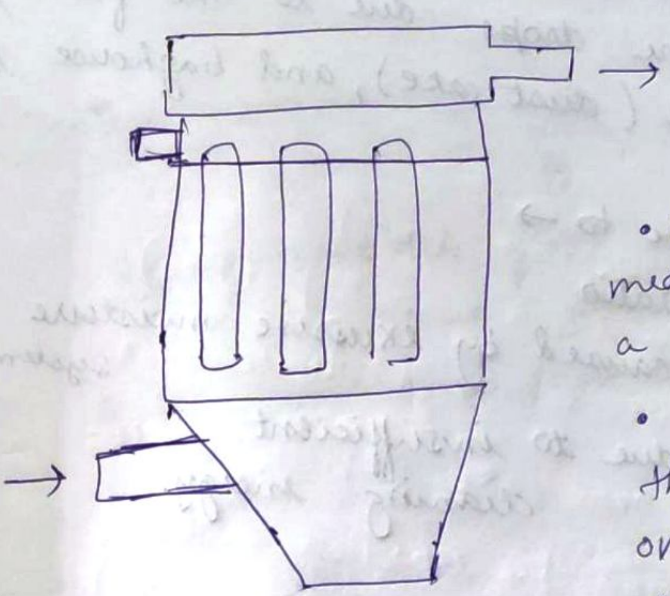
BAGHOUSES

Baghouses / fabric dust collector / fabric filters are air pollution control devices designed to use fabric filter tubes, envelopes or cartridges to capture or separate dust & other particulate matter.

BAGHOUSE COLLECTOR OPERATION



- Baghouse consist of filter media (bags) suspended inside a housing or casing.
- Fans on the outside of the housing blow the dirty or polluted air through the filters, capturing the suspended particulate matter & solids on the bags and pushing clean air through the outlet. While filtering, a baghouse bag allows the formation of a layer of particulate matter on its surface, called a dust cake. This dust cake continues to build until the thickness reaches a level where flow is sufficiently restricted, at this pt. bags are cleaned.

(*) AIR-TO-CLOTH RATIO → $\frac{\text{amount of air entering the baghouse}}{\text{total surface area of the filter fabric in the bag house.}}$

(*) DIFFERENTIAL PRESSURE → or pressure drop is a measure of resistance to gas flow in the system.
Baghouses with higher pressure drop requires higher powered fans to move air through the system, resulting in ↑ energy cost.

→ The total differential pressure is the sum of individual pressure drops due to the fabric, particulate layer (dust cake), and baghouse structure

High pressure drop due to →

- high air-to-cloth ratio
- Particulate adhesion caused by excessive moisture in the system.
- Blinded filter bags due to insufficient cleaning energy.

CLEANING MECHANISM

Bag house types :-

1) Reverse Air → Bags are cleaned by backwashing (reversing the air flow) within the chamber after shutting off the dirty gas flow and isolating the compartment

2) Mechanical Shaker → use mechanical shaking or vibrating actions to dislodge the filter cake. Bag bottoms are secured to a plate & their top are connected to horizontal beam.

3) Pulse Jet → or Reverse jet use compressed streams of high pressure air to remove particulate matter. During cleaning, brief (0.1 sec) pulses of air are pushed through the bag, dislodging solids which collect in a hopper below.

Bag Filter capacity (Q_G) → total air flow at the inlet of the baghouse (m^3/s)

$Q = \Sigma q = nq$ $\quad$ $n \rightarrow$ no. of hoods

air filtration velocity $= \frac{Q_G}{S} = m/s$

$Q_G \rightarrow$ total air flow at the inlet of the bag house (m^3/s)

$S \rightarrow$ total filteration area. (m^2)

Can velocity $= \frac{Q_G}{A}$

$A \rightarrow$ cross-sectional area of the filter chamber

* Air to cloth Ratio = air filteration velocity

→ Gross A/C ratio : take total ~~compart~~ sections / compartment into account.

→ Net A/c ratio : take only functional section into account.

2 types of operations :-

1) constant pressure → industrially used ($\Delta P \to$ const, $Q \to \downarrow$)

$$\boxed{t_f = \left(\frac{B}{2\Delta P}\right) V_G^2 + \left(\frac{C}{\Delta P}\right) V_G} \to \text{filtration time}$$

$$B = \left(\frac{\mu_G C_0}{\rho_B K}\right) \times \frac{1}{A^2} = \frac{K}{A^2}$$

C_0 = Cunnigham correction factor

ρ_B = Bulk density of filter cake.

$$C = \frac{\mu_G R_m}{A}$$

$R_m \to$ filter medium resistance (m^{-1})

$\mu_G \to$ filtrate viscosity (Gas viscosity) (Pas)

$A \to$ filter surface area (m^2) (collection area)

$\Delta P \to$ pressure drop over cake & filter medium (Pa)

$V_G \to$ vol. of Gas filtered for deposited dust of thickness (m^3)

If $R_m = 0$

$$\boxed{t_f = K^* \frac{V_G^2}{A^2}} \quad \left(\frac{m^3}{m^2}\right)^2$$

$t_f \to$ min

$$K^* = \frac{K}{2\Delta P}$$

$$\boxed{Q = \frac{V_G}{t_f + t_c}} \to \text{Capacity of Bag filter}$$

$$\boxed{t_T = t_f + t_c}$$

$t_f \rightarrow$ filtration time
$t_c \rightarrow$ cleaning time

⊛ to report the capacity of Bag filter total time (t_T) is used.

~~capacity~~ Capacity = $\dfrac{\text{VOL. of gas filtered}}{\text{filtration time} + \text{cleaning time}}$

$$\boxed{Q_{max} = \frac{V_G}{t_f}} \Rightarrow t_c = 0 \rightarrow \text{No cleaning is Required.}$$

⊛ $t_c = 30$ mins approx (mechanical Shaker)
⊛ $t_c = 10$ mins approx (Pulse & Reverse bed)
⊛ If no data is given on t_c then assume,

$$\boxed{t_c = t_f}$$

2. Constant Rate filtration or constant capacity filtration → In this ΔP constantly ↑.

$Q \rightarrow$ const
$\Delta P \rightarrow \uparrow$

$$\boxed{\Delta P = BQ^2 t + CQ}$$

at $t = 0$ $\quad \Delta P = CQ$

at $t = t$ $\quad \Delta P = BQ^2 t + CQ$

$C = \dfrac{\mu_G R_m}{A}$ $\quad \Delta P \rightarrow$ pressure drop over cake & filtrate medium (Pa)

$B = \dfrac{\mu_G \bar{C}}{A^2 \rho_B}$ $\quad \bar{C} \rightarrow$ avg dry cake mass

Ques:1 An old Bag filter from discontinued process is to be utilized for const. Pressure filtration at 12.7 mm of H_2O. the filter has 20 Bags of 7432.24 cm^2 each surface area. Cleaning time is 45 min.

For a given pressure filtration eqn :-

$$t_f = 674.82\, V_G^2$$

$t \rightarrow$ time (min)

$V_G \rightarrow$ vol. of air (m^3/cm^2)

Determine overall capacity of filteration at same condition

ESP

An electrostatic precipitator (ESP) removes particles from a gas stream by using electrical energy to charge the particles either positively or negatively. The charged particles are then attracted to collector plate carrying the opposite charge.

→ The collected particles may be removed from the collector plates as dry material (dry ESPs) $\xrightarrow{\text{mechanical impulses}}$, or they may be washed from the plates with water (wet ESPs).

Four components of ESP :-

1) <u>Gas distribution plates</u> → consists of several perforated plates which help maintain proper flow distribution of the entering gas streams.

2) <u>Discharge electrodes</u>:- These electrodes create ions that collides with the particles in the incoming gas stream and charge them.

3) <u>Collection Surface</u> :- (either plates or pipes) charged particles gets collected on this surface

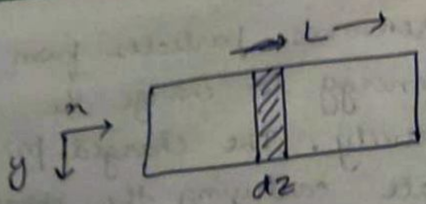
4) <u>Rappers</u> :- Rapping system is responsible for removing the collected particulate matter from the collection surface.

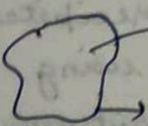
<u>TYPES</u>:

1) Dry ESP
2) Wet ESP
3) Plate ESP
4) Tubular ESP

} Learn about it

ESP COLLECTION EFFICIENCY (η)





collecting surface → cross-sectional area (A)

→ Perimeter (P)

$V_b \to z$ bulk gas velocity

$V_{PM} \to$ particle migration velocity

- Inlet = outlet + dust collected on the surface

in − out = collected.

$$A . V_b . (\Delta C) = V_{PM} \times P \times dz \times C$$

$$-\int_{C_0}^{C_L} \frac{dC}{C} = \frac{V_{PM}}{V_b} \times \frac{P}{A} \int_0^L dz$$

$$\ln \frac{C_L}{C_0} = -\frac{V_{PM} \times PL}{V_b A}$$

$A_C \to$ collecting surface area

$$\boxed{\eta = \frac{C_0 - C_L}{C_0} = 1 - e^{-\frac{V_{PM} \times A_C}{Q}}}$$

$A \to$ inlet area

$Q \to$ inlet flow rate of air (m^3/s)

$C_0 \to$ inlet concⁿ of particles − (kg/m^3)

$C_L \to$ outlet concⁿ of particles

$V_{PM} \to$ velocity with which particle is migrating to collecting surface.

→ depends upon field, spacing.

$$\boxed{v_{PM} = \frac{q_L \times E C}{3\pi \mu d_p}}$$

$E \rightarrow$ electric field (volts/m)
$C \rightarrow$ cunnigham correction factor
$q_{Lt} \rightarrow$ limiting charge (coulombs)
$\mu \rightarrow$ viscosity of gas (Pa.s)
$D_p \rightarrow$ particle dia (m)

⊗ v_{PM} is independent of gas flow rate.

$$q_{Lt} = q_{Lt}/_B + q_{Lt}/_{diff}$$

$$E = \frac{V}{S} = \frac{\text{voltage supplied}}{\text{Spacing}}$$

$S \rightarrow$ distance b/w wire & collecting plate

$$q_{Lt}/_b = ne$$
$$= f(r_p, E)$$

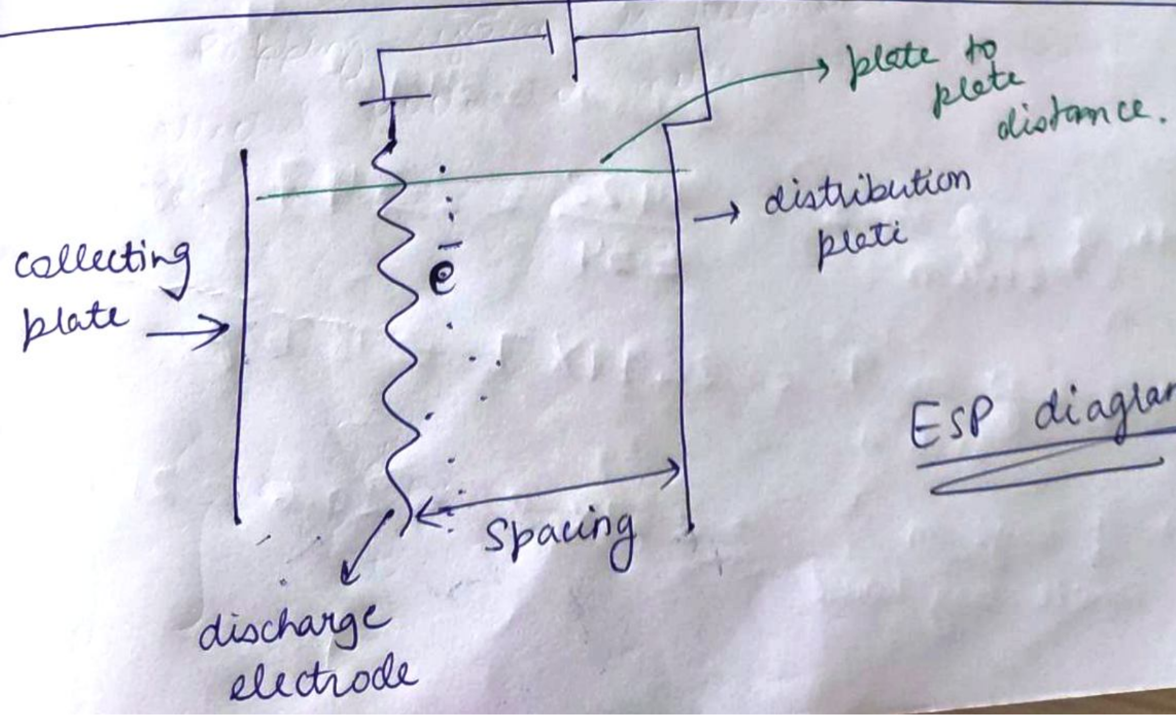
valid only for $E = 2.5$

for $E \neq 2.5$

$$q_{Lt}/_B = q_{Lt}/_b,\ E=2.5 * \frac{D_{E=2}}{D_{E=2.5}}$$

$$D = 1 + \frac{2(E-1)}{(E+2)}$$

$$q_{Lt}/_{diff} = ne = 2 \times 10^8\, r_p e$$



ESP diagram

Mechanism

1) Bombardment
2) Diffusional

Stages

→ ionization of $\bar{e}$
→ charging of particles
→ migration
→ collection
→ dust build up.
→ cleaning

(*) A single collecting plate offers 2 surface for dust collection.
So, collecting surface = 2X collecting plate.

Ques:3 (BAG FILTERS)

It is required to remove the dust from a iron core separation unit. The contaminated gas flows from the unit at the rate of 8.8 m^3/s at 45°C. A bag filter is used to remove the dust PM from the separation plant. the gas filter velocity is 1.5 m/min. Determin the cloth area repair to process such gas if the dia for the bag is 20 cm & length is 5 m. How many bags will be required for continuous cleaning of the bag.

Solution gas filter velocity $= \frac{Q}{S.A}$

$$\cancel{8.8\ m^3/sec} =$$

$$\frac{1.5}{60}\ m/s = \frac{8.8\ m^3/s}{S.A}$$

$$S.A = 352\ m^2$$

Area of 1 bag filter $= \pi d l + \frac{\pi d^2}{4}$

$$= 3.14 \times (0.2)(5) + \frac{3.14(0.2)^2}{4}$$

$$= 3.1714\ m^2$$

$$\text{No. of bags} = \frac{352}{3.171} \simeq 111 \text{ bags.}$$

Ques:4 Bag filters

A bag filter must process 15 m^3/s of water gas. the bag house has to be divided into 8 sections of repair cloth area so that 1 of the section is shut down for cleaning & maintainence work while remaining are working. air to cloth ratio is 9.0 m/min will provide sufficient treatment. The bags are 25 cm in dia & 7 m long. Determine the no. of bags & physical arrangement to make the above requirements.

total no. of section = 8

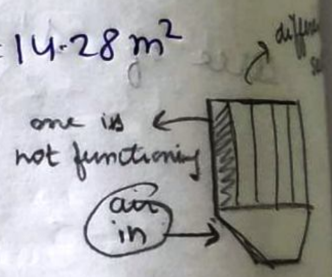
total functional section = 8-1 = 7

Solution: Total flow Rate of air $= 15\ m^3/s$

flow rate through 1 section $= \frac{15}{7}\ m^3/s$

S.A. of bag filters in 1 section $= \frac{Q}{A/C \text{ ratio}}$

$= \frac{15}{7} \times \frac{60}{9} = 14.28\ m^2$



S.A of 1 bag filter $= \pi DL + \frac{\pi D^2}{4}$

$= 3.14(0.25)(7) + \frac{3.14(0.25)^2}{4}$

$= 5.544\ m^2$

No. of bags in 1 section $= \frac{14.28}{5.54} = 2.577$ bags

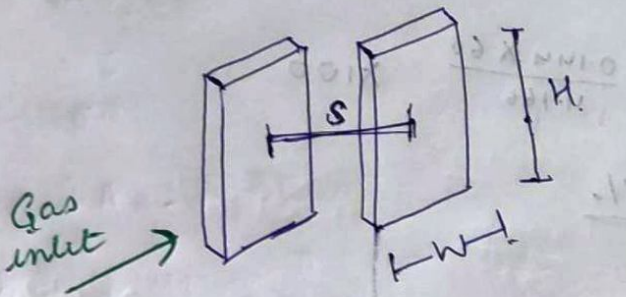
No. of bags in 7 section $= 2.577 \times 7 \simeq 18$ bags

No. of bags in whole bag house $= 2.57 \times 8 = 20.6 \simeq 21$ bags.

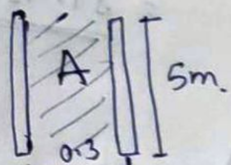
Ques:5 A horizontal parallel plate ESP consist of 5m height & 6 m depth with 30 cm plate to plate spacing having collection efficiency of 94.4% for handling contaminated gas of 180 m^3/min. the gas enter the ESP at 450°c & inlet loading is $10 g/m^3$

Calculate :-

i) Bulk velocity of the gas
ii) outlet loading
iii) particle migrating velocity
iv) efficiency for gas flow rate of 250 m^3/min.
v) Efficiency for collection if the spacing is changed to 20cm.



$H = 5m$
$W = 6m$
$S = 0.3m$.



cross-sectional area through which gas is entering (A) $= 0.3 \times 5 = 1.5 m^2$

$$\text{Bulk velocity} = \frac{Q}{A} = \frac{180}{60 \times 1.5} = \underline{2 m/s}$$

$$\eta = \frac{C_{in} - C_{out}}{C_{in}}$$

$$0.944 = \frac{10 - C_{out}}{10} \Rightarrow \underline{C_{out} = 0.56 g/m^3}$$

collection Surface area (A_c) $= 2 \times 5 \times 6 = 60\, m^2$

$Q = \frac{180}{60} = 3\, m^3/s$

$$\eta = 1 - e^{-\frac{V_{PM} A_c}{Q}}$$

$$0.944 = 1 - e^{-\frac{V_{PM}(\cancel{60})^{20}}{\cancel{180}\,3}}$$

$$e^{-V_{PM}(20)} = 0.056$$

$$\underline{V_{pm} = 0.144\, m/s}$$

iv) $Q = 250\, m^3/min$

$= \frac{250}{60} = 4.166\, m^3/s$

$$\eta = 1 - e^{-\frac{0.144 \times 60}{4.166}} \times 100$$

$= \underline{87.43\,\%}$

v)

Ques:6 As a recently hired engineer for an equipment vending company, you have been assigned the job of submitting a preliminary process design of an ESP of polluted gas

$Q = 120000\ m^3/hr$

$C_{in} = 85.5\ g/m^3$ $C_{out} = 87.\ mg/m^3$

$V_{pm} = 0.14\ m/s$

How many plates are required & then calculate the efficiency again.

Solution $\eta = \frac{C_{in} - C_{out}}{C_{in}} = 0.998$

$\underline{99.8\ \%}$

$Q = \frac{120000}{3600}$ ~~2000 m~~ $= 33.33\ m^3/s$

$0.998 = 1 - e^{-\frac{0.14 \times A_C}{120000}}$

~~$\frac{0.14 \times A_C}{120000} = 6.91$~~

$\frac{0.14 \times A_C}{33.34} = 6.21$

$A_C = 1479.96\ m^2$

$\simeq \underline{1480\ m^2}$

Let no. of plates be 10

No. of surfaces for collection $= 20$

area of 1 plate $= \frac{1480}{20} = 74\ m^2$

$74\ m^2 = \underbrace{8}_{length} \times \underbrace{9.25}_{width}$

permutation & combination

Ques:7 A gypsum plant emits 6000 m^3/hr of gases at 150°C & passes through a horizontal parallel plate type ESP having dimension as 3m high, 4m depth with spacing as 25 cm. Inlet & outlet loadings of dusts are 2.8 gm/Nm^3 & 50 mg/Nm^3

Normal cubic m

iv)

Calculate:

i) Efficiency of collection

ii) particle migration velocity

iii) efficiency when flow rate is doubled the original flow rate.

iv) % change in efficiency when spacing is ↑ by 10 cm keeping all other parameter constant.

Solution i) $Q = 6000\,m^3/hr$

$= \frac{6000}{3600} = 16.67\,m^3/sec$

$\eta = \frac{C_{in} - C_{out}}{C_{in}} = \frac{2.8 - 0.05}{2.8} = \underline{0.982}$

$A_c = 2 \times 3 \times 4$
$= 24\,m^2$

ii) $0.982 = 1 - e^{-\frac{V_{pm} A_c}{Q}}$

$0.982 = 1 - e^{-\frac{V_{pm} \times 24}{16.67}}$

$\frac{V_{pm} \times 24}{16.67} = 4.017$

$\underline{V_{PM} = 2.79\,m/s}$

iii) $\eta = 1 - e^{-\frac{2.79 \times 24}{33.34}}$

$\underline{\eta = 0.864}$

Ques:8 A parallel plate ESP having dimensions as 4m high, 5m depth with spacing b/w the plates as 25 cm separate dust from a flue gas at a temp of 150°C & 1.05 kg/cm². the gas flows through the precipitator at a rate of 100 m³/hr where a voltage 66,000V is applied.

Dp (μm)	0.05	0.1	0.2	0.4	0.8	1.2	5.0
% wt	2	15	20	33	15	10	5

Dp. is the particle dia in micron

$C = 1.0 + 0.172/D_p$
↳ cunnigham correction factor.

Calculate:

i) VPM

ii) overall collection efficiency.

iii) overall collection efficiency, if temp of the flue gas ↑ to 250°C due to malfunctioning of heat recovery system.

iv) If spacing is increased by 10 cm. what would be % change in overall collection efficiency keeping all other parameters const.

$L = 0.25\ m$

Solution: $Q = 100\ m^3/hr$

$= \frac{100}{3600} = 0.028\ m^3/s$

$V = 66,000V$

$E = \frac{V}{L} = \frac{66000}{0.25} = 264,000$

Calculation of Vpm: