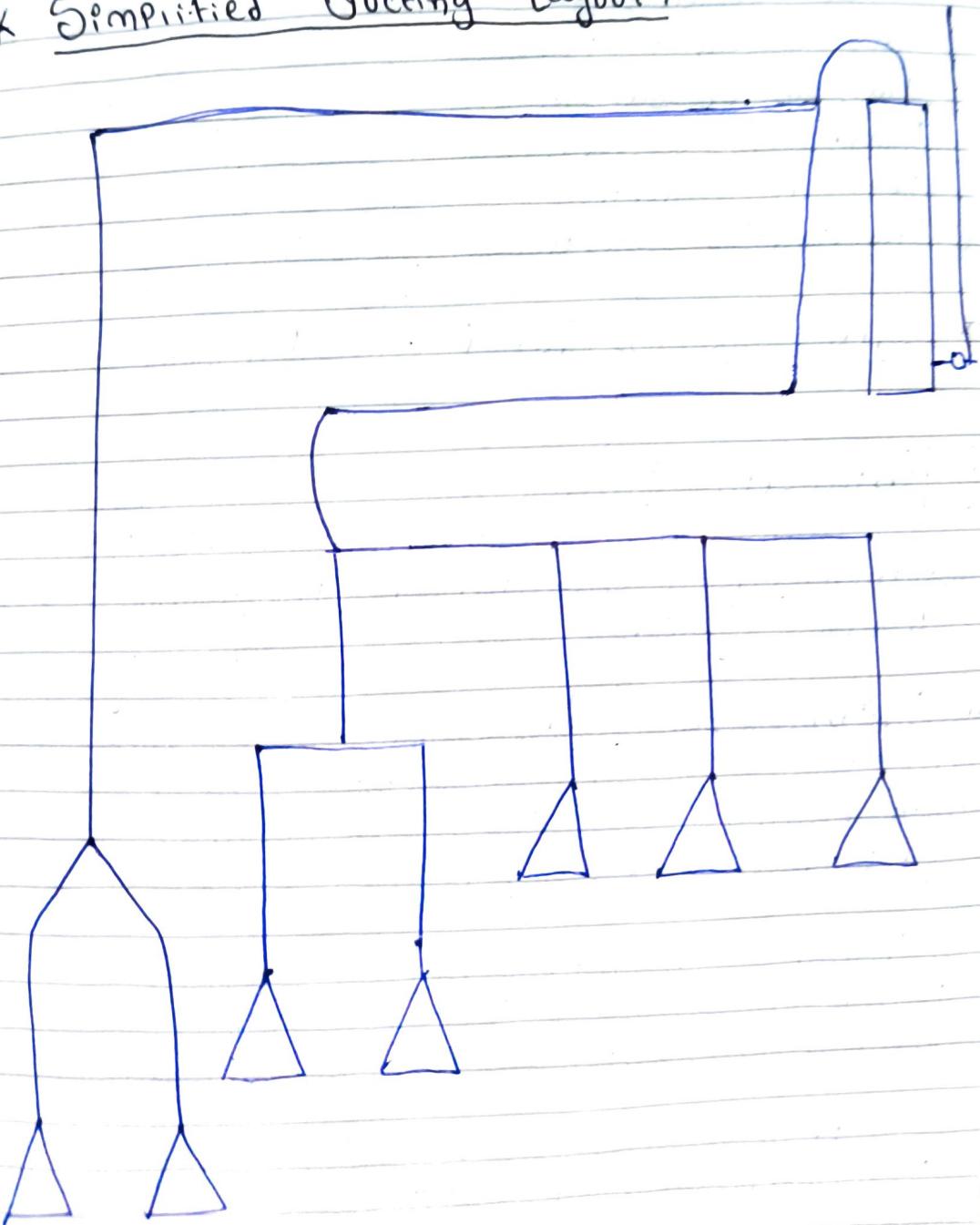
$$\Delta P_{losses} \approx Q_{\text{in}}$$

Net Flow rate

$$Q = Q' + Q''$$

$$Q_{\text{ACTUAL}} = 1.2 \times Q \quad ! \cdot Q = \text{net flow rate}$$

* Simplified ducting layout:



12/03/25

* Sampling and Measurement of Air Pollution

* Sampling Methods

- 1) Freeze Out Sampling
- 2) Grab Sampling
- 3) Stack Sampling
- 4) Smoke Sampling
- 5) Tape Sampling
- 6) High Volume Sampler
- 7) Dust Fall Sampler
- 8) Inertial Collector
- 9) Precipitator Collector.

* Test Methods for Major Air Pollutants

1) Particulate Matter (PM₁₀) -

High Volume Sampler with nozzle (filter)
designed to exclude particles greater than
10 microns diameter.

2) Sulphur dioxide : West-Graeke Method -

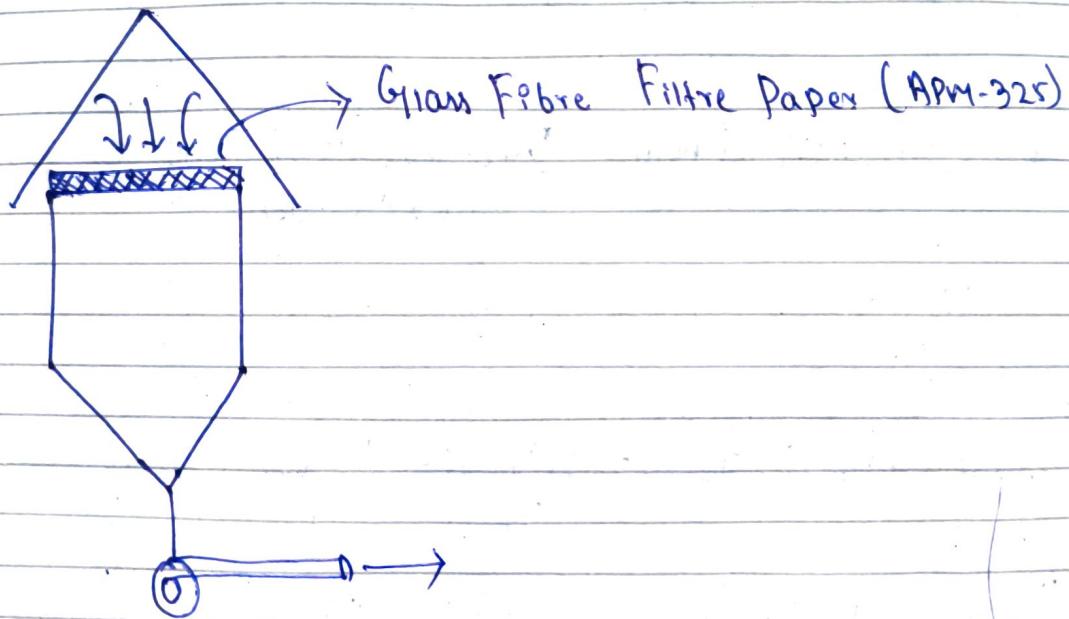
Air bubble through tetra chloro mercurate
then treated with Pararosaniline and
determined by Calorimetry.

3) Ozone : Air reacted with Ethylene to form a complex that is luminescent which is measured using a photomultiplier

4) Carbon monoxide - Non dispersive Infrared detector (NDIR).

- 5) Hydrocarbons: Gas Chromatograph (GC) or high Pressure Liquid Chromatograph (HPLC)
- 6) Nitrogen dioxide - Converted to NO and reacted with Ozone to form a Chemiluminescent material
- 7) Lead - Similar to PM_{10} the filtered material is dissolve in NaOH and hydrochloric acid and Pb determined using atomic Adsorption Spectroscopy or Inductively Coupled Plasma Spectroscopy (ICP).

* Glass Fibre Filter Paper:



At $t = 0 \rightarrow$ weight of filter paper = W_1
 At $t = 24\text{ hr} \rightarrow$ final weight of (dust + filter paper) = W_2

Calculated dust collected : $W_2 - W_1$

Note For measuring flowrate of Air \rightarrow Rotameter.

Flow rate (Q) = m^3/hr

$$\begin{array}{ll} t=0 & Q = Q_0 \quad (50 \text{ lpm}) \\ t=1 \text{ hr} & Q = Q_1 \quad (48 \text{ lpm}) \\ t=24 \text{ hr} & Q = Q_2 \quad (40 \text{ lpm}) \end{array}$$

Volume flow rate $Q_1 = LPM_1 \times \Delta t$
 $Q_2 = LPM_2 \times \Delta t$

$$Q_{av} = \frac{Q_1 + Q_2}{2}$$

* Gram of dust collected over filter paper
= $W_2 - W_1$.

* Conc. of PM_{10} = $\frac{W_2 - W_1 \text{ (gm)}}{Q_{av} \times \Delta t \text{ (lt)}} \cdot \text{mg/Nm}^3$

lit/min $\times 24 \times 60 \rightarrow \text{mg/Nm}^3$

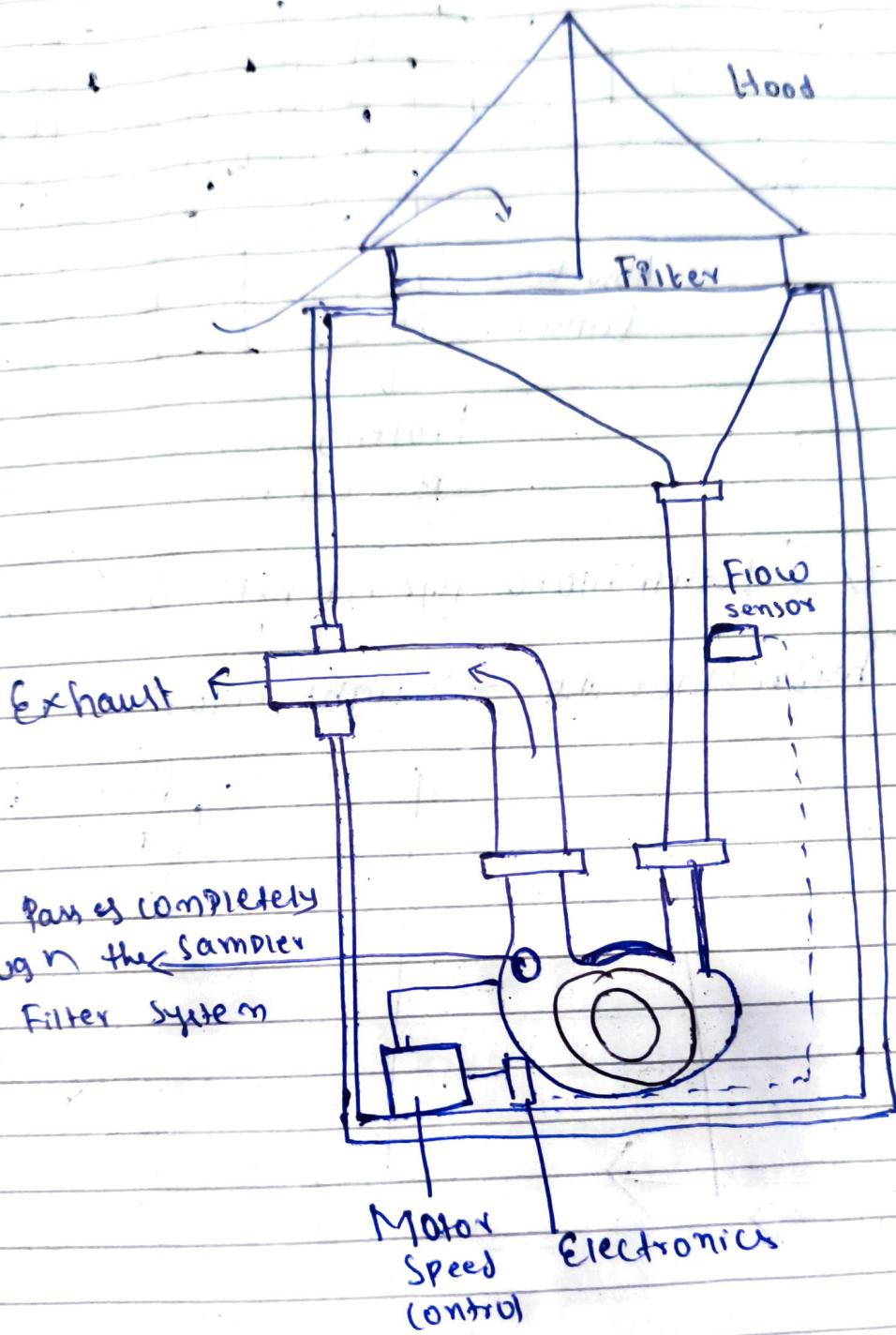
2) $Q_{av} \text{ at } P, T, = \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$

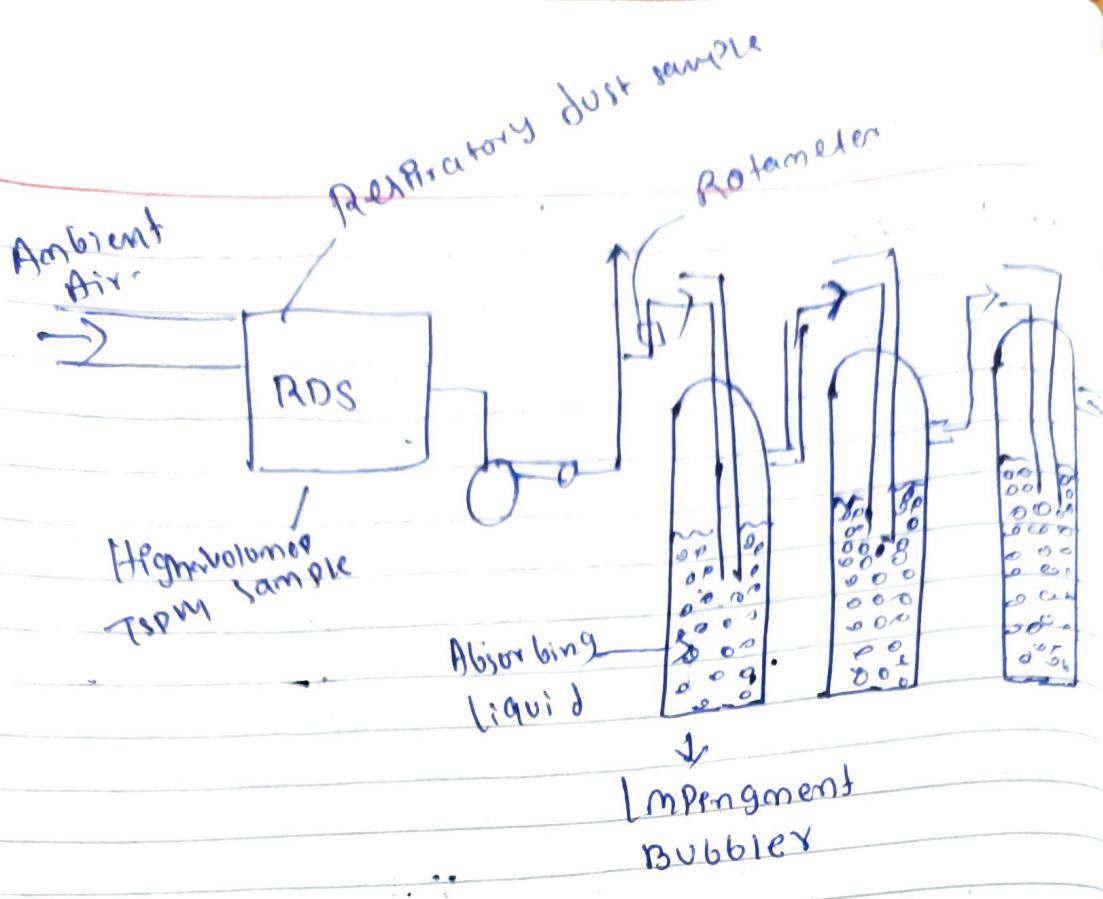
Size of Filter = 8" \times 10" (PM_{10})

3) Size of Filter = Circular 46mm ($PM_{2.5}$)

4)

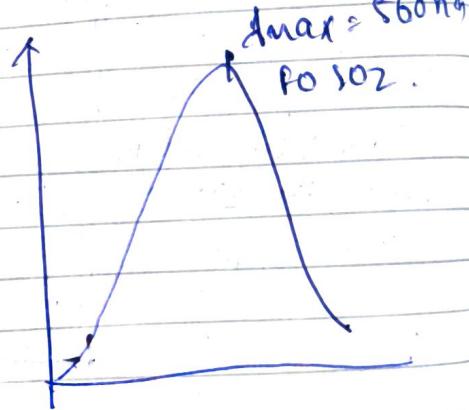
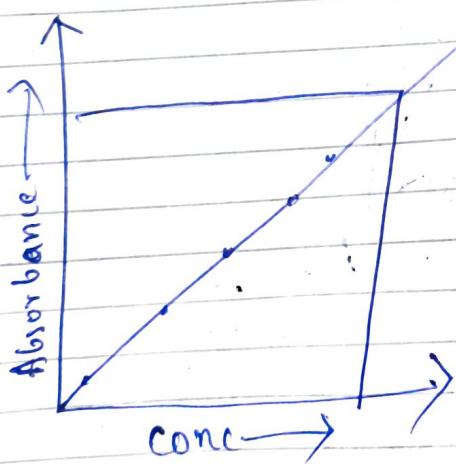
High Volume Sampler For total Suspended Particulates





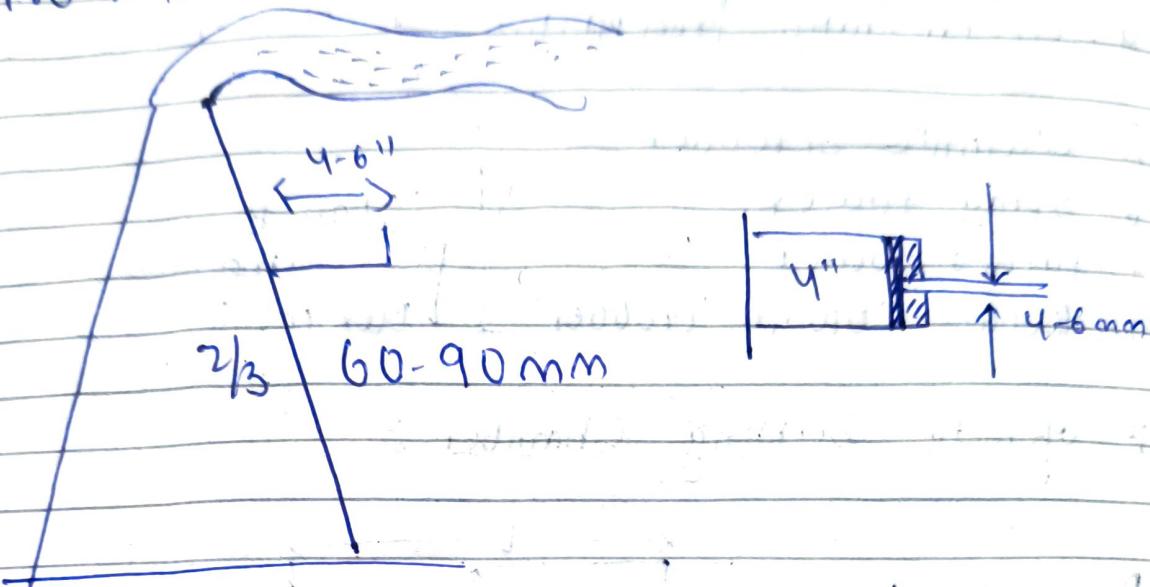
Solution \rightarrow Tetrachloro Mercurate soln.

* Rosalin hydrochloride \rightarrow light color.



Stack Sampling

It is a method used to determine the quantity and types of pollutants emitted from industrial stacks or chimney.



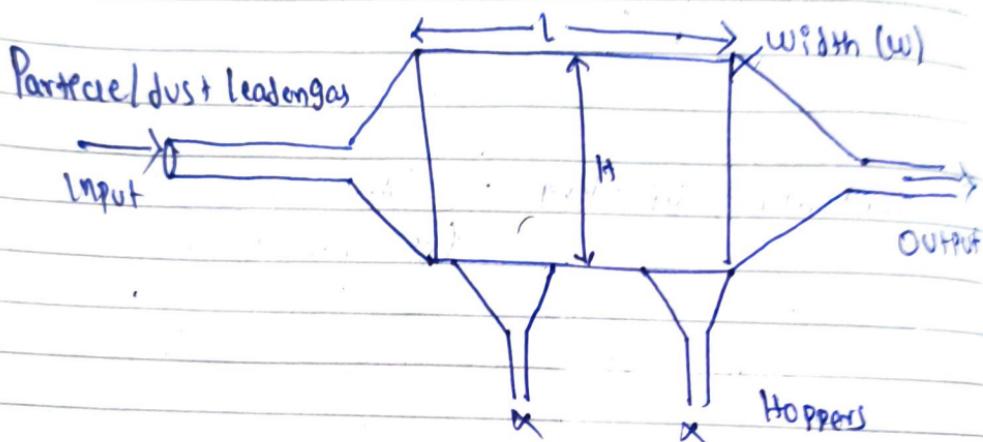
$$\text{Concentration of PM} = \frac{W_2 - W_1}{Q_{\text{five gas}} \times \text{Time}}$$

DT 19 | 08 | 2025

Design of Air Pollution Control Equipment:

- 1. Gravity Settling Chamber
 - 2. Cyclone separator.
 - 3. Bag House
 - 4. Electrostatic Precipitator
 - 5. Cyclonic Scrubber
 - 6. Spray tower
 - 7. Packed tower
 - 8. Bubble Column Scrubber
-]
- Class A
(For particulate matter)
- Class B
(For hydrocarbons)
NOx, CO₂, SO₂

Gravity Settling Chamber :-



If flow is turbulent, circulation may occur so always preferable to operate at Stokes law regime.

Terminal Settling Chamber:-

$$U_t = \frac{D_p^2 (\rho_p - \rho_g) \times g}{18 \mu}$$

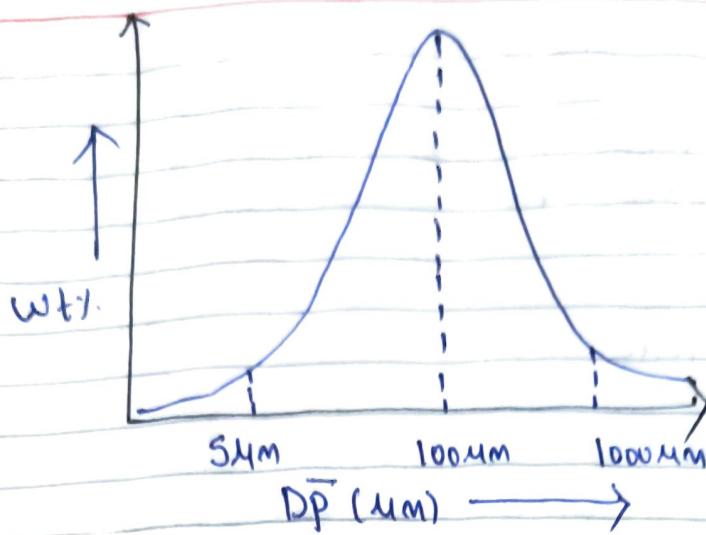
where

U_t = Terminal settling velocity

D_p = particle diameter.

ρ_p = particle density g = Acceleration due to gravity

ρ_g = gas density. μ = Viscosity.



* Efficiency

$$\eta = \frac{C_{\text{inlet}} - C_{\text{outlet}}}{C_{\text{inlet}}} \times 100$$

Where: C_{inlet} - Concentration of Particle and with Inlet
 \rightarrow gas Entering (mg/Nm^3)

C_{outlet} - conc. of Particle and outlet gas.

* Residence time :

$$t(z) = \frac{H}{U_t}$$

Where or

$t(z)$ - Residence time

H - Height

U_t - Terminal settling Velocity

Volume -

$$V = \frac{Q}{W \times H}$$

Where:

Q = Flow rate

W = Width

H = Height

Total Volume of chamber = $W \times H \times L$

$$\eta = \frac{h}{H}$$

$$h = U_r \times t(z)$$

The settle quickly

$h > H \rightarrow$ less effective] For effective control of
 $h < H \rightarrow$ more effective] dust Particulate residence time
Particles will not settle down

Stokes Law of Regime

$$U_r = \frac{D_p^2 \times (\rho_p - \rho_g) \times g}{18 \times \mu}$$

ρ_p = Given

$$\rho_g = \frac{P M}{R T}$$

P = Pressure
 M = molecular wt.

* In Stoke's law regime (ignores)

$$V_L = 0.003 \times \rho_p \times dP^2 \quad (\text{cm})$$

Laminar Flow

* For 100% removal of Particle

$$V_{ext}t > H$$

$$\eta = \frac{b}{H} = \frac{V_{ext}}{H}$$

$$\eta = \frac{\text{Volume of Chamber}}{\text{Capacity}} = \frac{H \times W \times L}{Q} = \frac{HWL}{WF \times V}$$

$$\eta = \frac{V_{ext}t}{H} = \frac{V_{ext}L}{H} = \frac{V_{ext}L}{H \times V} = \frac{V_{ext}L}{\frac{Q}{Wt} \times H}$$

$$\eta = \frac{V_{ext}WL}{Q}$$

$$\eta = \frac{D_p^2 (\rho_p - \rho_g) g \times WL}{18 \mu Q}$$

D_{PSO} → It means the Efficiency of the particle of that size to size is 50%.

$D_{PM_{50}}$

$$D_{PM_{50}} = \left[\frac{18 \mu \times Q}{(\rho_p - \rho_g) g \times WL} \right]^{1/2}$$

$$D_{PSO} = \left[\frac{q u Q}{(\rho_p - \rho_g) g w l} \right]^{1/2}$$

For design Purpose

$$H : W : l = 1 : 2 : 3$$

$$D_{P100} = \left[\frac{18 u Q}{(\rho_p - \rho_g) g l w} \right]^{1/2}$$

For Unknown Particle

* Calculate Efficiency

$$\eta = \left(\frac{D_p}{D_{p\min}} \right)^2 \times 100$$

* ① For laminar flow
 $(U_t = 0.003 f_p D_p)$

② Intermediate Region

$$U_t = F(N_{Re}, D_p, f_g)$$

3) Turbulent Region :

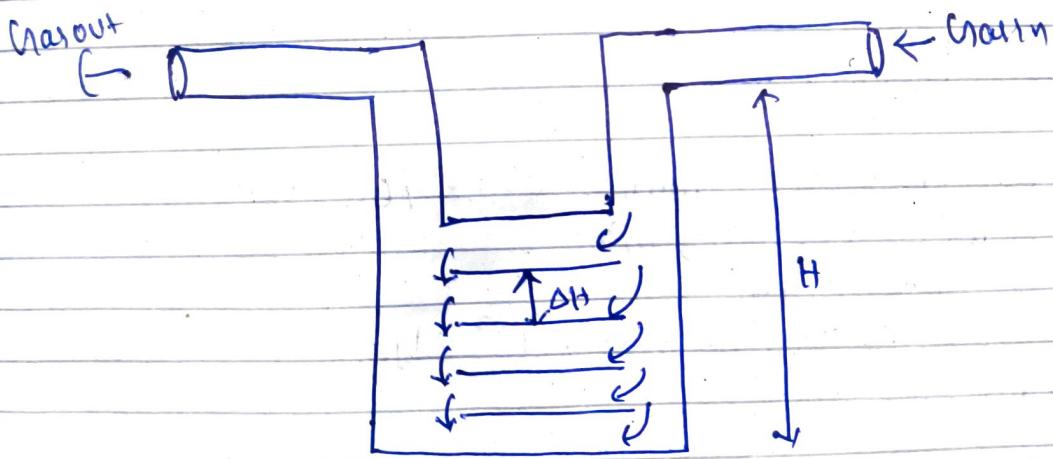
$$U_t = \left[3 \frac{\rho_p - \rho_g}{\rho g} \frac{D_p}{L} \right]^{1/2}$$

$$\eta = 1 - e^{-\frac{W_1 U_t H_c}{Q}}$$

Advantage \rightarrow cost ps low, Maintenance is of gravity settling chambers.

disadvantage. \rightarrow low efficiency huge space.

Multi tray Gravity Settling Chamber



ΔH = tray spacing

$$D_{pmin} = \left(\frac{18 \mu Q}{(\rho_p - \rho_g) g W L} \times \frac{S}{H} \right)^{1/2}$$

Q no.1 A Contaminated gas stream $657.89 \text{ m}^3/\text{min}$ passed through a gravity settling chamber for abatement of particle pollution. The five sieve analysis shows dust producing $30-130 \mu\text{m}$. It has been decided by the industry to maintain the emission Standard of Particulate matter as per Pollution control board above $100 \mu\text{m}$ Particle must be removed by simple Gravity settling chamber.

Design the Settling Chamber and the Collection efficiency for Interchange Particle size.

The temp. of the gas Stream 20°C
 density of particle $= 2700 \text{ kg/m}^3$
 Viscosity (μ) of gas $= 0.0176 \text{ CP}$

Ans:- Given :-

$$Q = 657.89 \text{ m}^3/\text{min} = 657.89/60 = 10.96 \text{ m}^3/\text{sec}$$

$$\rho_p = 2700 \text{ kg/m}^3$$

$$\rho_g = 1.2 \text{ kg/m}^3$$

$$\mu = 0.017 \text{ CP} = 0.017 \times 10^{-3} \text{ N/m}^2$$

$$D_{pmin} = 100 \mu\text{m}$$

$$D_{pmen} = \left[\frac{18 \times \mu \times Q}{(\rho_p - \rho_g) \times g \times W \times L} \right]^{1/2}$$

Substitute all value

$$D_{pmen} = \left[\frac{18 \times 0.017 \times 10^{-3} \times 10.96}{(2700 - 1.2) \times 9.81 \times W \times L} \right]^{1/2}$$

$$100 \times 10^{-6} = \left[\frac{18 \times 0.017 \times 10^{-3} \times 10.96}{(2700 - 1.2) \times 9.81 \times W \times L} \right]^{1/2}$$

$$WL = 12 \cdot 667 \approx 13$$

$$H:W:L = 1:2:3$$

~~00 00 00~~

Let $H=n$ then

$$W=2n$$

$$L=3n$$

$$WL = (2n)(3n) = 6n^2$$

$$13 = 6n^2$$

$$n = 1.471, \text{ so } H = 1.471 \text{ m}$$

$$W = 2n = 2 \times 1.471 = 2.94 \text{ m}$$

$$L = 3n = 3 \times 1.471 = 4.41 \text{ m}$$

$$H = 1.471 \text{ m}$$

$$W = 2.94 \text{ m}$$

$$L = 4.41 \text{ m}$$

* Volume

$$V = \frac{Q}{W \times H} = \frac{10.96}{2.94 \times 1.471}$$

$$V = 2.53 \text{ m}^3/\text{sec}$$

* Residence time

$$T = \frac{H}{V_t} =$$

$$V_t = \frac{\pi D^2 \times (P_p - P_g) \times g}{18 \mu} = \frac{100 \times 10^{-6} \times (2700 - 1.2) \times 9.81}{18 \times 0.0176 \times 10^{-3}}$$

$$V_t = 0.8357 \text{ m/s.} =$$

$$t_2 = \frac{1.471}{0.9357} = 1.76 \text{ sec.}$$

* Efficiency

$$\eta = \frac{h}{H}$$

$$h = V_f \times t$$

$$h = 0.8357 \times 1.76$$

Q.E.D.

$$\eta = \frac{0.8357 \times 1.76}{1.471} = 0.999$$

$$\boxed{\eta = 99.9\%}$$

$$\eta = \frac{V_f \times WL}{Q}$$

$$\boxed{\eta = \frac{0.9357 \times 13}{10.96}}$$

$$\eta = 0.991$$

$$\boxed{\eta = 99.1\%}$$

$$\eta_i = \left(\frac{D_p}{D_{p\min}} \right)^2 \times 100$$

Range = 30 = 130

$D_{p\min} = 100 \mu\text{m}$

Range (D _p)	$\eta_i = \left(\frac{D_p}{D_{p\min}} \right)^2 \times 100$
30	$\eta_i = (30/100)^2 \times 100 = 9$
40	$\eta_i = (40/100)^2 \times 100 = 16$
50	$\eta_i = (50/100)^2 \times 100 = 25$
60	$\eta_i = (60/100)^2 \times 100 = 36$
70	$\eta_i = (70/100)^2 \times 100 = 49$
80	$\eta_i = (80/100)^2 \times 100 = 64$
90	$\eta_i = (90/100)^2 \times 100 = 81$
100	$\eta_i = (100/100)^2 \times 100 = 100$
110	$\eta_i = (110/100)^2 \times 100 = 121$ = 100
120	$\eta_i = (120/100)^2 \times 100 = 144$ = 100
130	$\eta_i = (130/100)^2 \times 100 = 169$ = 100
140	
150	

If Efficiency is more than 100%
Assume that Efficiency is 100%.