# Flow of fluids

• orifice meter
• venturimeter
• Pitot tube • Rotameter

The substance which cannot resist permanent distortion.

# Fluid

- Mass of Substance
- Forms Layer over one another

# Importance

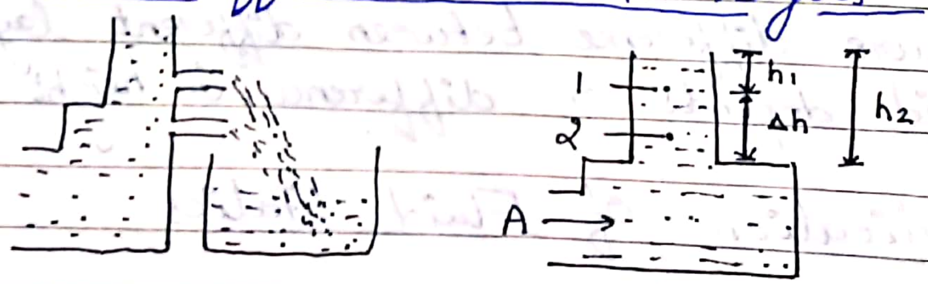
- Rate of flow of fluids.
- Flow of solid particles in suspension while pouring
- Flow of fluids while breaking collapsable tubes.

# When external pressure is applied layer of fluids roll over one another which makes the fluid to roll.

# Fluid Statics → Pressure may be defined as force exerted on a unit area

Fluid at rest State.

# Pressure Difference between layers of Liquids




Force acting on point 1
= Force on the surface + Force exerted by liquid above

— (1)

(Force = Pressure X Area)

Pressure on $P_1$ $\times S_1$ = Pressure on surface $\times$ Surface area + mass $\times$ acceleration — (2)

(mass = Vol $\times$ Density) $P_1 S = P_2 S$ + Volume $\times$ density $\times$ Accleration

(vol = area $\times$ height) $P_1 S = P_2 S$ + height $\times$ Area $\times$ Density $\times$ Acc

$$P_1 S = P_2 S + h_1 S \times \rho \times g \quad — (3)$$

$$P_1 = P_s + h_1 \rho g \quad — (4)$$

$$\text{Pressure at } P_2 = P_s + h_2 \rho g \quad — (5)$$

$$(5) - (4)$$

$$P_2 - P_1 = [P_s + h_2 \rho g] - [P_s + h_1 \rho g]$$

$$\Delta P = g[P_s + h_2 \rho] - g[P_s + h_1 \rho g]$$

$$\Delta P = g[\cancel{P_s} + h_2 \rho - \cancel{P_s} - h_1 \rho g]$$

$$\Delta P = (h_2 - h_1) \rho g$$

$$\boxed{\Delta P = \Delta h \rho g}$$

Pressure difference between different layers of liquid depends on difference in height.

# Application of Fluid Statics

- Depends on the working of manometer.

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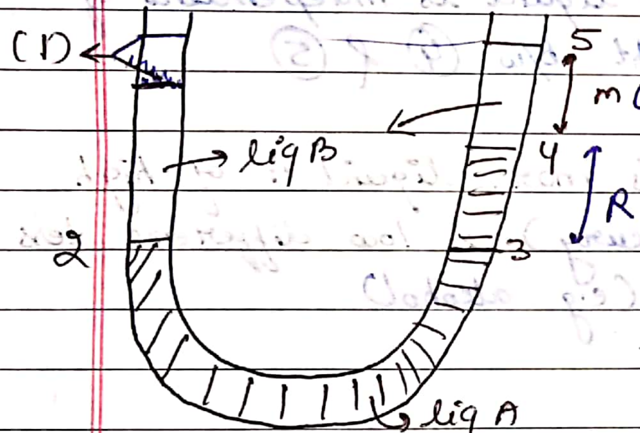
# Manometers

Device used for measuring pressure difference.

# 3 Types

- Simple
- Differential
- Inclined

# Simple Manometer




- Mostly used Manometer.
- U Shaped glass tube.
- 2 liquids are filled that are immisicible.
- Density for liquids A & B are $\rho_A$ & $\rho_B$

- when different pressure is applied at different tubes the miniscus of A liquid is lower in 1 tube & higher in other tube.

Then the pressure at two points is calculated -

Pressure at point 2 = $P_1 + (m + R)\rho_B g$

Pressure at point 3 = $P_1 + (m+R)\rho_B g$

Pressure at point 4 = $P_2 + m \rho_B g$

3 - 5

Pressure at point 4 = $P_1 + (m+R)\rho_B g - \rho_A R g$

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$$P_1 + \rho_B g (m+R) - \rho_A R g = P_2 + m \rho_B g$$

$$P_1 - P_2 = g m \rho_B - \rho_B (m+R) g + \rho_A R g$$

$$\Delta P = g m \rho_B - g m \rho_B - \rho_B R g + \rho_A R g$$

$$\boxed{\Delta P = (\rho_A - \rho_B) R g}$$

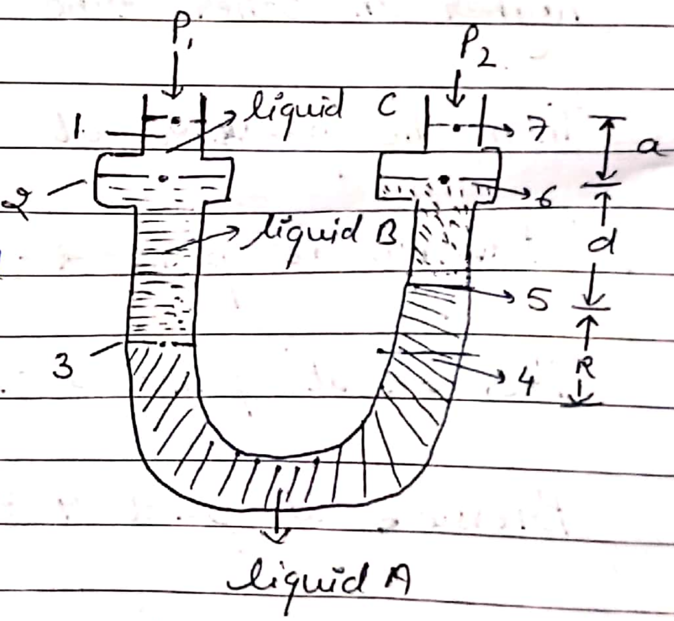
- Press. diff. is independent of height.
  Pressure difference between 2 liquid is independent of diameter of tube & height b/w ④ & ⑤

- When pressure difference is more liquid A of high density is filled (eg. mercury) & low difference less density liquid is used (e.g. alcohol)

# Application of Simple Manometer

- To calculate pressure difference of gas.
- Bernoulli's principle.

# Differential Manometers




Pressure at Point 3 = $P_1 + \rho(a+d+R)g$

$$\Delta P = R(\rho_A - \rho_B) g$$

$$\boxed{\begin{aligned} \Delta P &= P_1 - P_2 \\ \Delta P &= R(\rho_C - \rho_A) g \end{aligned}}$$

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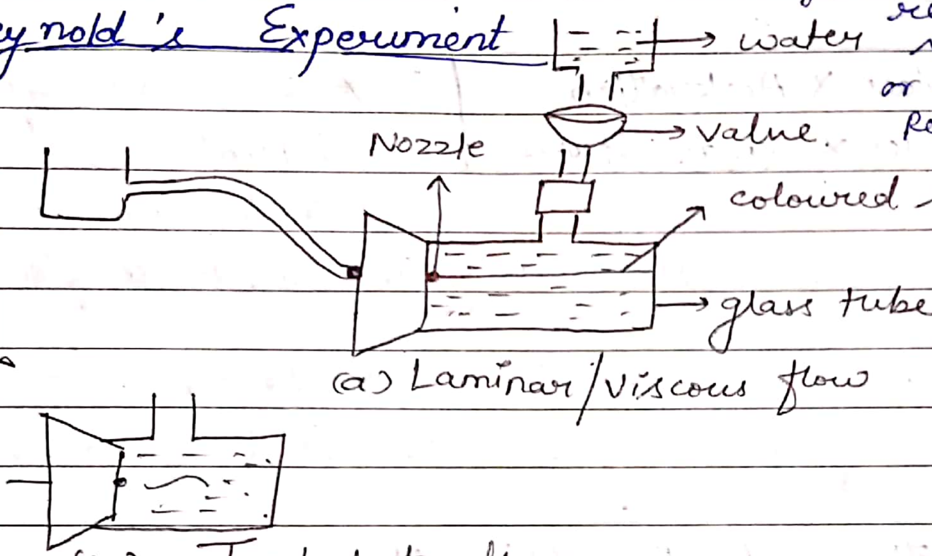
$$P_5 = P_2 + (d+a)\rho_B g$$
$$P_5 = P_1 + (d+a+R)\rho_B g - \rho_A R g$$

## Fluid Dynamics

When the liquid flows or it is in motion is called fluid dynamics.

## Reynold's Experiment




(a) Laminar/viscous flow

(b) Turbulent flow

A glass tube connected to reservoir of water. The rate of flow can be ↑ or ↓ through a valve. Reservoir of coloured soln connected to 1 end of glass tube through a nozzle. Coloured water is introduced into the glass tube thru a nozzle.

→ when the flow attains a certain velocity, it no longer remains steady & eddy currents appear. All the fluid particles are disturbed & get mixed with each other. There is continuous transfer of momentum to adjacent layers. Such a flow is called turbulent flow.

## Laminar flow

It is flow in which fluid particle flow in layers or with one layer sliding over the other. So, there is no exchange of fluid particles from one layer to another.

**Turbulent flow** - when the velocity of water is increased, the threads of coloured water disappears & the entire mass of water gets uniformly coloured. It indicates complete mixing of solution. Then, the flow of $H_2O$ is considered to be turbulent.

## Critical factor / Critical velocity

It is defined as average velocity of any fluid at which viscous flow changes to turbulent flow.

# Reynold's Number

Depends on 4 factors :-

- Diameter of pipe (in meters) = D
- Avg. velocity ($ms^{-1}$) = $\mu$
- Density of liquid ($kg/m^3$) = $\rho$
- Viscosity of fluid ($\eta$)

$$\boxed{Re = \frac{D\mu\rho}{\eta}}$$

$$\boxed{Re = \frac{\text{Inertial Forces}}{\text{Viscous Forces}}}$$

$$\boxed{Re = \frac{\text{Mass} \times \text{Accleration}}{\text{Area} \times \text{Shear Stress}}}$$

* When viscosity is more & accleration is less flow will be laminar.

* If velocity is less & acceleration is more flow will be turbulant.

* $Re < 2000$ → laminar

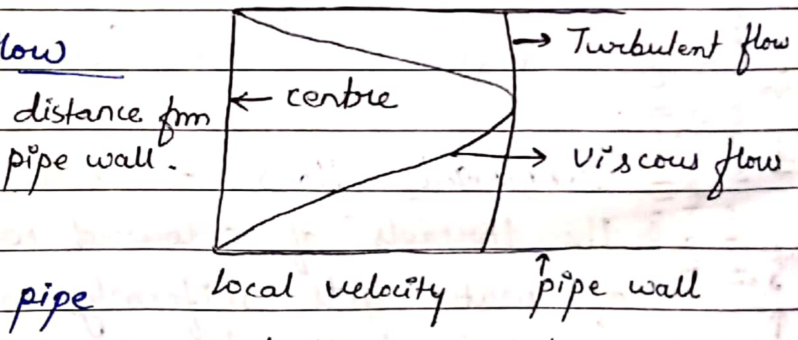
* $Re > 4000$ → Turbulant

* If Re is from 2000 − 4000 viscouls flow changes to turbulant flow.

# Applications of Reynold's Number

- To find out nature of fluid flow.
- To study the physical stability of suspens^n & emulsions.
- To study rate of heat transfer in fluids.

# Variation of fluid flow




* flow of fluid is max. in middle of pipe

* velocity of fluid approach 0 as pipe wall is approached.

Avg. velocity over whole cross section of pipe

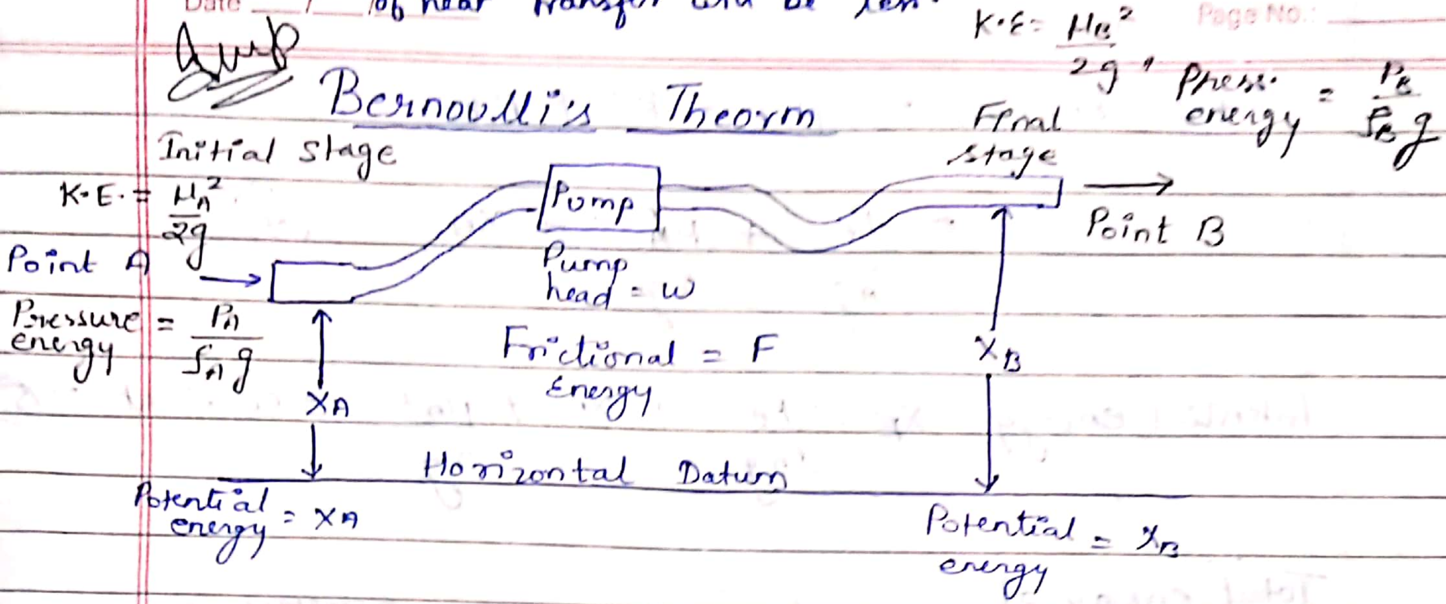
(1) Viscous flow → Av velocity ($\mu$) = Local velocity × 0.5

(2) Turbulant flow → Av velocity = local velocity × 0.8

* The layer which is present at pipe wall where velocity is 0 is c/d stagent layer. In this liquid is present in steady state.

* Application of Variation of fluid flow → Used to determine the rate of heat transfer. If the thickness of stagent layer is more the rate of heat transfer will be less.

## Bernoulli's Theorm




"Bernoulli's theorm states that in a steady state of the ideal flow of an incompressible fluid, the total energy per unit mass, which consists of pressure energy, kinetic energy and potential energy, at any point of fluid is constant."

Pressure energy at point A = $\frac{P_A}{\rho_A g}$ — (1)

Potential energy = $X_A$ — (2)

"Potential energy of a body is defined as the energy possessed by the body by virtue of its position or its configuration."

Kinetic energy = $\frac{u_A^2}{2g}$ — (3)

"KE of a body is defined as the energy possessed by the body by virtue of its motion".

Total Energy = P.E + KE + P.E

$$= \frac{P_A}{\rho_A g} + \frac{\mu_A^2}{2g} + x_A \quad -(4)$$

Potential energy $= x_B = \frac{P_A}{\rho_A g} + x_A + \frac{\mu_A^2}{2g}$ = constant $-(5)$

Total energy at point B $= \frac{P_B}{\rho_B g} + x_B + \frac{\mu_B^2}{2g}$ = constant $-(6)$

Acc. to energy conservation,
Input = Output

$$\frac{P_A}{\rho_A g} + x_A + \frac{\mu_A^2}{2g} = \frac{P_B}{\rho_B g} + x_B + \frac{\mu_B^2}{2g} \quad -(7)$$

Energy added by the pump = + W J $-(8)$

Energy loss due to friction = F J $-(9)$

(8) & (9) is inserted in point (7)

$$\boxed{\frac{P_A}{\rho_A g} + x_A + \frac{\mu_A^2}{2g} - F + W = \frac{P_B}{\rho_B g} + x_B + \frac{\mu_B^2}{2g}} \quad -(10)$$

This eqn is applicable b/w any 2 points in a system.

# Applications of Bernoulli's Theorm

→ Applied in the measurement of fluid flow by using orifice meter & ventori meter.
→ Applied in the working of centrifugal pumps.
→ It is easy to measure heights & applied as energy terms.

# Note. – Bernoulli's eqn. is numerically correct but it is not correct theoritically as each of the terms is actually energy & should be measured in J/mass. In practice, these are reffered as heights & measured in terms of height of a coloumn of liquid.

# Energy loss

- Friction losses
- Losses in fitting.
- Enlargement losses
- Contraction losses

(1) Friction Losses $\propto \rho \propto \mu \propto L$ length

$\propto \dfrac{1}{\text{diameter}}$

Fanning Equation

frictional factor

$$\boxed{\Delta P_f = \frac{2fu^2L\rho}{D}}$$

diameter

f depends upon
- Type of flow (viscous, turbulant)
- Inner surface of pipe.

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* Copper / lead pipe = 0.6
* New steel / cast iron = 1.0
* Old steel pipe = 1.0
* Badly rusted cast iron = 2.5

→ friction can be prevented by adding high molecular weight compounds (polymers) in low concentration.

→ fanning equation is applicable for straight pipes & turbulant flow.

For viscous flow

*→ Hasen Poiesclly Equation

viscosity

$$\boxed{\Delta P = \frac{32 L \mu \eta}{D^2}}$$

Note → friction losses are permanent because friction cannot be eliminated but can be reduced.
PE & KE are converted into heat.

(2) loss in fittings
When we insert fittings in a pipe the flow of fluid is distrubted, velocity decreased & loss of energy.

Its reasons are -
- Change in bending of pipe
- Inserting walls or fittings in pipe.

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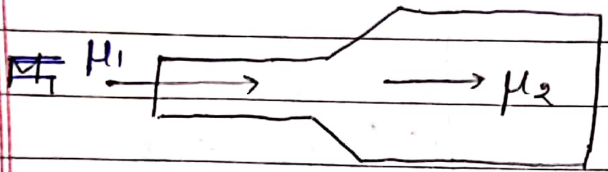
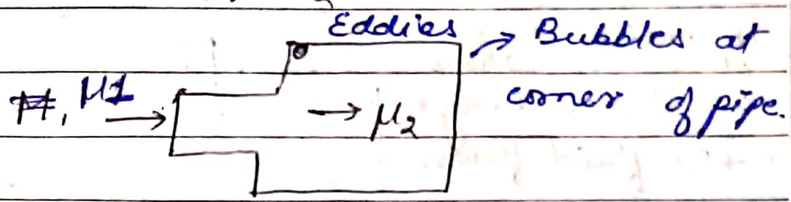
(3) Enlargement losses

$\mu_1 \simeq \mu_2$ $\qquad\qquad$ $\mu_1 > \mu_2$

~~$M_1 > M_2$~~



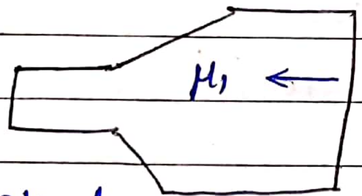



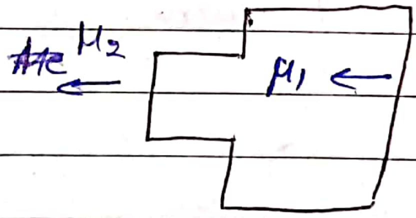

(Gradual enlargement)
(No loss of energy). $\qquad$ (sudden enlargement)

* Sudden enlargement losses –

$$\boxed{\Delta H_e = \frac{(\mu_1 - \mu_2)^2}{2g}}$$

(4) Contraction losses




(No loss of energy)
Gradual Compression $\qquad$ sudden compression
(loss of energy)

$$\Delta H_e = \frac{K \mu_2^2}{2g}$$

- K depends on type of flow & area of opening
- If opening is circular & flow will be turbulent
  $K = 0.04$

→ Rate of flow is amount of fluid flown out in particular time.

Principle :- Bernoulli's theorm, ↑ in velocity decreases pressure & this pressure fall is measured by manometer.

Date ___/___/_____ Page No.:

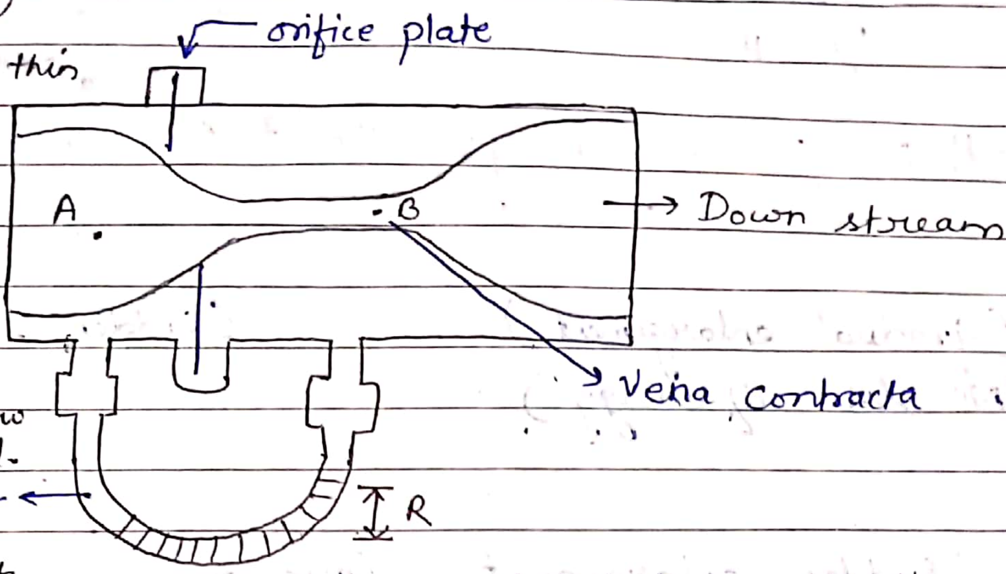
# ① Orifice Meter

**Construction**

It consists to be a thin plate with sharp apertures through which fluid flows.

It is normally placed b/w 2 long straight pipes so that other fittings do not alter the flow rate being measured.

A manometer is connected to two points A & B to measure the pressure difference




Acc. to bernoulli's theorm —

$$\frac{P_A}{\rho_A g} + x_A + \frac{\mu_A^2}{2g} - F + \omega = \frac{P_B}{\rho_B g} + x_B + \frac{\mu_B^2}{2g}$$

- Height at same level ∴ cancelled
- Same liq. ∴ density same i.e. $\rho_A = \rho_B = \rho$
- assume friction is zero.
- since at same level ; work. done zero.

$$\therefore \frac{P_A}{\rho g} + \frac{\mu_A^2}{2g} = \frac{P_B}{\rho g} + \frac{\mu_B^2}{2g}$$

$$\frac{1}{2g}(\mu_B^2 - \mu_A^2) = \frac{1}{\rho g}(P_A - P_B)$$

$$(\mu_B^2 - \mu_A^2) = \frac{2g}{\rho g}\Delta P \quad \text{— (I)}$$

- Now from eq^n of fluid statics —

$$\Delta P = \Delta H \rho g \quad , \quad \Delta H = \frac{\Delta P}{\rho g} \quad \text{— (II)}$$

Application used to determine $\mu_A$ & $\mu_B$. Ratio of $\mu_A$ & $\mu_B$ gives the ratio of area of orifice to area of pipe.

Date Also, to determine volume of liquid flowing /hour. Page No.:

Substitutⁿ (II) in (I), we get

$$(\mu_B^2 - \mu_A^2) = 2g\Delta H \quad , \because \left(\Delta H = \frac{\Delta P}{\rho g}\right)$$

now takⁿ underroot at both side -

$$\boxed{\sqrt{\mu_B^2 - \mu_A^2} = \sqrt{2g\Delta H}} \quad \text{or} \quad \left[\sqrt{(\mu_B^2-\mu_A^2)} = C_o\sqrt{2g\Delta H}\right]$$

* at point of orifice & at vena contrata to co-relate velocities we use a co-efficient '$C_o$' which depends on the ratio of $\frac{\text{Pipe diameter}}{\text{orifice diameter}}$.

If ratio $= \frac{1}{5}$, A velo < B velo., we consider $\mu_A$ as negligible,

$\therefore$ we get as -

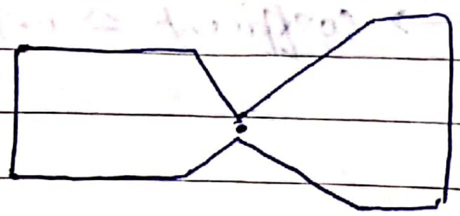
$$\boxed{\mu_o = C_o\sqrt{2g\,\Delta H}}$$

{ $\mu_B$ or $\mu_o$, $\because$ it is at orifice }

$\mu_o$ = velocity of fluid at the point of orifice.
$\Delta H$ = difference in pressure head.

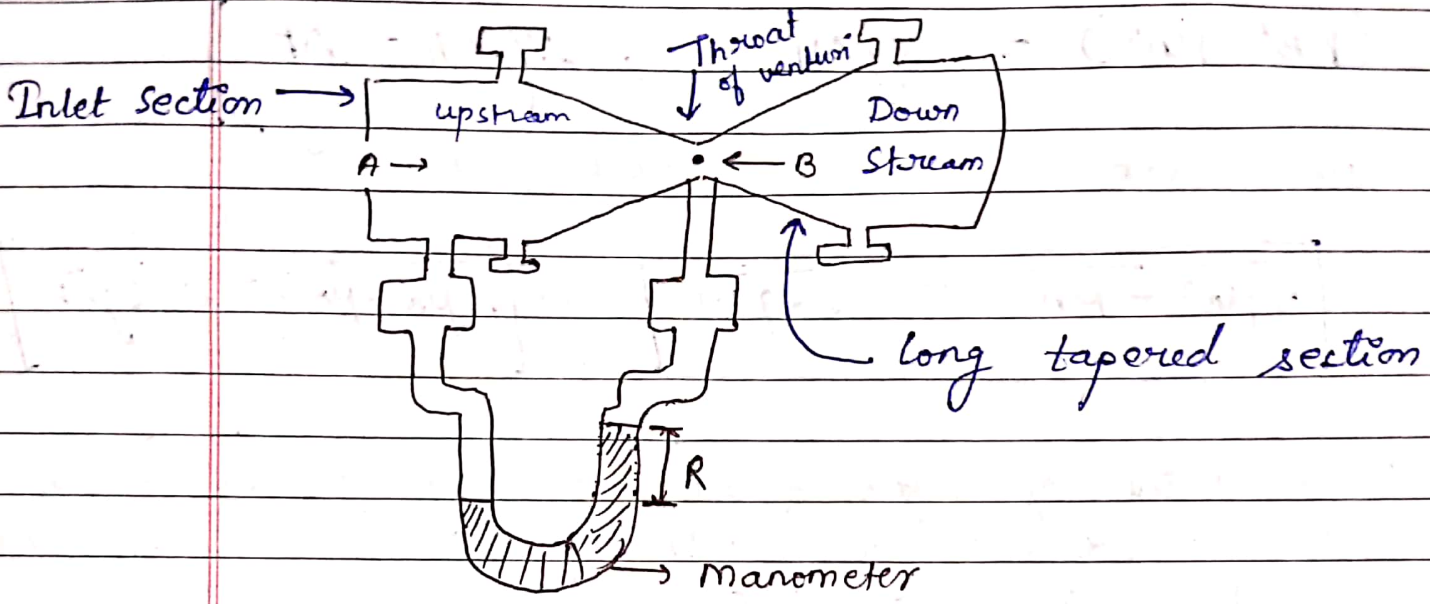
## (2) Venturimeter

$$\boxed{\text{final eq}^n \ (\mu_v) = C_v\sqrt{2g\,\Delta H}}$$



$(C_v = 0.98)$ ↓ a constant

(II) Venturi meter




**Principle** – Bernoulli's Theorm ↑ in velocity ↓ the pressure and this decrease in pressure is measured by manometer.

**Construction** – Consists of 2 tapered sections inserted in a pipeline placed b/w long straight pipes so that other fittings will not alter the flow of fluid rate.
- Upstream cone shorter than downstream cone.
- Tapering is smooth & power loss are absent in downstream.

**Working** – Called as variable head meter as it measures variable pressure difference across a fixed constriction. Velocity ↑ in the throat so the pressure decreases & this pressure drop is measured by manometer

$$\mu_v = C_v\sqrt{2g\,\Delta H}$$ → diff. in pressure height

$\mu_v$ → velocity at the point of venturi

$C_v$ → coefficent $\simeq 0.98$

Advantages

- Commonly used for liquids, especially water, can also be used for measurement of gases.

Disadvantages

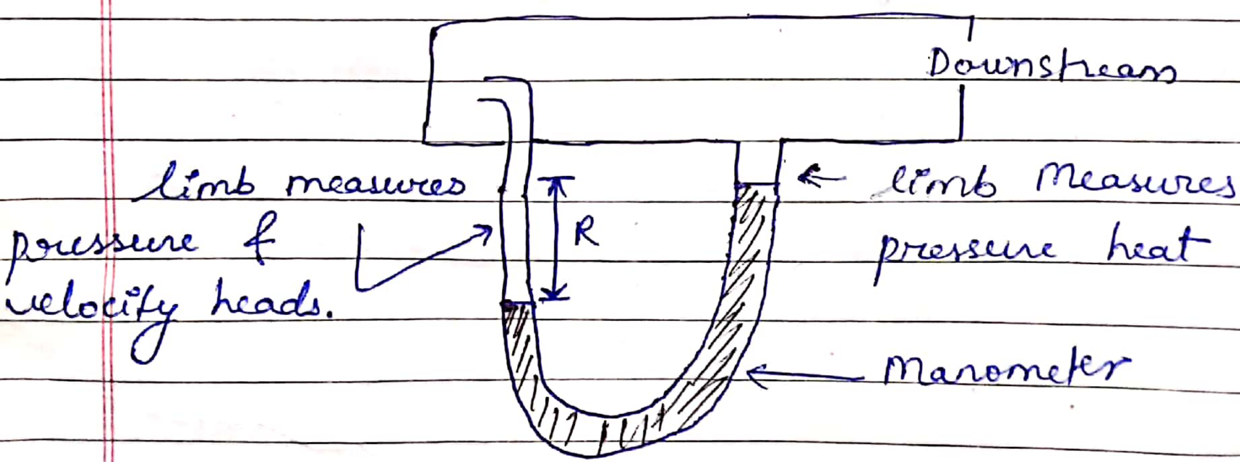
- Expensive
- Occupies more space
- Ratio of throat diameter to pipe diameter cannot be changed.

(III) Pitot Tube

- also known as insertion meter.
- size of sensing element is small as compared to size of flow channel.
- point of measurement is centre of channel.

→ one tube ⊥ to direction of flow & other ∥ to direction of flow.

→ Both connected by manometer




- used to measure velocity head of flow.
- Velocity of fluid increased at narrow constriction.
- This results in decreased pressure.
- Tube at right angle = Pressure head.
- Tube pointing upstream = Pressure head & velocity head.

R = Pressure head + Velocity head − Pressure head

R = Velocity head

$$\boxed{\mu = C_p \sqrt{2g \, \Delta H_p}}$$

→ Advantages :- Measures velocity at one point.

→ Disadvantages

- Eddies within the pressure tube disturb reading.
- Do not give average velocity directly.
- Reading is small for gases. for gases working on low pressure, multiplying guages should be used.

(IV) Rotameter

- Variable area meter. Measures the area of flow to produce constant head differential.
- Consists of a vertical tapered tube tube, mounted with narrow end down.
- Tube made of glass on which linear scale attached.

# Size Reduction or Comminution or Diminution or Pulverisation

Size reduction is a process of reducing large solid unit mass into small unit mass, corous particles or fine particles.

# Objectives of Size Reduction

1. Content uniformity ✓
2. Uniform flow ✓
3. Effective extraction of drug ✓
4. Effective drying ✓
5. Improved physical stability ✓
6. Improved dissolution rate ✓
7. Improved absorption rate ✓
   * dosage form
   * Reduce irritation.

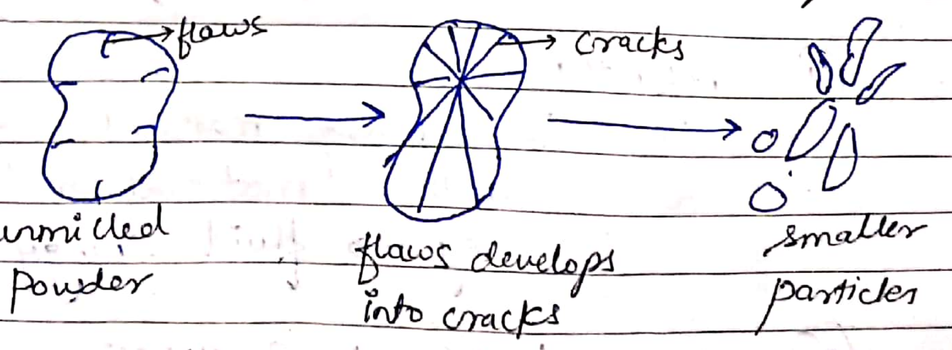
* Increased surface area
  ↓
  dissolution rate of drug ↑ses.
  ex → micronised size of Griseofulvin (antifungal drug)
  ↓
  5 times better absorptⁿ.
* Ease of mixing
* Stability of suspensⁿ
  ↓
  decreased stablisatⁿ rate.
* stable emulsion
* Increased absorption

# Disadvantages

1. Drug degradation (due to drug red., temp. is generated hence drug is little degraded)
2. Poor mixing (since particle small they get aggregated)
3. Contamination. (impurities will be added durⁿ the process)

# Mechanism

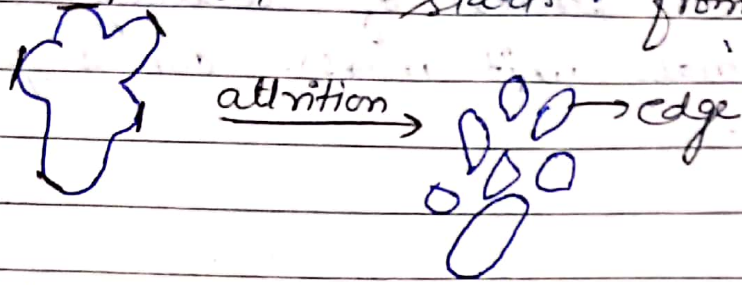
1. Impact




* whenever pressure is applied, particle breaks & process is called as impact.

## (2) Attrition

- Whenever rubbing occurs between two surfaces.
- Breakdown starts from edge.




# Modes of Stress

## (1) Cutting

→ Material or drug is cut with the help of sharp instrument.

eg → cutter mill

## (2) Compression

- Material is crushed b/w two heavy rollers.

eg → Roller mill

## (3) Impact

* Hammers or Bars are used

* (a) Hammers rotate :- material stationary & hammers continously hit the matterial. ex → Hammer mill

(b) Hamer stationary :- material go & hit the hammer. eg → fluid energy mill.

## (4) Attrition

- Any two heavy materials get rubbing action along with material or drug.

eg → fluid energy mill.

## (5) Combined Impact & Attrition

eg → Ball Mill

1-3 (soft) 4-7 (intermediate) 8-10 (hard)

# Factors affecting Size Reduction. (1-10)

→ device used to measure is Moh's scale.

① **Hardness** — It is easy to break brittle drug or less hard (soft materials)

② **Toughness** — It is hard to break a tough material.
eg → wet wood log, fibres.
* soft but tough material is hard to break.
ex- difficult to break a rubber than black board chalk stick.

③ **Stickness** — more sticky material, it is tough to break it. as particles get adhere to themselves & also the meshes may get blogged.

④ **Moisture Content** → it can affect no. of ppts like hardness, toughness & viscosity.
* wet & dry grinding
50% moisture (wet) ; 5% max moisture must be there (dry).

⑤ **Material Structure**
* If material fibrous → more problematic size reductⁿ.
* If cracks pnt, it is easy to break it.

⑥ **Softening Temp.**
* It is used for thermo labile drugs
ex → waxy materials (stearic acid) may find difficulty bcz of this).

⑦ **Purity Required.**
* Inner surface of ~~material~~ mill must have extra layer to avoid contamination of material.

⑧ **Physiological effects**
- Poisnous matterial must be reduced in closed chambers.

→ **Slipperiness** → material shows lubricating action & reduces effecting grinding.

(9) Ratio of feed size to product

100 m —— 1mm
↓
50 → 10 ↗

(10) Bulk density

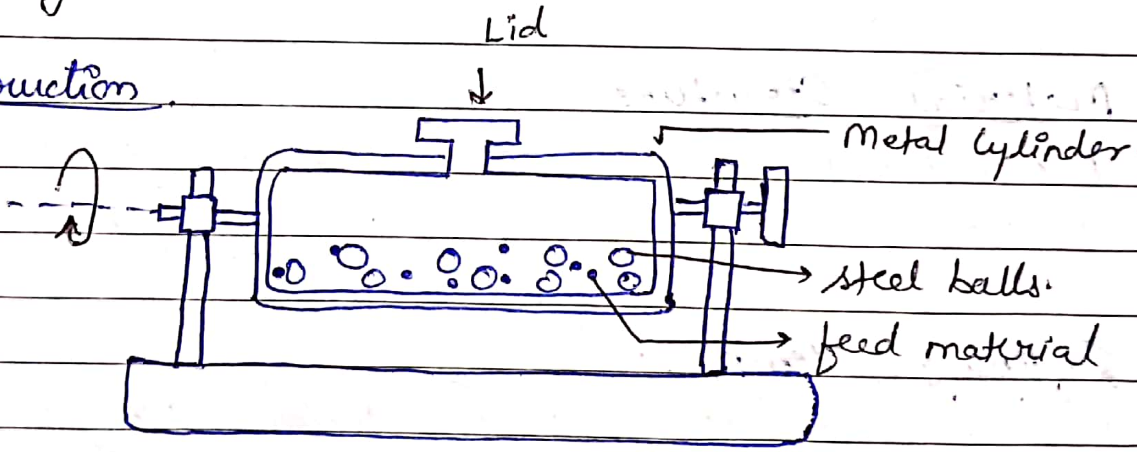
Density defines which method to used for the size reduction.

# Ball Mill or Pebble Mill (Tumbling Mills)

Principle (Impact & Attrition)

- Impact b/w rapidly moving balls & powder materials, both enclosed in a hollow cylinder.
- At low speeds, balls roll over each other & attrition (rubbing action).

Construction



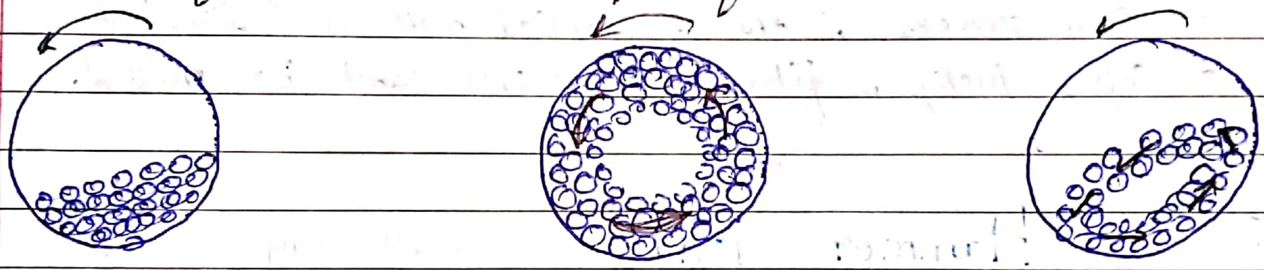

The construction of Ball Mill

- It consists of a Hollow Cylinder which is mounted on metallic frame & can be rotated on its longitudinal axis.
- Cylinder's length is slightly greater than diameter.
- Cylinder → made of metal & lined with Chrome. Even in pharmaceutical industry cylinders are sometimes lined with rubber or porcelain.

- cylinder occupies 30 to 50 % balls
- Ball's wt. is kept constant.
- Ball size depends upon - size of feed
  - diameter of mill.
- Balls are made of steel, iron or stoneware & these act as grinding material.

## Working

- drug which is to be ground is filled in cylinder upto 60% of volume.
- fixed no. of ball is introduced & cylinder is closed &
- mill is rotated on its longitudinal axis.
- Speed of rotatn is an imp. factor.



**low speed**
↓
- Balls roll over each other
- Attrition will be the predominant mode of stress.

**high speed**
↓
due to centrifugal force balls thrown on wall, hence grindn does not occur.
↓
compressn by the balls will not be sufficient for effective comminution of substance.

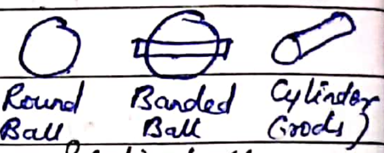
**correct speed.**
↓
Centrifugal force occurs
↓
balls pickedup by mill walls & carried nearly to top where they break contact from wall & fall to bottom to be picked up.
↓
Impact stress introduced
↓
size redu. effective.

# Uses

- for grindn particle size upto 100 to 5mm or less.
- particularly used for hard and abrasive materials.
- stainless steel balls are used in productn of opthalmic & parenteral productn & in this less chance of contamination due to wear & tear.
- At low speeds used for milling dyes, insecticides, etc.

## Advantages

- very fine powder obtained.
- Used for batch operation.
- Suitable for both wet & dry grinding processes.
- Toxic substances can be milled.
- Since, mill is closed system, sterility can be achieved.
- Milling operations can be accomplished (done) in an inert atmosphere to prevent oxidation.
- Balls can be of various shapes & size

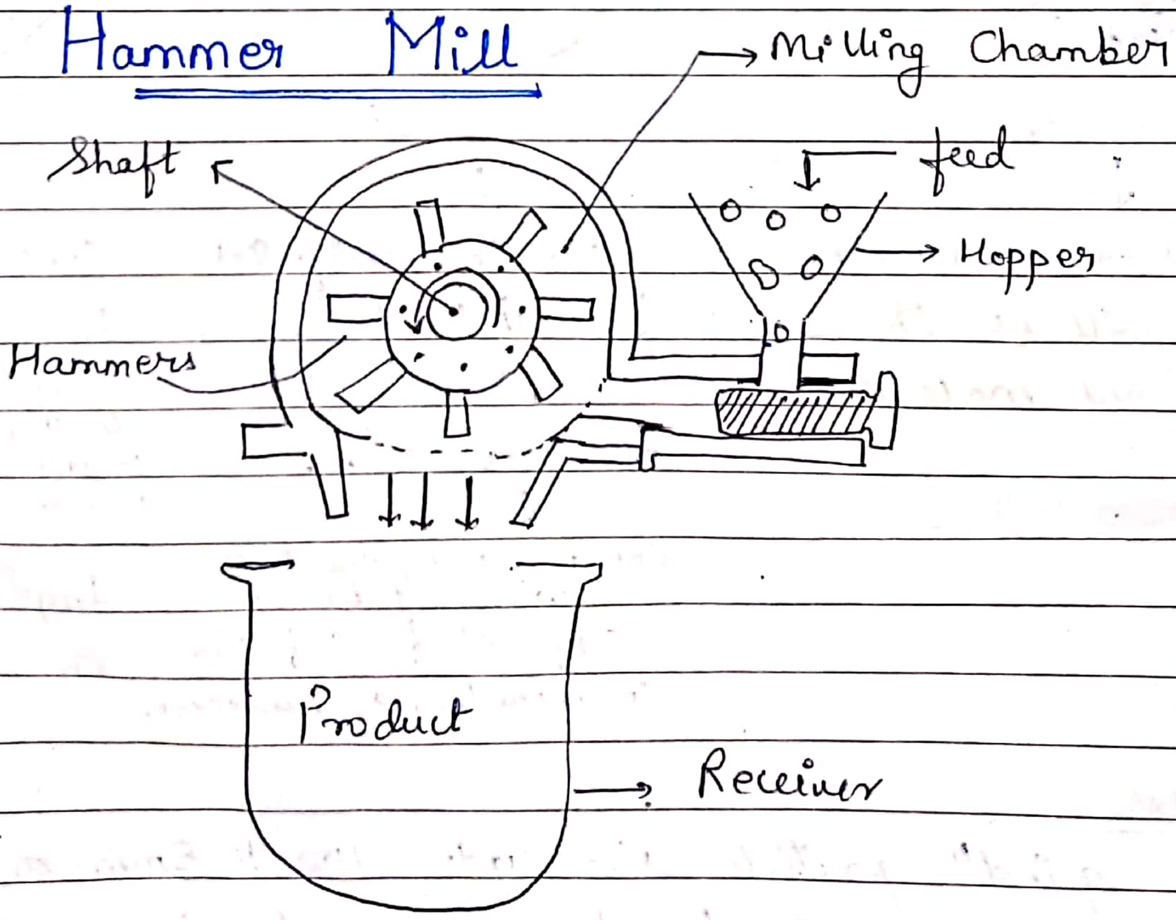



& cubic balls.

## Disadvantages

- very noisy
- Wear occurs by walls as well as casing, can cause contaminatn.
- Slow process, energy applied rate is limited.
- Soft, tacky, fibrous materials can't be milled.

## Hammer Mill



Principle :- Impact

→ Impact is seen b/w rapidly moving hammers mounted on rotor & the powder material.

# Construction

- Can be of vertical or of horizontal shaft type.
- Hammers made of → hardened steel, Stainless steel

Impact surface made of haystellite & carbaloy {Extremly abrasive resistant materials}

→ can be of several shapes. (basic are • stirrup
• Bar }

extensively used in tablet granulation.

→ Blades can either be flat or sharp edges. or even both on either sides.

→ These are either rigid or swing-type.

* free swing type → advantage → increase clearance b/w hammers & screen. incase of excessive builds.

- Entire unit is closed in chamber which has a removable screen through which material must pass.
- screen → not woven
  → made of metal of varyⁿ thickness with holes.

# Working.

- Hammers → continous motion (8000 – 15000 RPM)
- feed in hopper → flow vertically down → horizontally → Hammers continous motⁿ → matterial to small particles → pass thru screen → exit particle due to tangential size is small than the aperture

"Faith is the bird that feels the light when the dawn is still dark." – Rabindranath Tagore

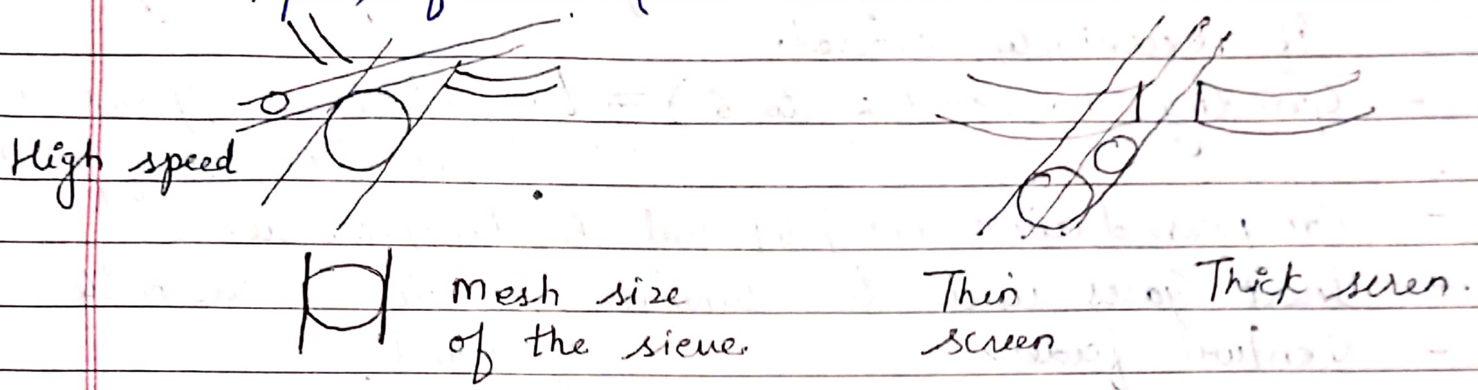
- Screens are interchangeable to achieve fineness.
- Hammers ⟶ centrifugal fan • so as large amount of air is drawn through mill
  • To counteract heat generated during milling.

Fineness of powder is regulated by :-
* rotor speed
* feed rate
* clearance b/w hammers & grinding plates
* Number & type of hammers
* size of discharge sheet.

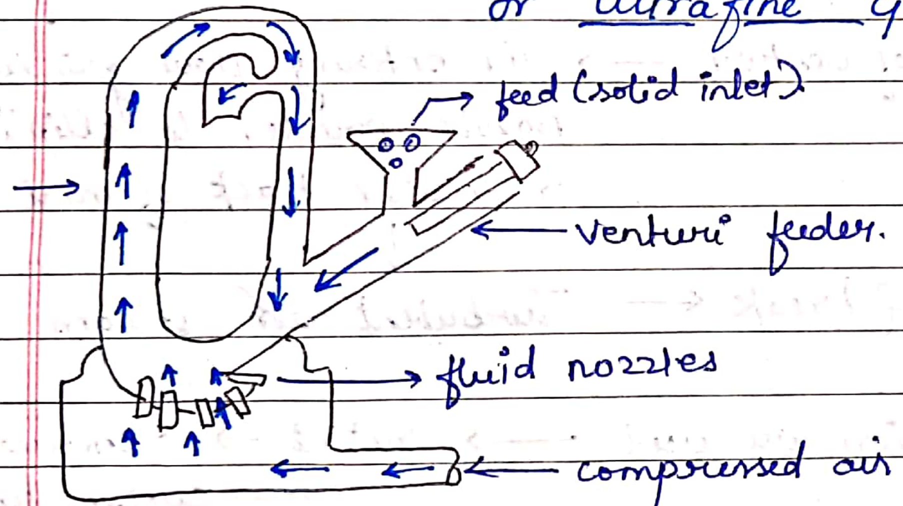
# Uses
- fine, moderate grindⁿ.
- particle size (10 to 400 nm).
- non-abrasive to moderately abrasive & brittle materials are used.
- used for dry materials, wet filter press cake.
- fibrous material ⟶ reduced by cuttⁿ edge
- Brittle material ⟶ Impact

Advantages
- easy setup, dismantle & clean up.
- minimum scale-up problems.
- small space is occupied.
- versatile (speed & screen can be changed)
- ∵ operated in closed environment, dust reduced & explosⁿ hazards prevented.

Disadvantages.
- screens may get clogged.
- Heat build up is more, product degradatⁿ possible.
- wearing of screens & mill possible.
- sticky, fibrous & hard materials can't be milled.




# Fluid Energy Mill or Jet Mill or Micronizers or Ultrafine Grinders




Principle (impact & Attrition)

→ feedstock suspended within high velocity air stream.
→ Milling occurs due to high velocity collision b/w suspended particles.

# Construction

- It has an elliptical pipe (height = 2 meters & diameter = 20 to 200mm)
- mill surface
  ⇓
  either soft stainless steel or tough ceramics.
- mills contact surfaces may be changed or replaced if excessively eroded.
- Grinding nozzles (2 to 6) = tangential or opposed to initial flow path of powder
- Compressed air = 600 kilopascal to 1 megapascal.
- Inert Gases used to eliminate oxidation of susceptible compound.
- Venturi feeder
- Outlet with classifier which allow air escape.

# Working

Powder → inlet of venturi → air entering thru grinding nozzle powder to elliptical or circular track of mill
↓
Turbulent air stream → particles collide & break
↓
Impact & attrition are used → outlet → removed by cyclone seprator or bag filter.

* Coarse particle again repeats process until particle reduced sufficently.

# Uses

- Reduce particle size of antibiotics & vitamins
- Used to obtain better bioavailability
- Ultrafine grinding obtained.
- Moderately hard particles can be grinded.

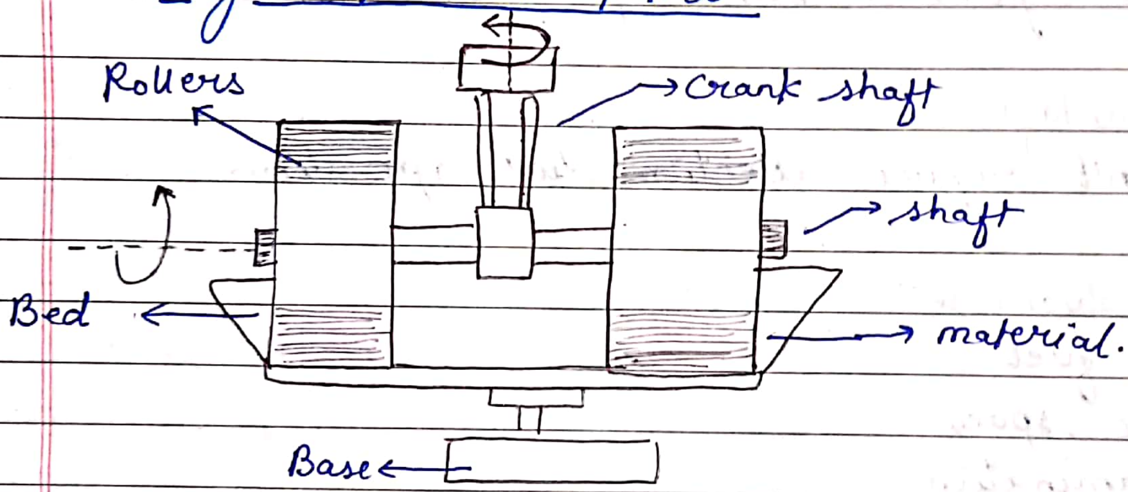
Advantages

- no moving particle, no heat production.
- Rapid. (size obtained 30mm or less)
- no wear of mill, contamination not possible.

Disadvantages

- Can't mill soft, tacky & fibrous material
- Expensive equipment.

# Edge Runner Mill




Principle

- Crushing (compression).
- shearing force also involved durin stone movement.

Construction

- Two heavy rollers (tonnes)
- Bed (stone or granite)
- Roller has central shaft & revolve on its axis.
- Rollers are mounted on horizontal shaft & move around bed.

→ Working (a batch process)

- Material → bed (in path of stone wheel) ⟶ stone revolve on axis + travel round shallow stone bed.
- Size reductn ⇒ shearing + crushing.
- Grinded material ⟶ passed thru seive.

# Uses
- used for grinding tough, fibrous materials.
- Grinds plant-based products.

Advantage
- doesn't require attention durn operation.

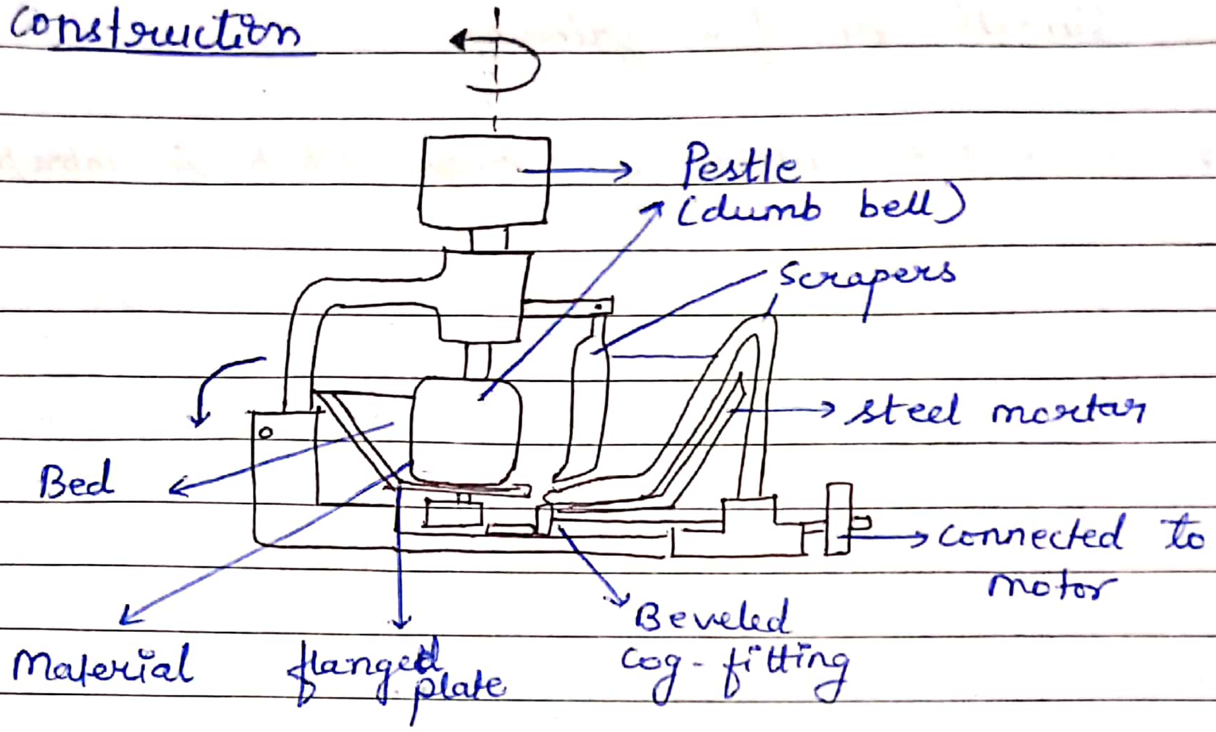
Disadvantage
- High fuel
- more space
- contamination
- time consuming
- not used for sticky materials

# End Runner Mill

Principle → Crushing (compression)

- Reductn obtained by crushing b/w heavy wt. of steel pestle.
- Shear stress also involved during movement of mortar & pestle.

## Construction




- mechanical mortar & pestle.
- It has :- ⊙ steel mortar fixed to flanged plate.
  ⊙ under flanged plate, a bevelled cog fitting is attached to horizontal shaft bearing a pulley, ∴ mortar & plate can be rotated on high speed.
  - Pestle dumbell shaped (balancing & efficient grinding).
  - Bottom of pestle flat.
  - Pestle has a hinged arm with it, due to this pestle can be raised from mortar for emptying & cleaning.
  - Narrow central portion of pestel is longer than the band of arm around it, ∴ pestle can rise & fall over all material in mortar.

## Working

- Material in mortar & scraper puts the material in path of pestle.
- Mortar revolves at high speed, pestle is in this hence it causes pestel to revolve.
- During this size reductn achieved by shearing & crushing.
- Material collected & passed thru sieve to get desired size powder.

# Size Sepration

Date __/__/__ Page No.: ____

* Size ~~reduction~~ sepraⁿ is a unit operation that involve ~~a~~ the sepration of a mixture of various sizes of particles into two or more portions by means of screening surfaces.

- also known as sieving, sifting, classifying or screening.
- Technique based on physical differences b/w particles such as shape, size & density.

- Screening - seprating particle acc. to size alone through sieve.
- Material remaining on given screening surface — oversize or plus material
- material passing through the screening surface — undersize or minus material

# Applications

1. In production of tablets & capsules, it is a method to determine particle size & size distribution.
2. As quality control tool for raw materials like griseofulvin & aspirin.
3. To test efficency of size reduction equipment or process.
4. To recover valuable products or byproducts.
5. To prevent environmental pollution.

# Official Standards For Powders

- Mainly powders are either fine or coarse.
- Acc. to Indian Pharmacopoeia, degree of coarseness or fineness is expressed with reference to nominal aperture size of sieve through which powder is able to pass.

# Grade of powder

| Grade of powder | Sieve thru which all particles must pass | Nominal mesh aperture size | Sieve thru which 40% particles pass | Nominal mesh aperture size. |
|---|---|---|---|---|
| Coarse | 10 | 1.7 mm | 44 | 355 µm |
| Moderately Coarse | 22 | 710 µm | 60 | 250 µm |
| Moderately fine | 44 | 355 µm | 85 | 180 µm |
| | 60 | | | |
| Fine | 85 | 180 µm | — | — |
| Very fine | 120 | 125 µm | — | — |

# Coarse Powder

It is a powder whose particles pass through a sieve with normal mesh aperture of 1.70mm (No. 10 sieve) & not more than 40% thru a sieve with nominal mesh aperture of 355µm (no. 44 sieve)

* Coarse powder = Percolation process.
* moderately Coarse = tinctures

| Liquid Extract | Useful Part | Grade of Powder |
|---|---|---|
| Ashoka | Stem bark | Coarse |
| Nux Vomica | seeds | moderately Coarse |
| Rauwolfia | roots | moderately coarse |
| Ergot | sclerotia | moderately fine |
| Ipecac | root | fine |
| Ephedra | stem | fine |

# Sieves → wire mesh type

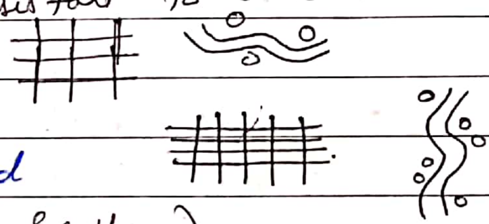
→ Sieves are simplest & sieving is most frequently used method of size sepration.

→ Each sieve is given a no. which represents meshes tht in one inch or in 2.54 cm

## Construction

- constructed from wire cloth with square meshes.
- wire are of brass, bronze, stainless steel or any suitable material.
- Sieve should not be coated or plated, there must be no rxn b/w seive material & substance to be seived.
- Material for construction must be resistant to corossion.

## Types Of Sieve



- Woven Wire Sieve → Plain / Twilled
- Bolting Cloth sieve (silk, nylon & cotton)
- Closely spaced bars (screens)
- Punched plates (Perforated screens) — for coarse sizing

- **Sieve Number**

  No. of meshes per linear length of 25.4mm.

- **Nominal Size of Aperture**

  - It indicates the distance between two adjacent wires.

  Represents the size of square apertures.

  BP 1996 gives the nominal mesh aperture size for majority of sieves in mm or µm.

* Generally iron wire used but disad (corossive nature)

* Brass, Phosphor-bronze & Stainless steel → (corrosion resistant, good strength, non-contaminati qualities).

* Non-metals (Nylon & terylene used which reduce risk of metallic contaminat)

- Purched plates or perforated screens used for special purposes.

Scanned by CamScanner

# Modes Of Motion In Size Sepration

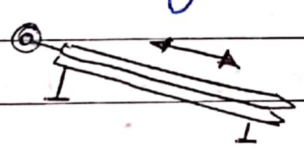
- Screening
- Agitation → oscillation, Vibration, Gyration
- Brushing
- Centrifugal Force.

→ **Agitation**

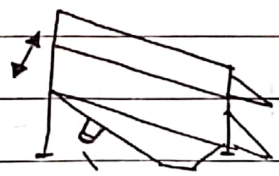
seives agitated in no. of ways :-

(a) Oscillation

- Sieve mounted on frame that oscillates back & froth, i.e, reciprocal motion.
- Simple method.
- material may roll over sieve surface.
- motion parallel to sieve plane.
- Sieves can be slightly tilted.
- Reciprocating motion is Induced by means of ordinary eccentric on rotating shaft

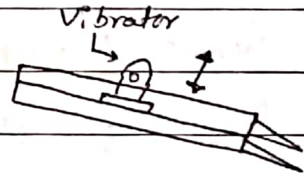


Oscillatory moth of screen.



Eccentric vibrator

(a) Mechanically Vibrated.




(b) Electrically Vibrated.

(useful in Chemical Industry)

Vibration

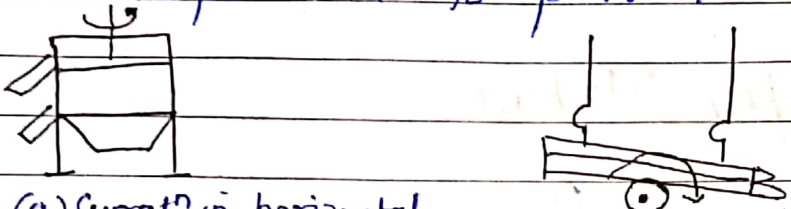
- seive vibrated at high speed with help of eccentric device.
- vibrat^n help the powder to pass thru the seive.

ex → Hum-mer screen.

- vibration also prevent blending of meshes.

## Gyration

- seive is on rubber mounting & connected to an eccentric flywheel.
- This gives rotatary movement to small amplitude to the sieve, which in turn gives spinning motion to particles that helps them to pass thru the sieve.



(a) Gyratn in horizontal plane (b) Gyratn in vertical plane

**Adv** • agitatn = inexpensive, simple & Rapid.

**disad** - low limit of particle size.
Not useful for wet powders as clogging occurs.
Durn agitatn, attrition occurs which causes size reductn.

# Brushing Method

- A brush is used to remove particles from seive & to keep meshes clear.
- Circular seive :- Brush is rotated in middle.
- Horizontal cylindrical seive :- In this spiral brush is rotated on the longitudinal axis.

ex → Brush shifter
(used for size sepration of greasy or sticky powders such as waxes & soaps)

# Centrifugal Method

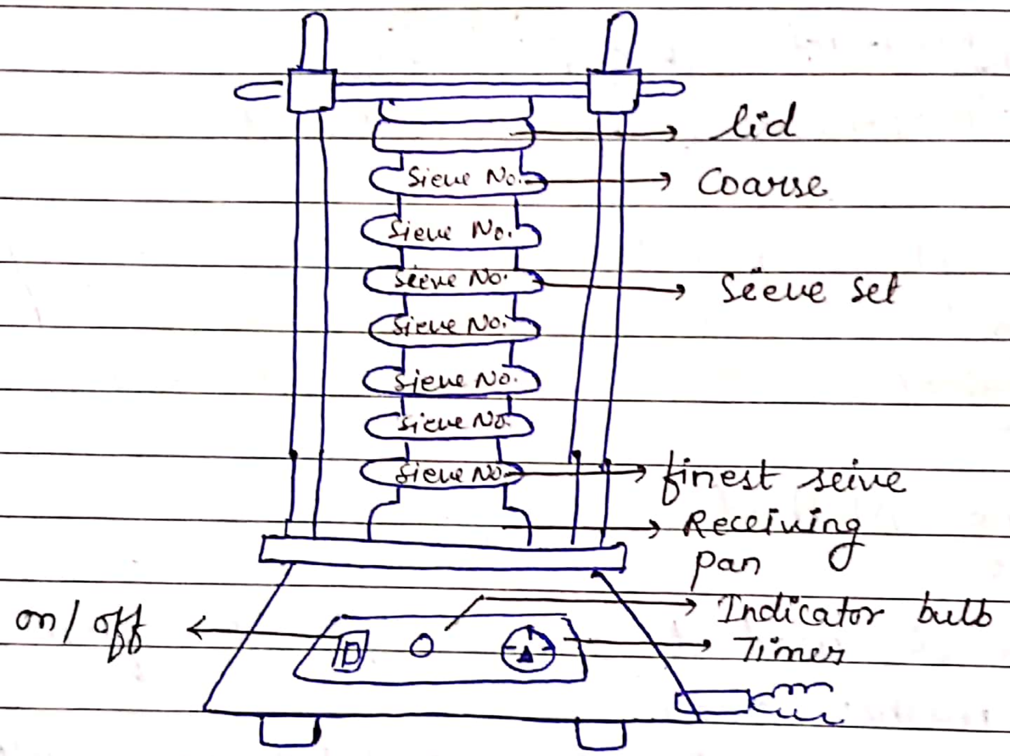
- In this a high speed rotor is fixed inside vertical cylindrical seive, so that on rotation the particles are thrown outwards by centrifugal force.
- By air jet air currents are passed to seprate the particles.

ex → cyclone seprator & air seprator

advantages

- When because of ventional seiving seives get blocked in such cases these methods are extremely beneficial.
- beneficial for fine particles.

# Seive Shaker Machine




* laboratory Sieve Shaker Machine

Principle (agitation)

- Powdered drug is seprated acc. to its particle size, using number of seives in a nest.
- These are subjected to agitation for rapid size sepration.

Construction

- Standard seives of different mesh numbers are available commercially as per specifications of IP & USP.

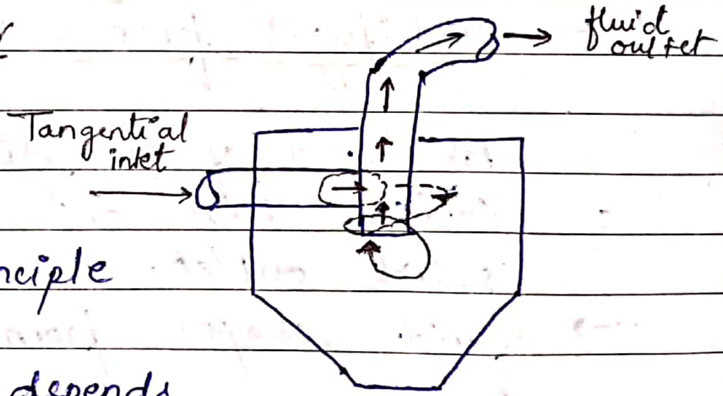
- These seives are fixed in mechanical shaker apparatu

Working
- Seives arranged in nest with coarse at top.
- 50g sample placed on top seive
- Seive set fixed to mechanical shaker apparatus & shaken for time duration of 20mins.
- Powder retained on each seive is weighed.

Advantages
- Inexpensive
- Simple
- Rapid with reproducible results.

Disadvantages
- lower limit of particle size is 50µm.
- Not useful for wet powders due to clogging of meshes.
- Error.. occurs in estimation due to attrition which causes reduction in particle size.

# Cyclone Separator




Principle
- These ~~are~~ mainly seprate the solids from fluids.
- This is based on principle of centriful force.
- The sepration process depends not only on the particle size, but also on density of particles.
- On basis of fluid density, it seprates all types of particles.
- It is also possible to allow fine particles to be carried by fluid.

"Faith is the bird that feels the light when the dawn is still dark." –Rabindranath Tagor

## Construction

- It consists of vertical, cylindrical vessel.
- It has conical base or bottom.
- Upper portion of vessel is fitted with tangential inlet.
- Outlet is arranged at base.
- Outlet for air is provided at center of top, which extend inwardly into separator to prevent air short circuiting directly from inlet to outlet of fluids.

## Working

→ The solids are suspended in gas or steam & are introduced tangentially at very high velocity into vessel.

→ Tangential inlet → most common type → least expensive & most efficent.

→ Now rotatory motion takes place inside vessel.

→ Due to this vortex formation occurs.

→ centrifugal force + vortex throw solid to the wall.

→ As speed of air diminishes, particles fall to the conical base and are discharged through solid outlet.

→ fluid escapes from central outlet at the top.

## Uses

- To seprate solid from gases.
- Used for size sepration
- for seprating heavy or coarse fraction from fine dust.

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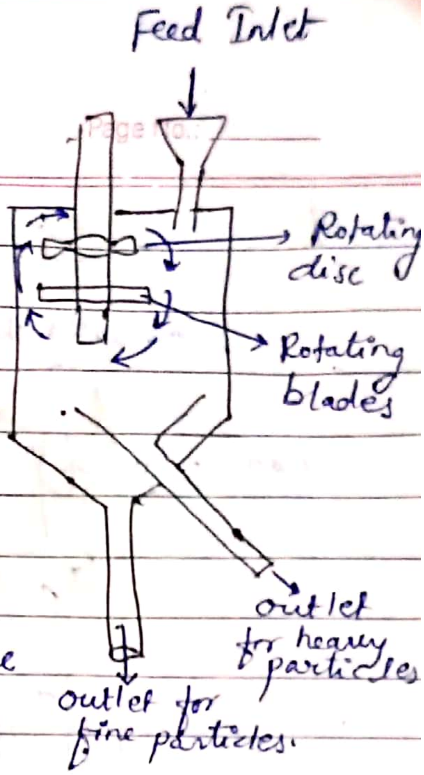
# Air Seprator




## Principle

- Centrifugal force is used to seprate Solids.
- Air environment is obtained by means of rotating.
- Stationary blades are used to improve the sepration.
- Size at which sepration occurs depends upon :- (1) Blades (2) Speed of Rotation.

## Construction

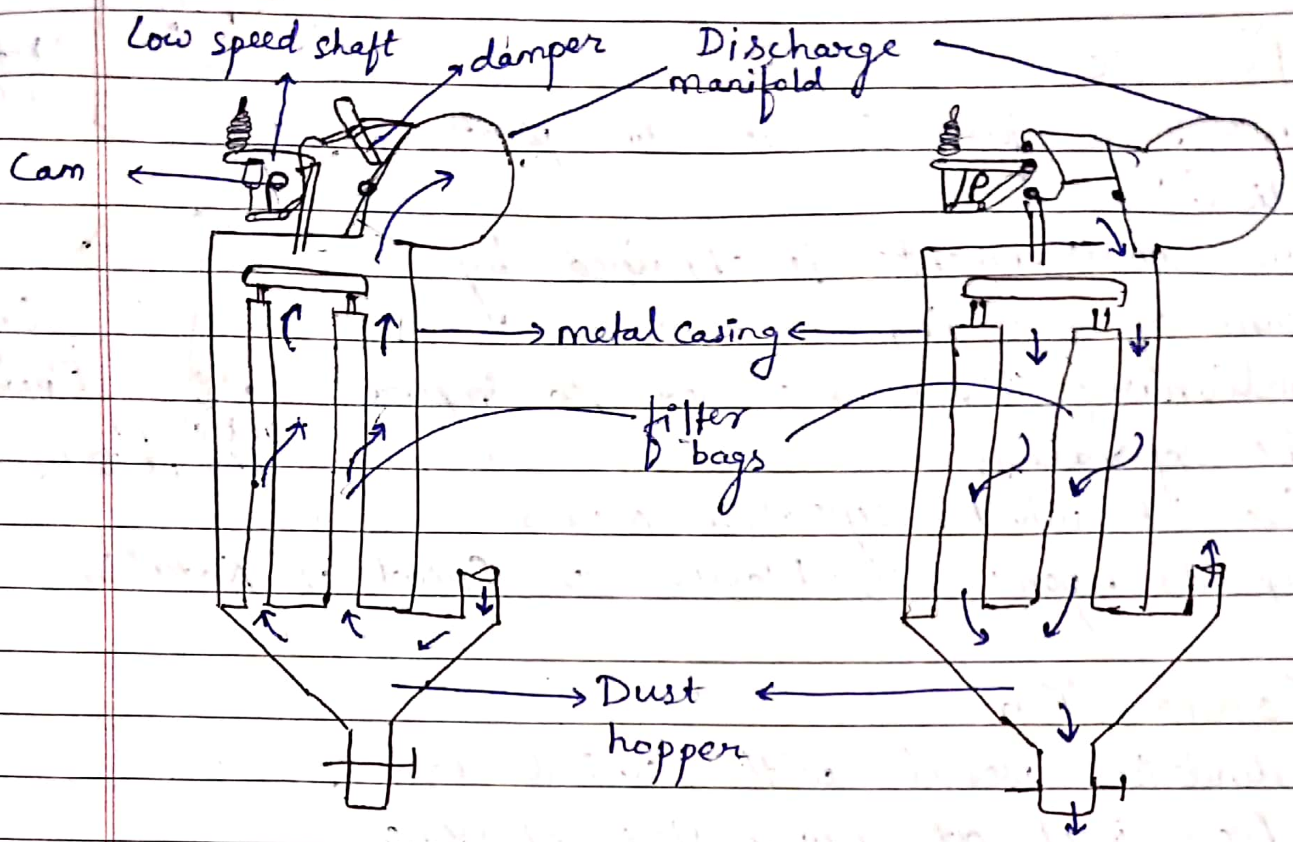
- Cylindrical vessel with conical base.
- Feed inlet at upper side of venel
- Rotating & rotating blades attached to central shaft to produce air environment.
- At base, two outlets, one for fine particle & another for heavy.

## Working

- Discs & blades rotated with help of motor.
- These produce air current (as shown by arrows)
- Sample powder introduced through feed inlet.
- feed falls on rotating disk
- Fine particles are picked up & carried into spaces where air velocity sufficently reduced.
- fine particles are dropped & ultimately collected at the outlet meant for fine particles.
- Heavy particle fall forward & removed by outlet

**Uses** → These are attached to ball mills or handmill to seprate & return over-sized particles for further size reduction

# Bag filter




## Principle

- In this size sepration of fines (dust) from milled powder achieved in two steps.

- In 1st step milled powder is passed through a bag filter (cloth) by applying suction on opp. side of feed entry. It facilitates sepration.

- In next step; pressure is applied inorder to shake bags so that powder adhering bag falls off which is collected from conical base.

## Construction

- It has no. of bags (cotton, wool, fabric)
- Bags are suspended in a sheet metal container.
- Hopper arranged at bottom of filter to receive feed.
- At top there is a provision for exhaust.

- Adjacent to exhaust, Bell crank lever arrangement is built to bring filter to normal atmospheric conditions.

## Working – Occurs in 2 steps

- Feed is seprated from air by passing through cloth bag.
- Bags are shaken to collect fine particles sticked to walls.
- These 2 steps further controlled by bell crank lever arrangement.

- In bell crank lever arrangement, a shaft & a cam rotate at low speed.
- Simultaneously, the cam can either press the bell crank lever or does not come in contact.
- On it damper changes the position & allows follo. 2 steps:-

## Filtering Period

- Durn this period gas containing dust enters through the hopper.
- Then it is passed inside the bags at the top of apparatus.
- Vaccum fan produces a pressure below atmospheric press. inside the apparatus. As a result, particle get trapped within the bags.

## Shaking Period

- Durn this period, bell-crank lever rotates & changes the position of damper.
- The outside air enters through the top in the metal casing & ∴ the vaccum is broken.
- At same time, it causes voilent shaking or jerking actions to the bags.
- Dust or fine particles displaced from bags.
- Max. portn of dust falls into the hopper which is withdrawn further from conical base.

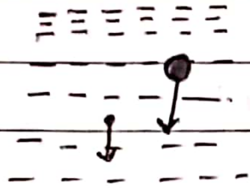
# Elutriation Method

Elutriation is a method of sepration of particles in a powder based on low density of fine particles & high density of coarse particles using fluid flow.

## Diff. b/w Elutriation & Sedimentation

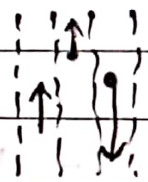
### Sedimentation

- Particles move in direction of gravity.
- fluids stationary & particle settle on basis of their velocity.



### Elutriation

- Some particles move against gravitational force.
- fluid flows in opp. direction of settling movement.
- upward velo > settling velocity of particle.



### Uses

- applicable incase of insoluble solid (kaolin & chalk) which are subjected to wet grinding by sedimentation or elutriation.

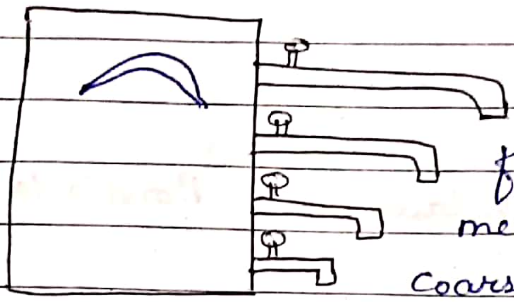
### Advantage

- continous process
- Sepraction of size fraction is quick.

### Disadv.

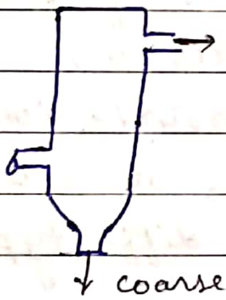
- Suspension should be diluted, which may not be desirable is certain cases.

## Static Tank Method.




- Powder /paste made by levigation, kept in this tank.
- Powder + water = mixed well, solid particle distributed uniformly in liquid during stirring.
- Particles allowed to settles on basis of density.
- Particles collected on basis of density.
- Powders are dried & thus various size fraction collected.

## Single sepration with mobile liquid




- In this elutriating process, the particles are suspended in a moving fluid, generally water.

- The apparatus consists of vertical column of glass tube with an inlet near the bottom of introducing the suspension.
- An outlet is provided at the top for the overflow of fluid of fine particles. The feed is introduced from the bottom.
- Generally fluid is allowed to flow in upwards direction, while particle moves downwards due to gravitational force.
- If upwards velocity < settling velocity = sedimentation occurs.
- If settling velocity < upwards velocity = particles moves upwards with fluid flow.

# Laws Governing Size Reduction

Theories of Size Red.

Kick's law — Rittinger's law — Bond's law

→ **Kick's Law**

Acc. to this law, energy req. to reduce size of particle is propotional to ratio of initial size of a typical dimension to the final size of that dimension.

$$E = K_K \ln\left[\frac{d_1}{d_2}\right]$$

where,

$K_K$ = Kick's constant

$E$ = Energy required per mass of feed

$d_1$ = avg. initial size of pieces (m)

$d_2$ = avg. size of ground particles (m)

$d_1/d_2$ = size reduction ratio, it is used to evaluate relative performance of diff. type of equipments.

Coarse grinding has $d_1/d_2 = 8:1$

fine grinding has $d_1/d_2 \approx 100:1$

Application – This law gives reasonably good results for coarse grinding where there is a relatively small i/c. in surface area per unit mass.

→ **Rittinger's Law** → applicable for smooth materials

This law states that energy req. for size red. of unit mass is propotional to new surface area produced.

$$E = K_R \left[ \frac{1}{d_2} - \frac{1}{d_1} \right]$$

where, $E$ = Energy required per mass of feed.
$K_R$ = Rittinger's constant
$d_1$ = avg. initial size of pieces (m)
$d_2$ = avg. size of ground particles (m).
$1/d$ = (surface area)

so, eq. becomes,

$$E = K_R (S_n - S_i)$$

$S_n$ = initial specific surface area
$S_i$ = new surface area.

Application - This law gives better results with fine grinding where there is much greater inc. in surface area.

→ Bond's law

It states that energy req. for size red. is prop. to new crack length.

$$\frac{E}{W} = \sqrt{\frac{100}{d_2}} - \sqrt{\frac{100}{d_1}}$$

where,
$E$ = energy req. per mass of feed
$W$ = Bond work index work required to reduce a unit weight
$d_1$ = diameter of seive aperture 80% of mass of feed to pass.
$d_2$ = diameter of seive aperture that allows 80% of mass of ground materials to pass.

# Theories of Size Reduction

- Griffith Theory

If a drug has flaws & microscopic cracks. when pressure is applied these flaws get widened. 1st weaker flaws break then on applying more pressure stronger flaws are broken & finally we get small particles of our drug.

$$T = \sqrt{\frac{YE}{c}}$$

where,

T = Tensile strength
Y = Yong's Modulus
E = Surface Energy
c = Critical Attack Path

- If flows are not present in a particle, force of milling produces new flaws.

Useful work $\propto$ New crack length formed.

Usually surface of particle is irregular. The applied force initially takes on high portion of surface leads to high stress & ↑ of temp. Bonds get weak flaws are created. Thus deformation occurs.

Strain energy needed to extend crack $\propto$ New crack length.

- Tougher particles donot exhibit brittle behaviour. They undergo particle flow that allows the particle step over one another & this deformation required energy.

"The butterfly counts not months but moments, and has time enough."–Rabindranath Tagor

# Objectives of size Sepration

- To formulate uniform dosage form

→ Size red. of solid material never gives particles of sam size. The material obtained must undergo a sepration technique to get a narrow size range.

- To prepare granules of larger size

While undergoing size sepration small particles gets seprated from larger granules & the granules of desired size are obtained.

- To seprate undesirable particles

while sepration occurs impurities get removed from the material we will obtain.

# Applications of Size sepration

- It can be used as a method to determine particle size & size distribution, which are used in the production of tablets & capsules.
- Can be used as a quality control tool for the analysis of raw material. Eg - aspirin
- To test the efficiency of a size reduction equipment process.