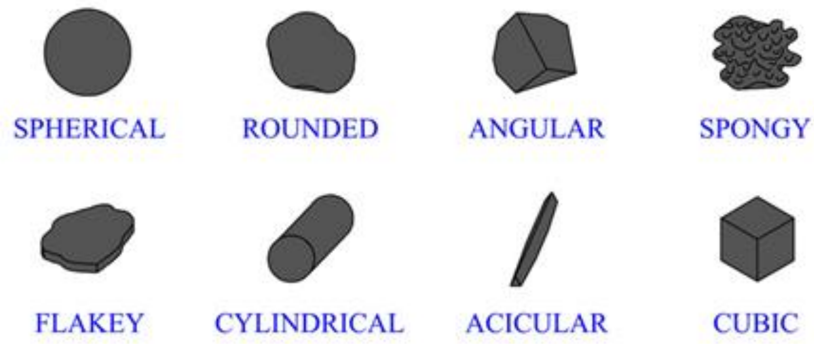
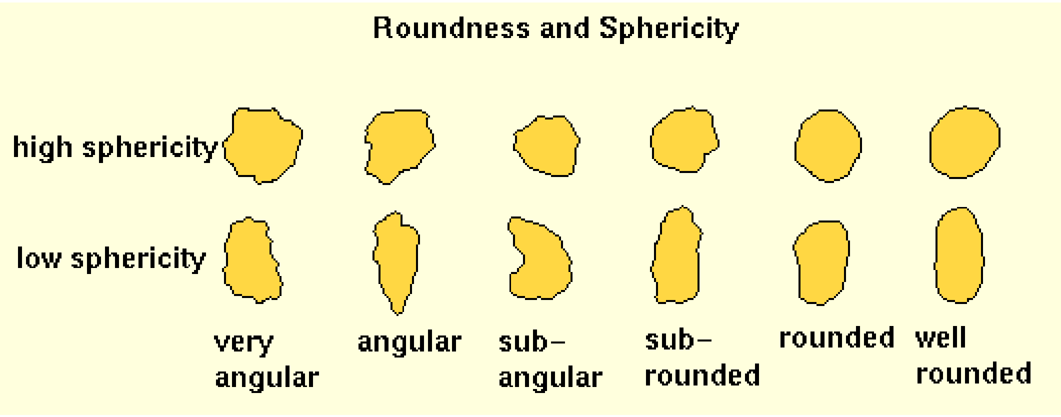
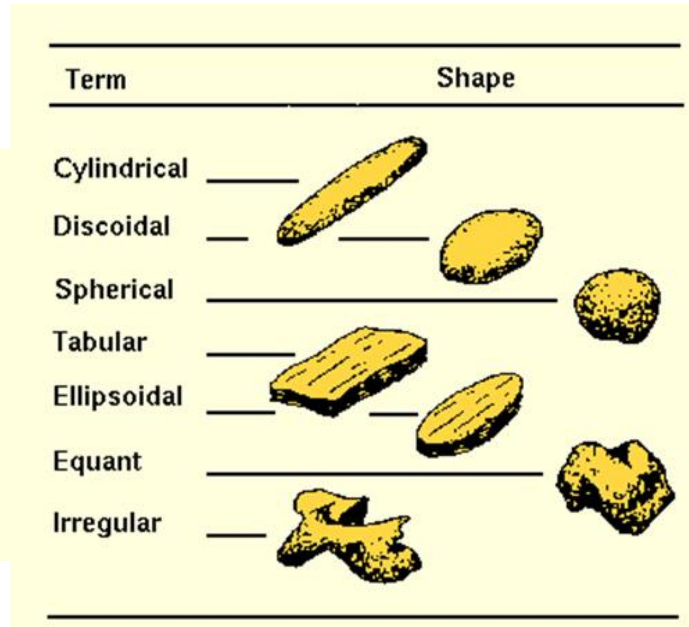
PARTICLE SIZE ANALYSIS

CHARACTERIZATION OF SOLID PARTICLES

- SIZE
- SHAPE
- DENSITY







SPHERICITY, φ_s
Equivalent diameter, Nominal diameter

- $\varphi_s = \dfrac{Surface\ of\ a\ sphere\ of\ same\ volume\ as\ particle}{surface\ area\ of\ the\ particle}$
- Let
- $v_p = volume\ of\ particle, s_p = surface\ area\ of\ tha\ particle,$
- $D_p = \textbf{Equivalent diameter} =$

$Diameter\ of\ sphere\ which\ has\ same\ volume\ as\ particle v_p = \frac{\pi}{6} D_p{}^3$

- Surface area of the sphere of diameter Dp, $S_p = \pi D_p{}^2 = \frac{6 v_p}{D_p}$

$$\varphi_s = \frac{S_p}{s_p} = \frac{6 v_p}{s_p D_p}$$

It is often difficult to calculate volume of particle, to calculate equivalent diameter, Dp is taken as **nominal diameter** based on screen analysis or microscopic analysis

Sphericity of particles having different shapes

Particle	Sphericity
Sphere	1.0
cube	0.81
Cylinder, length = diameter	0.87
hemisphere	0.84
sand	0.9
Crushed particles	0.6 to 0.8
Flakes	0.2

Sphericity, Table 7.1, McCabe Smith

- Sphericity of sphere, cube, short cylinders(L=Dp) = 1

VOLUME SHAPE FACTOR

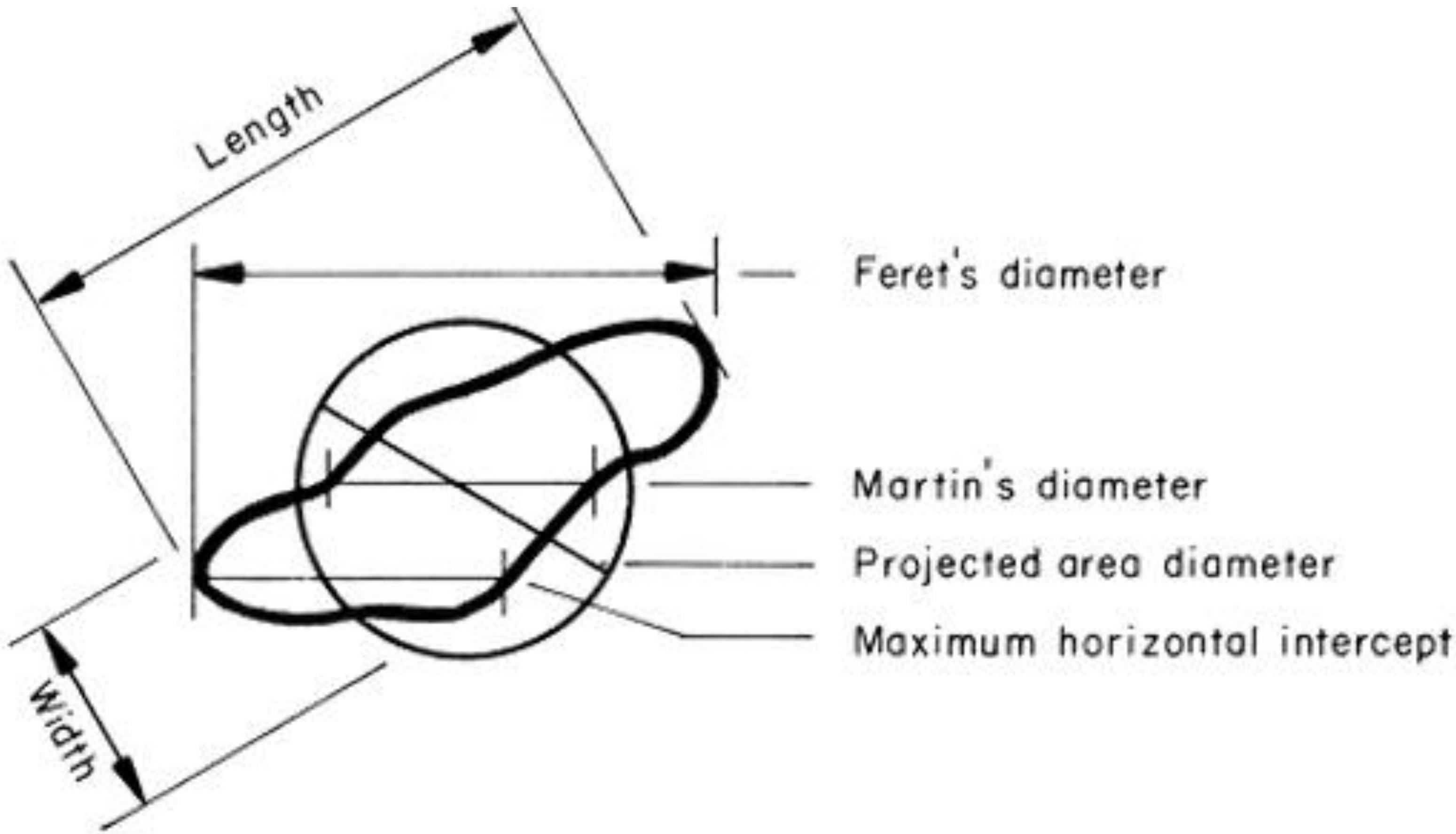
$$v_p \propto D_p{}^3$$

$$v_p = a\, D_p{}^3$$

Where , a = volume shape factor

For sphere, $v_p = \frac{\pi}{6} D_p{}^3$ or $a = \frac{\pi}{6}$

Commonly used measurements of particle size



Particle size/ units

- Equivalent diameter : Diameter of a sphere of equal volume
- Nominal size : Based on;
    - ✓ Screen analysis and
    - ✓ Microscopic analysis
- For Non equidimensional particles Diameter is taken as second longest major dimension.
- Units:

✓ Coarse particles – mm

✓ Fine particles in micrometer, nanometers

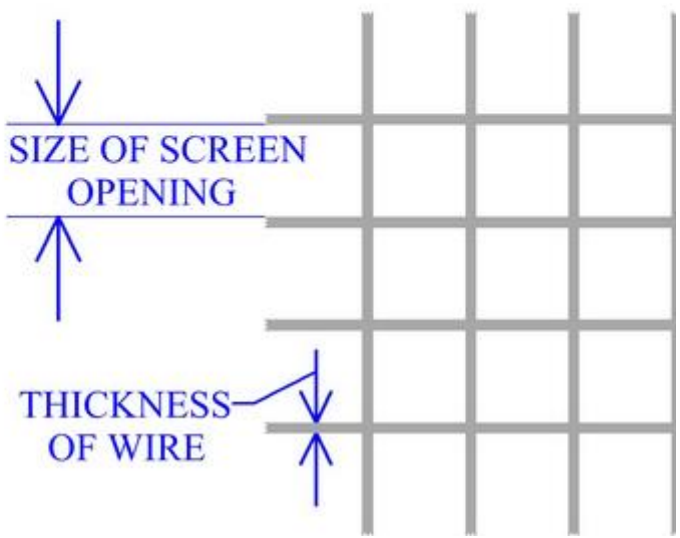
✓ Ultrafine - surface area per unit mass, sq m/gm

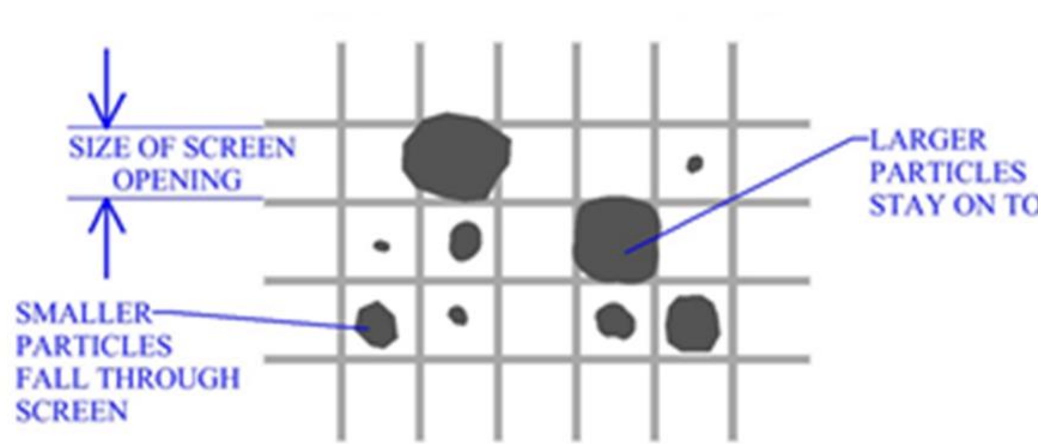
Particle size determination

- Screening $> 50\ \mu m$
- Sedimentation and elutriation - $> 1\ \mu m$
- Permeability method - $> 1\ \mu m$
- Instrumental Particle size analyzers : Electronic particle counter – Coulter Counter, Laser diffraction analysers, Xray or photo sedimentometers, dynamic light scattering techniques

Screening

- Mesh Number = Number of opening per linear inch
- $Clear\ opening = \frac{1}{mesh\ number} - Wire\ thickness$





Standard Screen Sizes

BSS= British Standard Screen

IMM= Institute of Mining & Metallurgy

U.S. Tyler mesh

US. ASTM= American Institute for testing Materials

- Ratio of aperture of two consecutive sieves= 2, $\sqrt{2}$, $\sqrt[4]{2}$ [2, 1.41,1.18]

British fine mesh (B.S.S. 410)[3]			I.M.M.[4]			U.S. Tyler[5]			U.S. A.S.T.M.[5]		
Sieve no.	Nominal aperture		Sieve no.	Nominal aperture		Sieve no.	Nominal aperture		Sieve no.	Nominal aperture	
	in.	μm		in.	μm		in.	μm		in.	μm
						325	0.0017	43	325	0.0017	44
						270	0.0021	53	270	0.0021	53
300	0.0021	53				250	0.0024	61	230	0.0024	61
240	0.0026	66	200	0.0025	63	200	0.0029	74	200	0.0029	74
200	0.0030	76							170	0.0034	88
170	0.0035	89	150	0.0033	84	170	0.0035	89			
150	0.0041	104				150	0.0041	104	140	0.0041	104
120	0.0049	124	120	0.0042	107	115	0.0049	125	120	0.0049	125
100	0.0060	152	100	0.0050	127	100	0.0058	147	100	0.0059	150
			90	0.0055	139	80	0.0069	175	80	0.0070	177

MIXED PARTICLE SIZE ANALYSIS: Differential and Cumulative Screen Analysis

- $Average\ particle\ size, \overline{D_{p_i}}$
- Mass fraction, x_i
- Cumulative mass fraction , ϕ
  - Cumulative mass fraction bigger than a particle size
  - Cumulative mass fraction smaller than a particle size
- Differential screen analysis curve
  - Plot Mass fraction vs Average particle size
- Cumulative screen analysis curve
  - Plot Cumulative mass fraction vs Average particle size

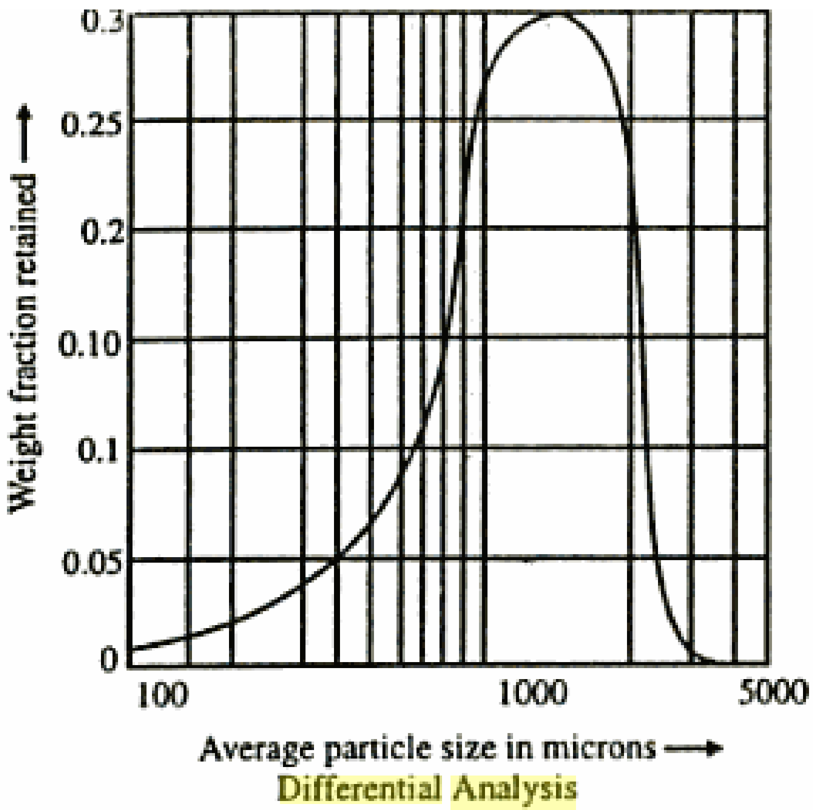


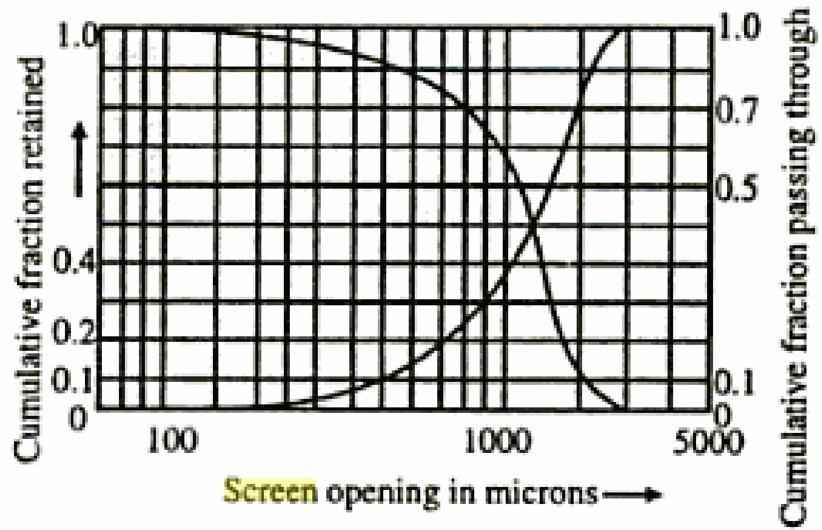
Upper and bottom collecting tray
Test sieves of punching sheets
Test sieves of woven wire mesh


Sl. No.	Mesh No.	Screen Opening D_{pi} (cm)	Mass retained on a screen m_i (gm)	Mass Fraction $x_i = m_i/M$	Average particle diameter $\overline{D_{pi}}$	Φ, Cumulative fraction Larger than $\overline{D_{pi}}$	Cumulative Fraction Smaller than $\overline{D_{pi}}$
1							1.00
2							
3							

Pan						1.00	0.00
			$\sum m_i = M$	$\sum x_i = 1$			

Differential and Cumulative Screen Analysis Curves





MIXED PARTICLE SIZES : Surface area, Specific Surface area, Volume surface mean diameter

- $v_p = volume\ of\ particle,$
- $s_p = surface\ area\ of\ particle,$
- $D_p = Diameter\ of\ particle$
- $\rho_p = density\ of\ material$
- Number of particles in a mass of "m"
- $N = \frac{Total\ volume}{volume\ of\ one\ particle} = \frac{m/\rho_p}{v_p}$
- Total surface area:
- $A = Ns_p = \frac{m}{v_p\ \rho_p}\ \frac{6v_p}{D_p\varphi_s} = \frac{6m}{\varphi_s\rho_p D_p}$ $\left[\varphi_s = \frac{6v_p}{D_p s_p}\right]$

Specific surface area, A_w,area/mass

- $A = Ns_p = \frac{m}{v_p\,\rho_p}\frac{6v_p}{D_p\varphi_s} = \frac{6m}{\varphi_s\rho_p D_p}$ $[\varphi_s = \frac{6v_p}{D_p s_p}]$
- $A_{total} = \frac{6m_1}{\varphi_s\rho_p\overline{D_{p1}}} + \frac{6m_2}{\varphi_s\rho_p\overline{D_{p2}}} + \cdots \ldots. + \frac{6m_n}{\varphi_s\rho_p\overline{D_{pn}}}$
- $A_w = \frac{A_{total}}{M} = \frac{6m_{1/M}}{\varphi_s\rho_p\overline{D_{p1}}} + \frac{6m_2/M}{\varphi_s\rho_p\overline{D_{p2}}} + \cdots \ldots. + \frac{6m_n/M}{\varphi_s\rho_p\overline{D_{pn}}}$
- $A_w = \frac{6x_1}{\varphi_s\rho_p\overline{D_{p1}}} + \frac{6x_2}{\varphi_s\rho_p\overline{D_{p2}}} + \cdots \ldots. + \frac{6x_n}{\varphi_s\rho_p\overline{D_{pn}}}$
- $A_w = \frac{6}{\varphi_s\rho_p}\sum_{i=1}^{n}\frac{x_i}{\overline{D_{pi}}}$

Volume surface mean diameter
[also known as Sauter Diameter]

- $\overline{D_s} = \frac{6}{\varphi_s\rho_p A_w} = \frac{6}{\varphi_s\rho_p\frac{6}{\varphi_s\rho_p}\sum_{i=1}^{n}\frac{x_i}{\overline{D_{pi}}}} = \frac{1}{\sum_{i=1}^{n}\frac{x_i}{\overline{D_{pi}}}}$

AVERAGE PARTICLE SIZE

- Volume surface mean diameter:

$$\overline{D_s} = \frac{6}{\varphi_s \rho_p A_w} = \frac{1}{\sum_{i=1}^{i=n} \frac{x_i}{\overline{D_{pi}}}}$$

- Arithmetic Mean Diameter:

$$\overline{D_N} = \frac{\sum_{i=1}^{n}\left(N_i \overline{D_{pi}}\right)}{\sum_{i=1}^{n} N_i} = \frac{\sum_{i=1}^{n}\left(N_i \overline{D_{pi}}\right)}{N_T}$$

- Mass Mean diameter

$$\overline{D_w} = \sum_{i=1}^{n} x_i \overline{D_{pi}}$$

- **Number of particles:**

$$N_i = \frac{m_i/\rho_p}{a\overline{D_{pi}}^3} \quad and \ N_T = \sum_{i=1}^{n} N_i = \frac{1}{a\rho_p} \sum_{i=1}^{n} \frac{m_i}{\overline{D_{pi}}^3}$$

VOLUME MEAN DIAMETER

- Volume mean diameter: Diameter of a particle with average volume:
- $Average\ particle\ vol = \frac{Total\ volume}{N_T} = a\overline{D_v}^3$

$$N_i = \frac{m_i/\rho_p}{a\overline{D_{pi}}^3} \qquad and\ N_T = \sum_{i=1}^{n} N_i = \frac{1}{a\rho_p}\sum_{i=1}^{n}\frac{m_i}{\overline{D_{pi}}^3}$$

$$a\,\overline{D_v}^3 = \frac{Total\ volume}{Total\ number} = \frac{M/\rho_p}{\frac{1}{a\rho_p}\sum_{i=1}^{n}\frac{m_i}{\overline{D_{pi}}^3}} = \frac{1/\rho_p}{\frac{1}{a\rho_p}\sum_{i=1}^{n}\frac{x_i}{\overline{D_{pi}}^3}}$$

$$D_v = \left[\frac{1}{\sum_{i=1}^{n}\frac{x_i}{\overline{D_{pi}}^3}}\right]^{1/3}$$

Number of particles
Shape Factor a

- $v_p = a{D_p}^3$
- $N_T = \sum_{i=1}^{n} \frac{m_i}{a\rho_p \overline{D_{pi}}^3}$
- Number of particles per unit mass

$$N_w = \frac{N_T}{M} = \frac{1}{M}\sum_{i=1}^{n} \frac{m_i}{a\rho_p \overline{D_{pi}}^3} = \frac{1}{a\rho_p}\sum_{i=1}^{n} \frac{x_i}{\overline{D_{pi}}^3}$$

$$N_w = \frac{1}{a\rho_p \overline{D_v}^3}$$

Sl. No.	Mesh No.	Screen Opening D_{pi} (cm)	Mass retained on a screen m_i (gm)	Mass Fraction $x_i = m_i/M$	Average particle diameter $\overline{D_{pi}}$	Φ, Cumulative fraction Larger than $\overline{D_{pi}}$	Cumulative Fraction Smaller than, $\overline{D_{pi}}$
	4		0				
	6		25				
	8		125				
	10		325				
	14		250				
	20		160				
	28		50				
	35		20				
	48		10				
	65		8				
	100		6				
	150		4				
	200		3				
	pan		2				

PROPTERTIES OF MASSES OF PARTICLES

- Bulk density or **apparent density**, ρ_b, is defined as the weigh per unit volume of material including voids inherent in the material as tested. It is a measure of the fluffiness of the material.

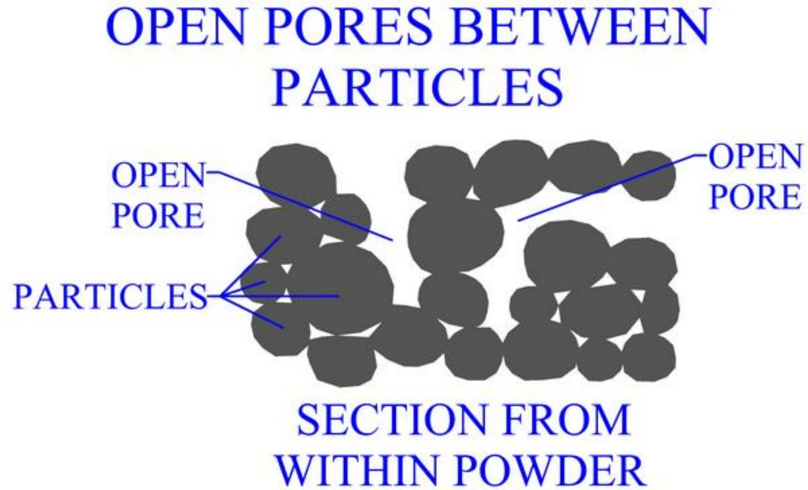
$$\rho_b = \frac{m}{V_T} = \frac{m}{V_p+V_v} \text{ and } \rho_t = \frac{m}{V_p}$$

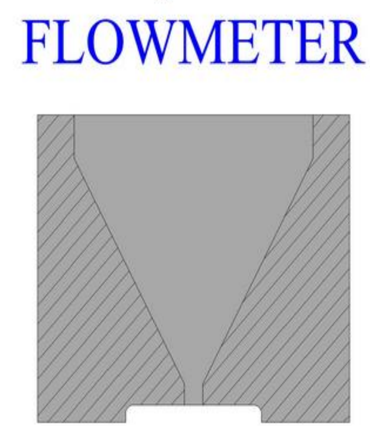
- **Porosity,** It is the ratio of the void volume and bulk volume.

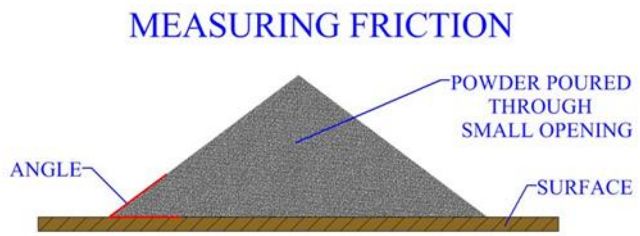
$$\varepsilon = \frac{V_v}{V_T}$$

$$\varepsilon = \frac{V_T - V_p}{V_T} = 1 - \frac{V_p}{m}\frac{m}{V_T} = 1 - \frac{\rho_b}{\rho_t}$$

Pourabilityis defined as a measure of the time required for a standard quality of material to flow through a funnel of specified dimension. It characterizes the handling properties of fine particles







- **Angle of repose,α_τ,** is defined as the angle formed between sloping side of a cone shaped pile of material and the horizontal if the mass is truly homogeneous, α_τ would be equal to α_m, the **angle of internal friction.** In practice, the angle of repose is smaller than the angle of internal friction, of those inside the mass and are often drier and sticker.
- **Coefficient of internal friction** is the measure of resistance present when one layer of solids over another layer of same particles. It is defined as:

Coeff. Of internal friction =**tan** α_m

- For free flowing material α_m is between 15^0 to 30^0

- In solid masses the pressure is not the same in all directions. If pressure is applied in one direction it creates some pressure in other directions, but it is always smaller than the applied pressure. It is minimum I the direction at right angles to the applied pressure. The ratio of the normal pressure to the applied pressure in a mass of solid, is a material constant, generally denoted by K'

$$K' = \frac{normal\ pressure}{applied\ pressure} = \frac{1 - sin\alpha_m}{1 + sin\alpha_m}$$

K' approaches zero for cohesive solids and free flowing material its value is between 0.36 to 0.6

- **Coefficient of external friction** is the measure of the resistance at an interface between particles and the wall of different material of construction.

Coefficient of External friction = tan β_S

  - Where β_S is the **angle of external friction of solid and material.**

SOLIDS CONVEYING

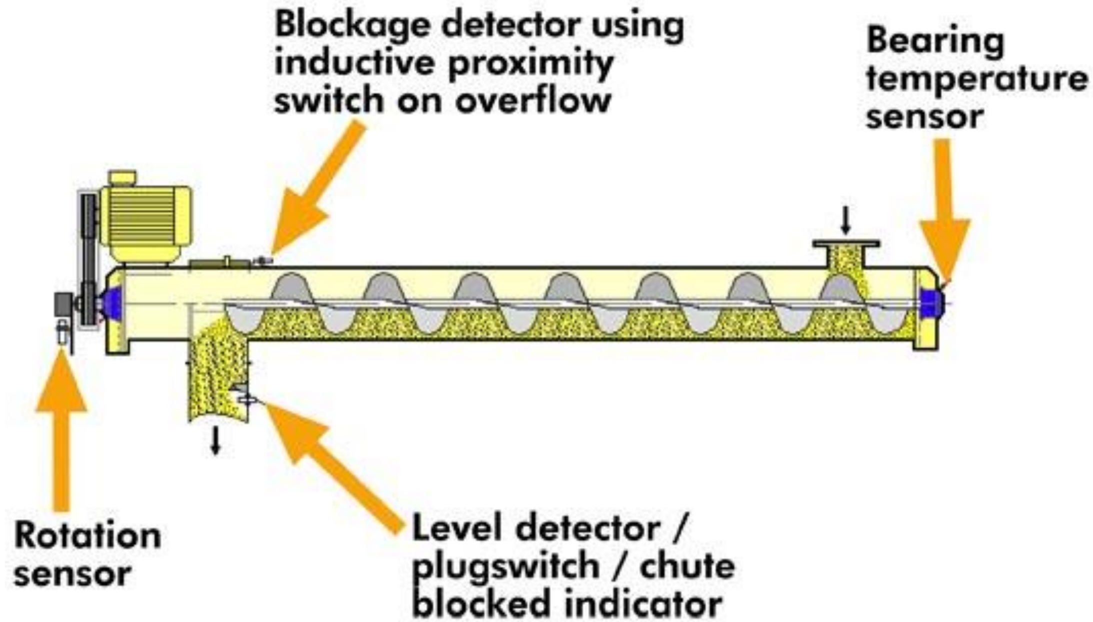
- Screw conveyors
- Belt conveyors
- Bucket elevators
    - Spaced-Bucket Centrifugal-Discharge Elevators
    - Spaced-Bucket Positive-Discharge Elevators
    - Continuous-Bucket Elevators
    - Super-capacity Continuous-Bucket Elevators
    - V-Bucket Elevator-Conveyors
    - Skip Hoists
- Vibrating or oscillating conveyors
- Continuous flow conveyors
    - Apron Conveyors
- Pneumatic conveyors
- Hydraulic Conveyors

SELECTION OF CONVEYORS

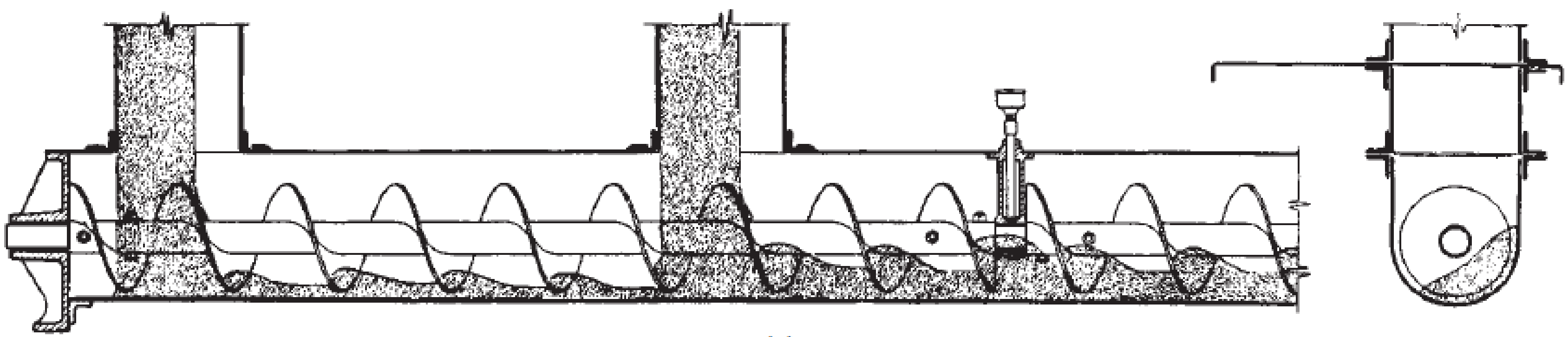
- Capacity requirement : Belt for larger capacity and screw cannot handle large capacity
- Length of travel : belt conveyors ; miles, Pneumatic convey 300m, vibrating conveyor even less
- Lift or lift and horizontal shift : single or mixed
- Material characteristics – chemical and physical, size, friability, flowability abrasiveness, moisture or oxidation effect
- Processing requirement; dewatering, heating cooling

Screw conveyor

- Helicoid (helix rolled from flat steel bar) or sectional flight mounted on a pipe or shaft rotating in a U shaped trough
  - Horizontal of slight incline upto 20ofinely divided solids, sticky material, semisolid materials, boiler ash. Etc.
  - Continuous spiral for dry granular free flowing material
  - Discontinuous spirals for wet, muddy and thick materials.
  - Short distance upto about 40m
  - Types of flow :
    - Archemedian flow or
    - Plug flow
  - Unit operation – mixing, heating & cooling with hollow shaft

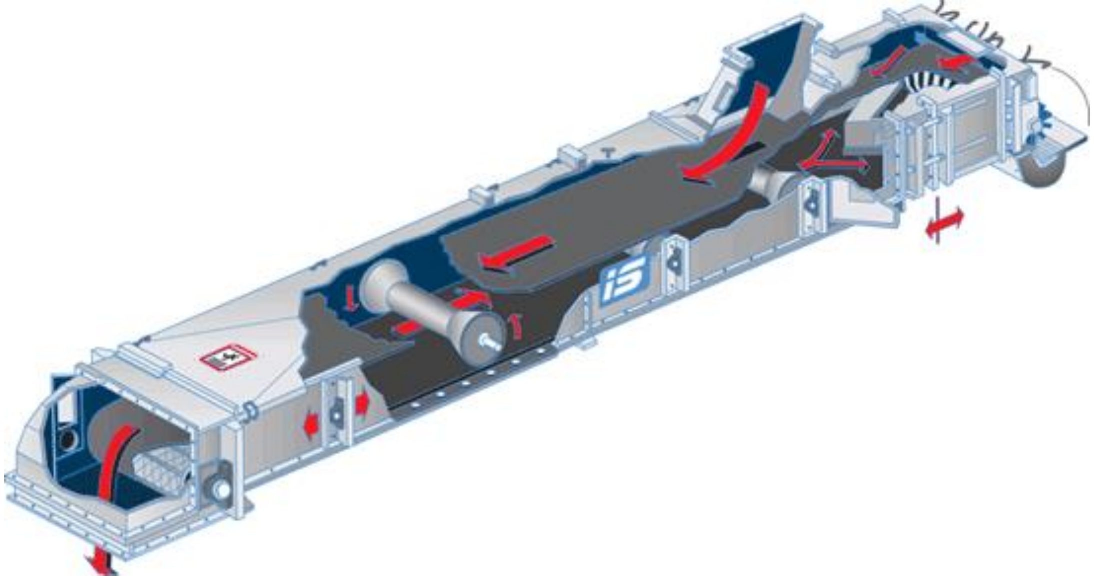


Blockage detector using inductive proximity switch on overflow
Bearing temperature sensor
Rotation sensor
Level detector / plugswitch / chute blocked indicator

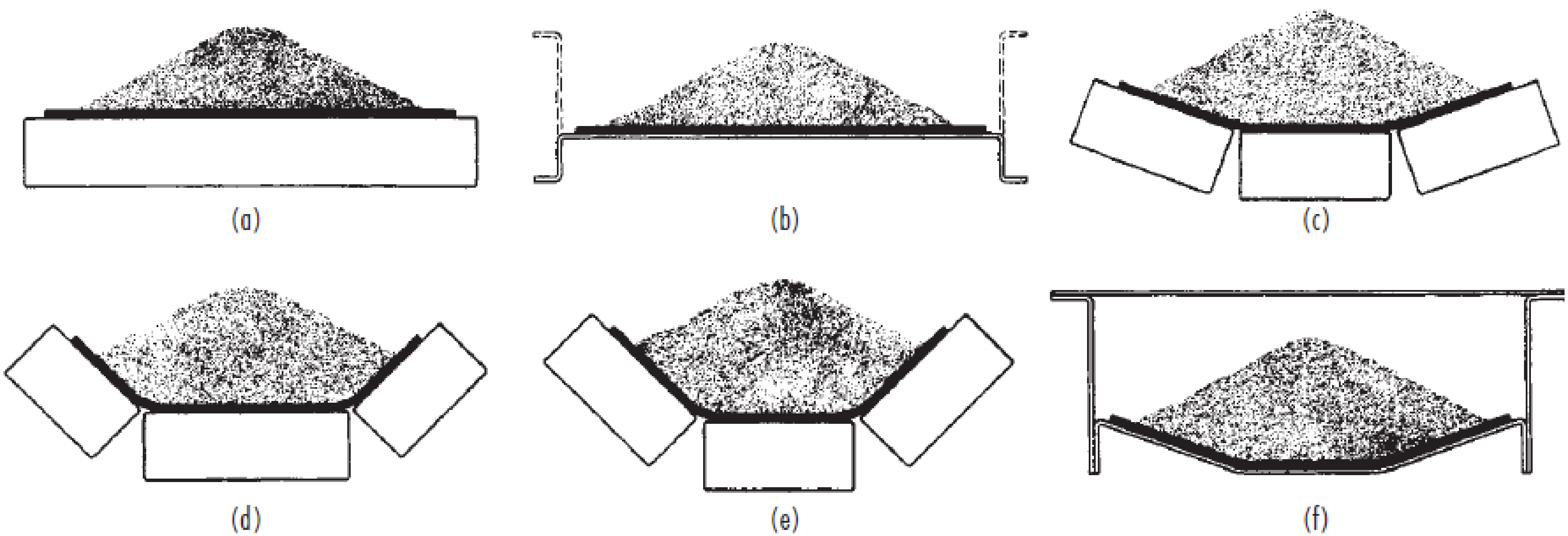


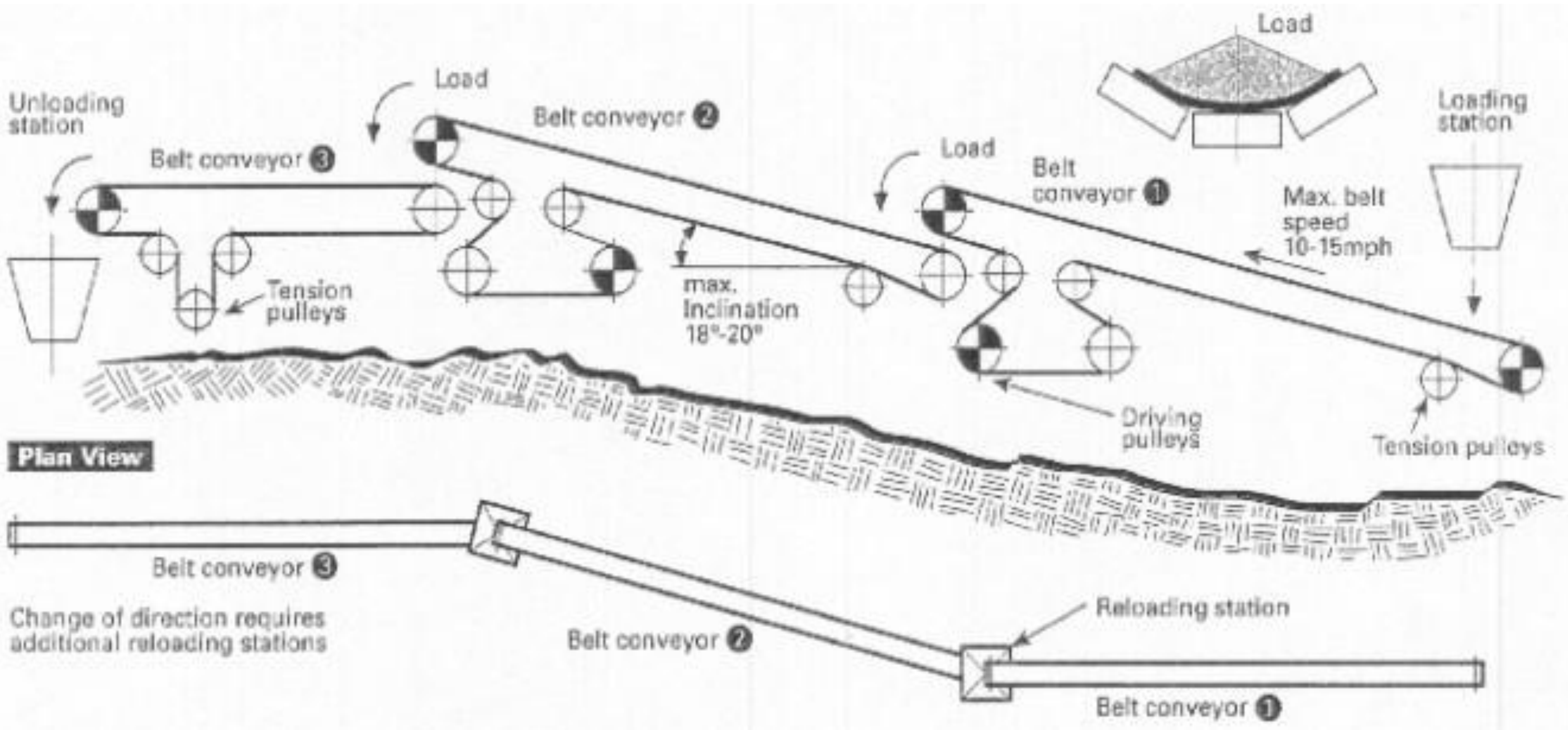
BELT CONVEYORS

- Continuous **belt** passing around two large pulleys at two ends, **one drive pulley** other **tail** pulley.
  - Universal application
  - Very long distances several km
  - Speed up to 300m/min 5000tons/hr
  - Slope upto 30o
  - Material – neoprene, Teflon, natural rubber, vinyls, cotton, asbestos fibre, etc.
  - Various designs of idlers
  - May require cleaning by revolving brush, metal or rubber scraper, taut wire

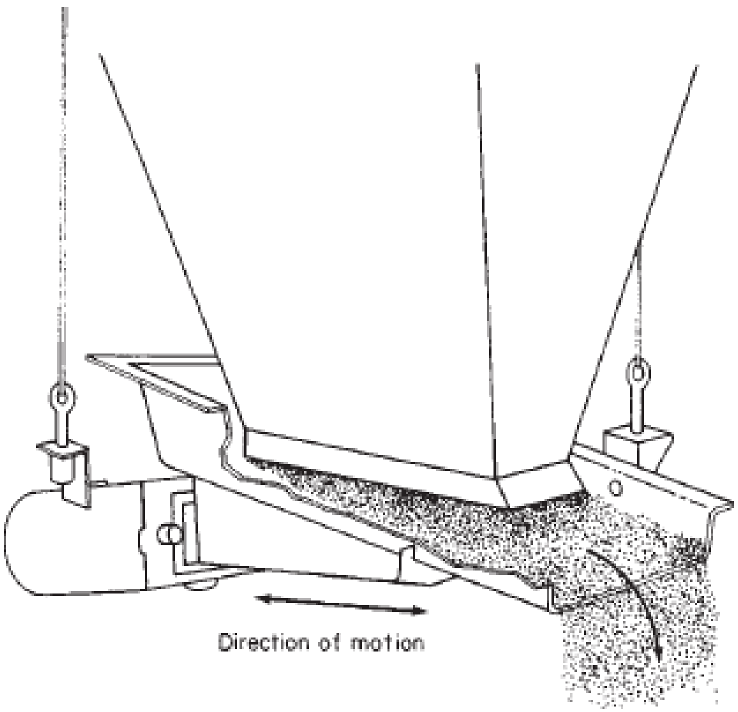


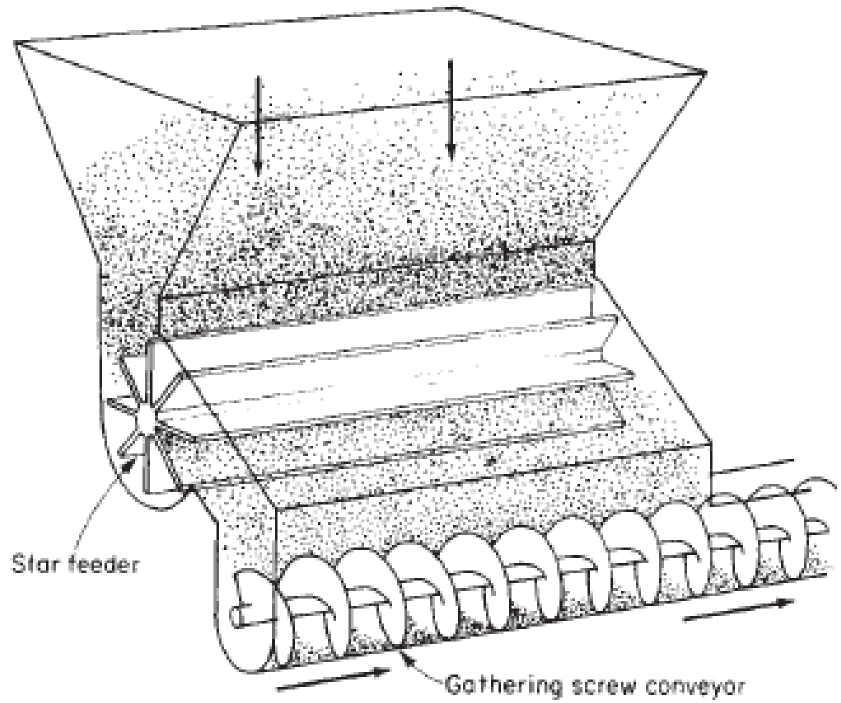
Idlers and Plate support arrangements:
(a) Flat belt on idler (b) flat belt on continuous plate (c)troughed belt on 20 deg idler (d) troughed belt on 45 deg idler (e) Same as d but with rolls of equal lengths (f) troughed plate on continuous plate



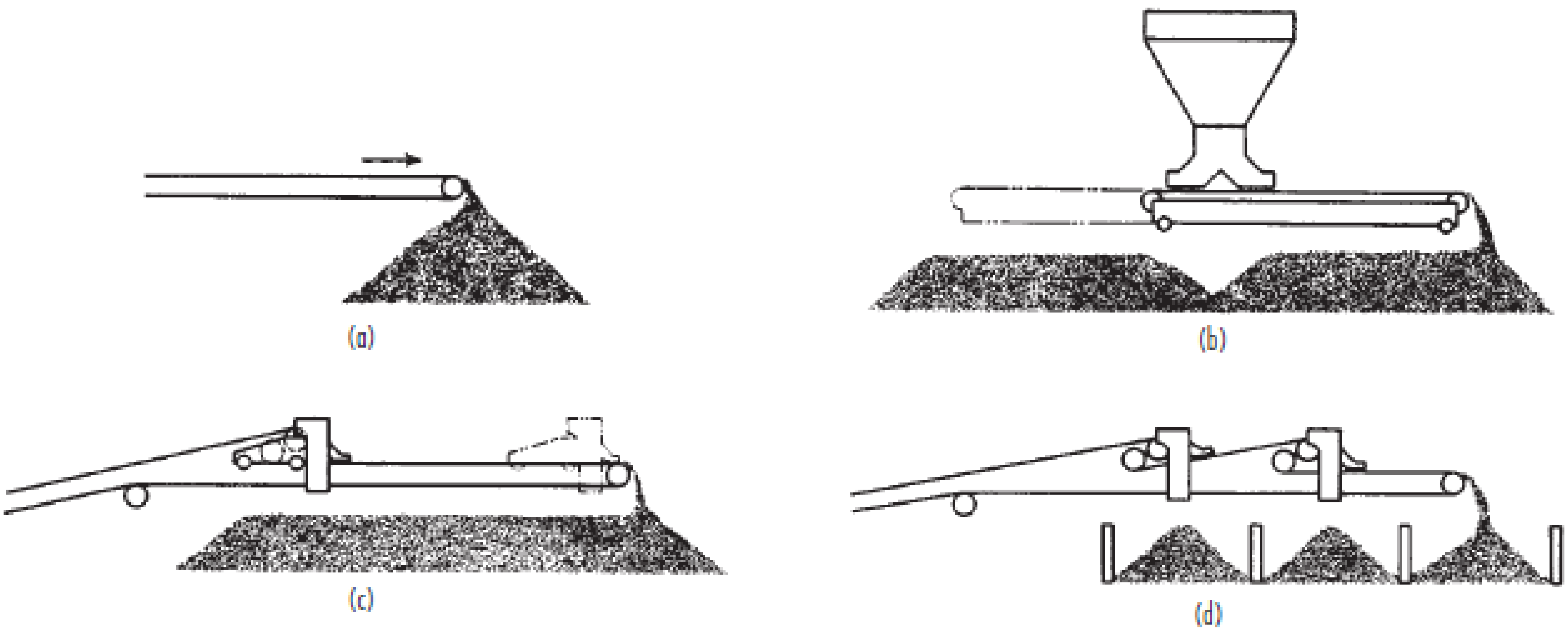

Load
Unloading station
Load
Belt conveyor 2
Belt conveyor 3
Load
Belt conveyor 1
Loading station
Max. belt speed 10-15mph
Tension pulleys
max. Inclination 18°-20°
Driving pulleys
Tension pulleys
Plan View
Belt conveyor 3
Change of direction requires additional reloading stations
Reloading station
Belt conveyor 2
Belt conveyor 1

Feeders to Belt conveyors- Vibratory and Star Feeder





BELT CONVEYOR DISCHARGE ARRANGEMENTS: (a) over end pulley (b) over end pulley by reversible shuttle conveyor (c) through travelling tripper(d) through fixed trippers



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FOOD PROCESSING BELT FABRICATION : CUSTOM BAKERY BELTING & BELT CONVEYORS

With a perfect belt for every application, discover what Great Lakes Belting can do for your bakery!

LIGHTWEIGHT BELTING

Automation of the manufacturing processes has led to small pulleys and process conditions that lend themselves to the flexibility and versatility of lightweight belting. The thermoplastic, heat welded splices provide superior reliability, flexibility and sanitary properties.

Other key belt properties for this market segment are low stretch/shrink, cut and abrasion resistance, oil/fat resistance, good product release/grip properties, easily cleanable/hygienic constructions, lateral flexibility/stability and conformance with FDA/3A/USDA standards.

Click Here to Learn More about the Basics of Lightweight Belting

MODULAR BELTING

Many food manufacturers embrace the use of plastic modular belts for their sanitary benefits (e.g., non-porous thermoplastics, contoured easy to clean surfaces, partially exposed hinge rods, etc.), low maintenance and ease of repair. Industrial manufacturers also see the value that plastic modular belts add to the bottom line.

These inherent benefits include higher strength, lower weight, lower product-to-belt fiction levels, as well as high resistance to abrasives and corrosives.

Click Here to Learn More about Plastic Modular Belting

RESOURCES

Basic Elements of Equipment Cleaning and Sanitizing in Food Processing and Handling Operations: A useful guide to cleaning and sanitizing procedures.

Volta Belting : Flat Belts for the Food Industry: These smooth base belts have cut and abrasion resistant surfaces, eliminating any crevices where bacteria may harbor. Their non-absorbent nature also makes cleaning simple and environmentally friendly, with a drastic reduction in water usage and cleaning time.

Volta Belting - Conveying Solutions : Simply Safe and Hygienic: Governments and consumers expect unblemished safety processes from farm to fork.

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Bakery, confectionery, snack foods, meat and poultry, dairy, fruits and vegetables, and seafood - Great Lakes Belting can help you design a custom conveyor system that will save you time and money.

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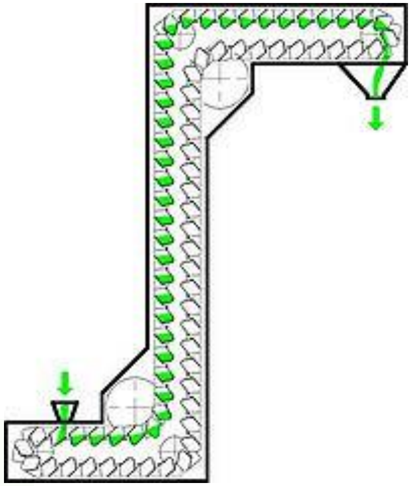
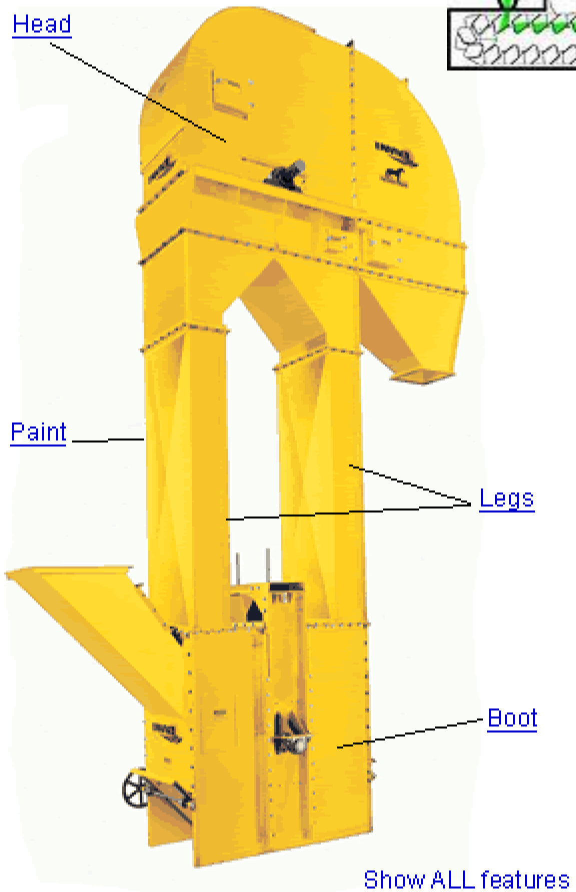
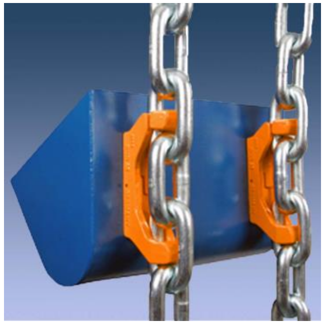
BUCKET ELEVATOR



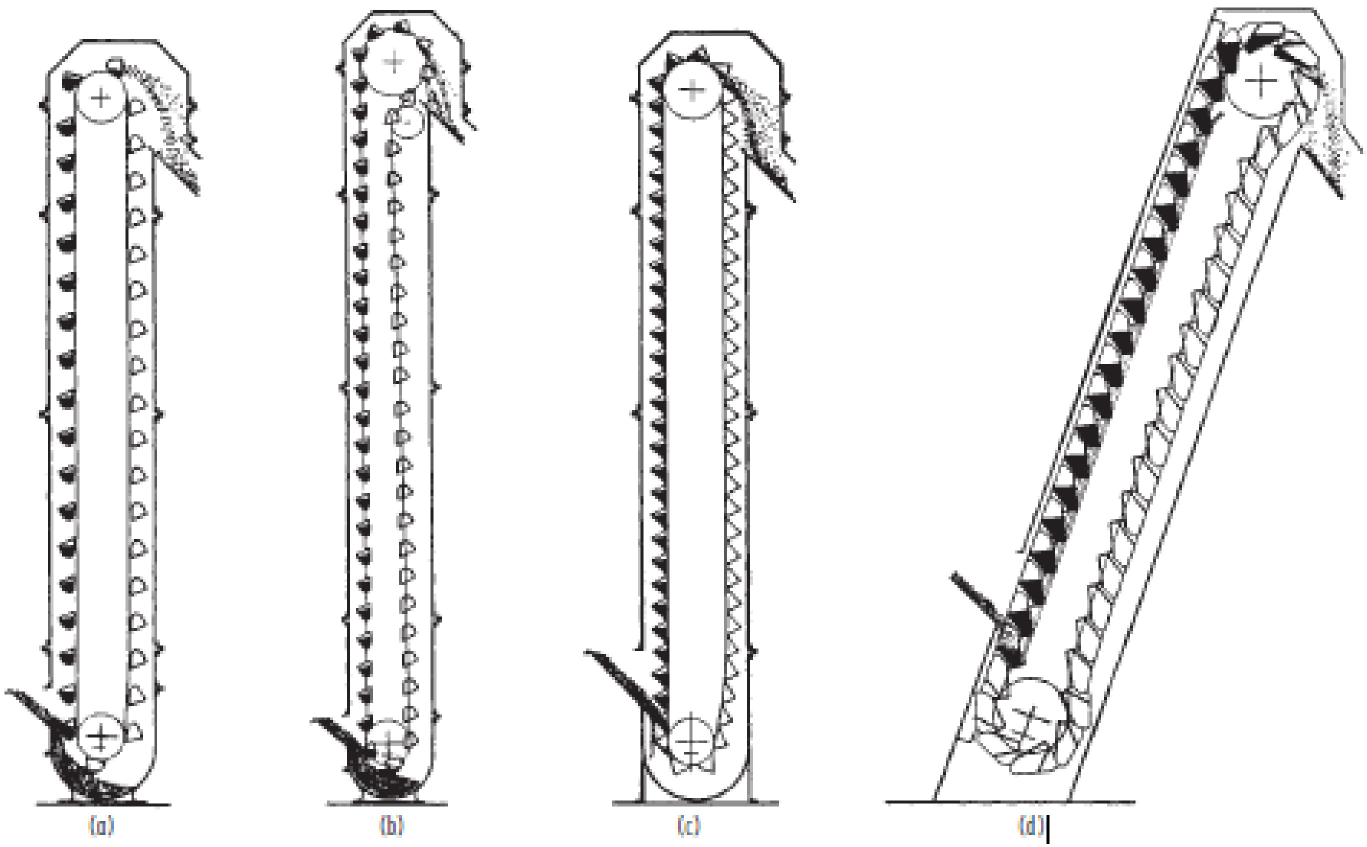




- Bucket elevator consists of a number of buckets attached to a continuous double strand chain which passes over two pulleys
- Solids fed directly to bucket and also scooped up from the bottom.
- Emptied from the top by turning of the bucket.
- Line speed 1-2m/s

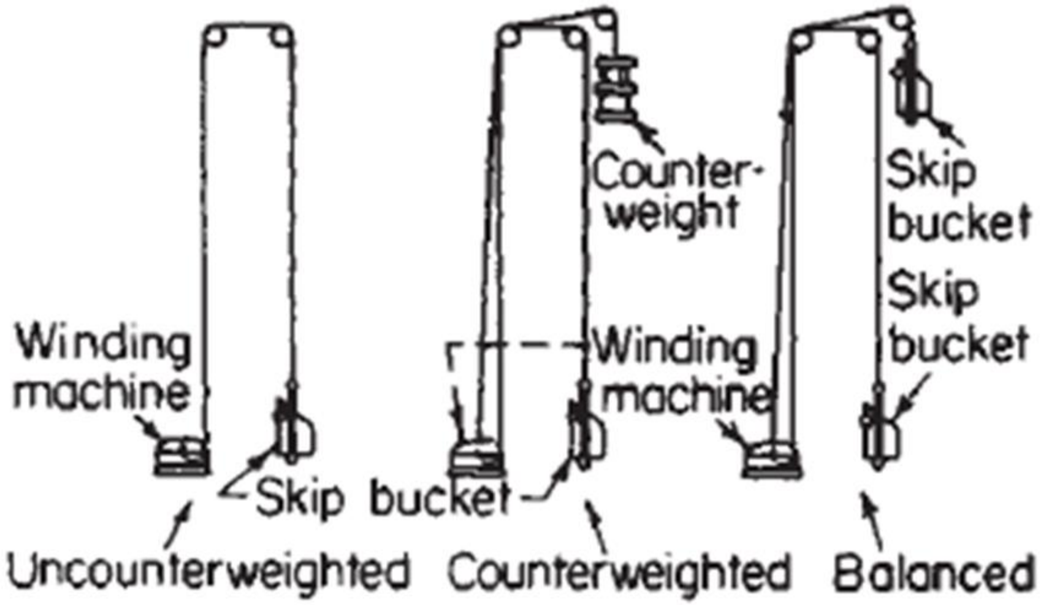
BUCKET ELEVATORS

(a)Spaced-Bucket Centrifugal-Discharge Elevators
(b)Spaced-Bucket Positive-Discharge Elevators
(c)Continuous-Bucket Elevators
(d)Supercapacity Continuous-Bucket Elevators



- Spaced bucket ; Centrifugal discharge – free flowing, fine or small lump material like grain, coal, sand or dry chemicals
- Spaced bucket positive discharge- buckets are for sticky materials which tend to lump, inverted for positive discharge, knockers can also be used
- Continuous – finely pulverized or fluffy materials, the back of the preceding bucket serves as a discharge chute for the bucket. Gentle movement Preventing degradation
- Super capacity continuous bucket: Very high tonnage, big particles, Generally inclined

SKIPHOIST: Batch bucket elevator

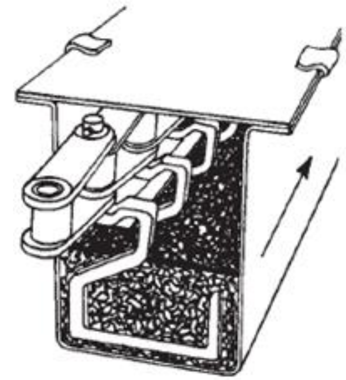


- Uncounter weighted: only winding machine power requirement is high
- Counter weight : reduces power consumption
- Balanced use two buckets and hence works twice as fast

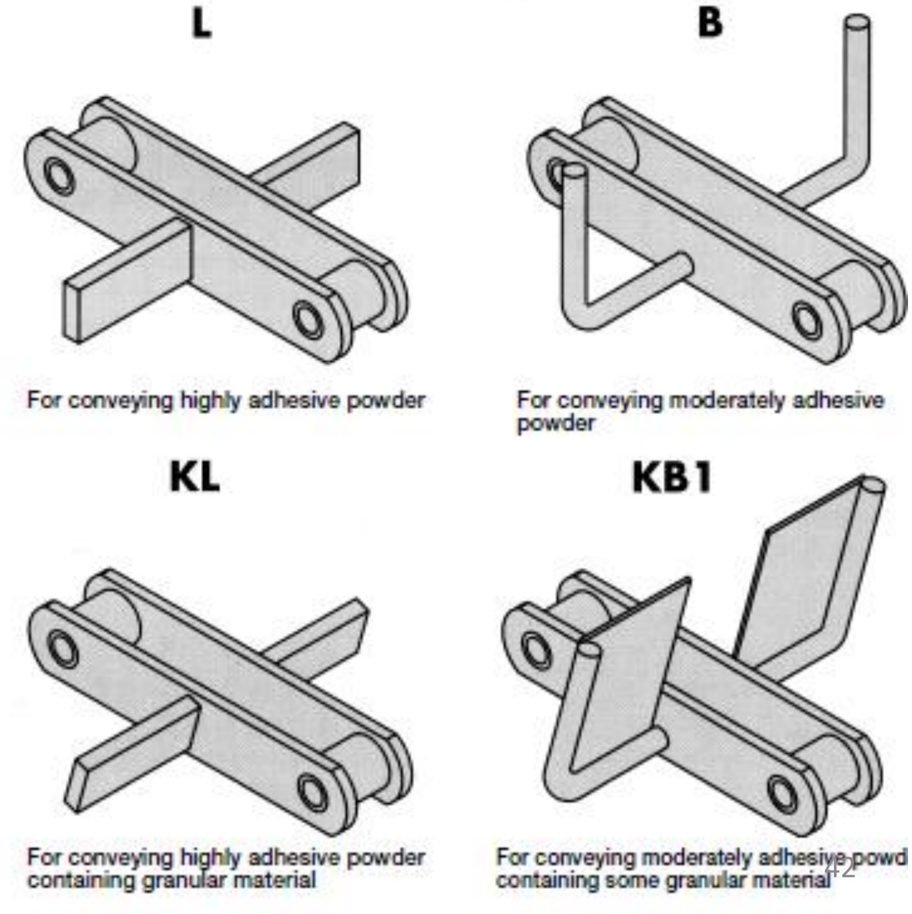
CONTINUOUS FLOW CONVEYOR

- **Principle:** When a surface is pulled transversely through a mass of granular powder or small lump material it will pull a cross section of material along with it which is greater than the area of the surface itself.
- **Generally a chain with blades is operated in a powder to cause the powder to flow in the same direction.**

FLIGHTS FOR CONTINUOUS FLOW CONVEYORS

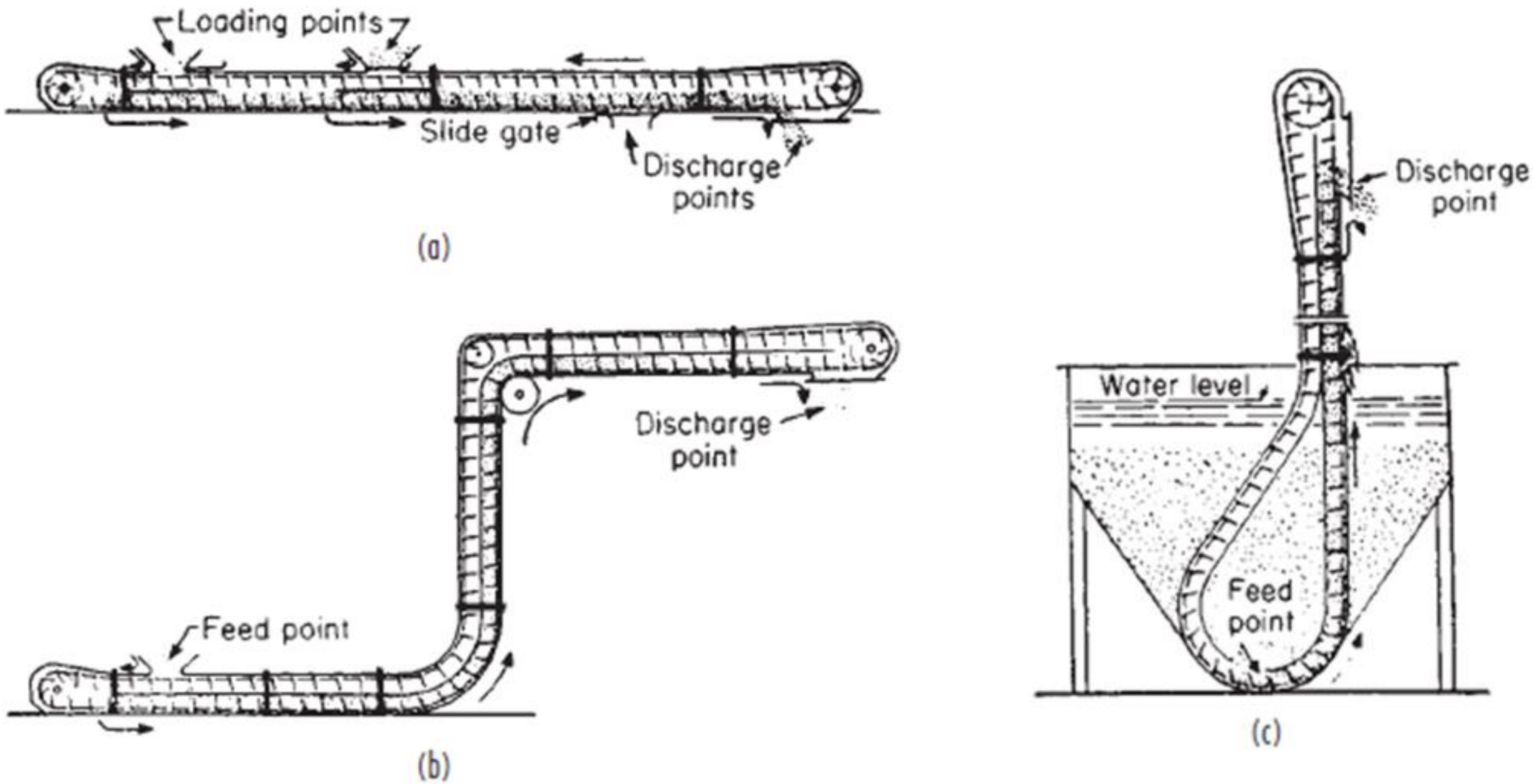


- L- highly adhesive powder
- B-moderate adhesive powder
- KL highly adhesive powder containing granular material
- KB1 – Moderately adhesive powder containing some granular material



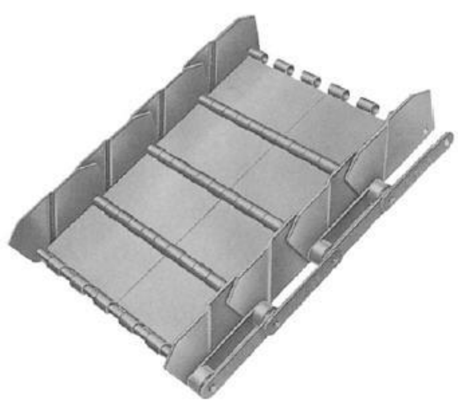
CONTINUOUS FLOW CONVEYORS:

(a) Horizontal (b) Z type (c) Loop feed elevator for dewatering

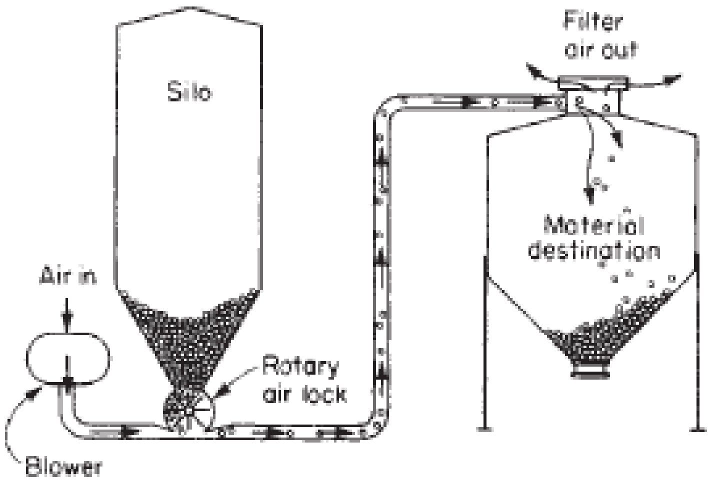


APRON COVEYORS

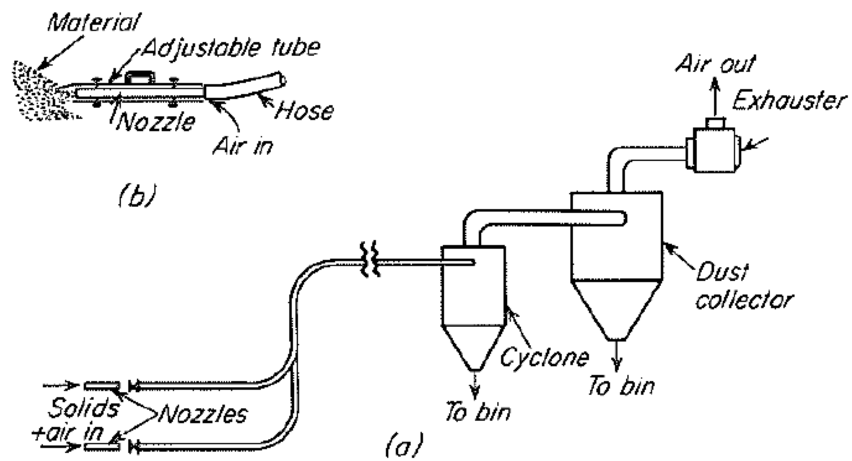
- A type of continuous flow conveyor where series of overlapping pans are mounted between two strands of roller chains

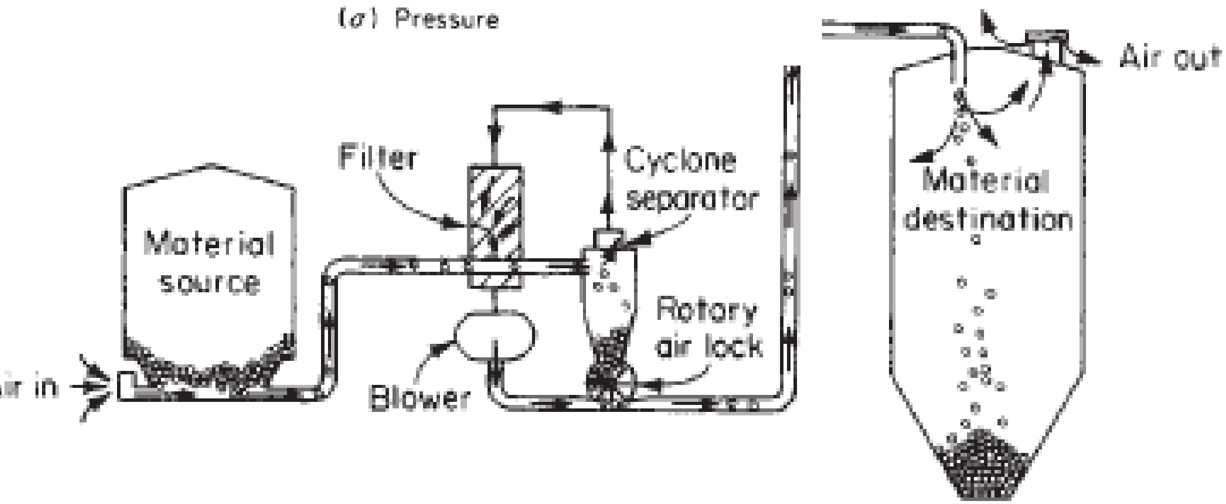


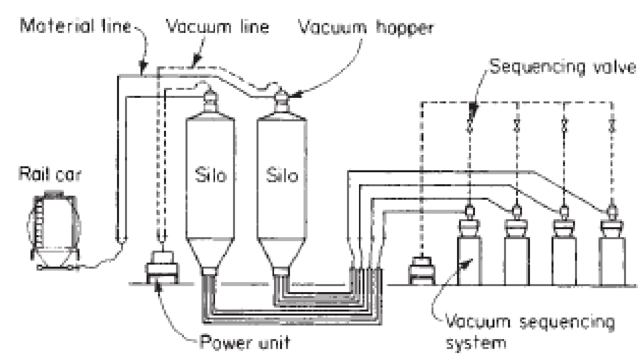
PRESSURE, VACUUM, PRESSURE-VACUUM PNEUMATIC TRANSPORTATION



(a) Pressure



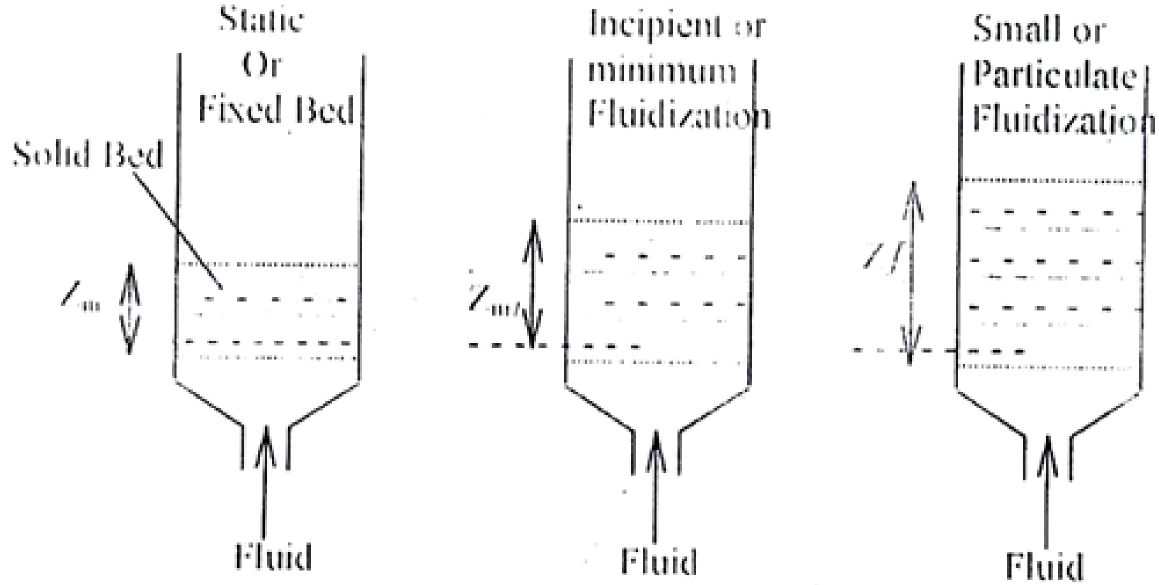


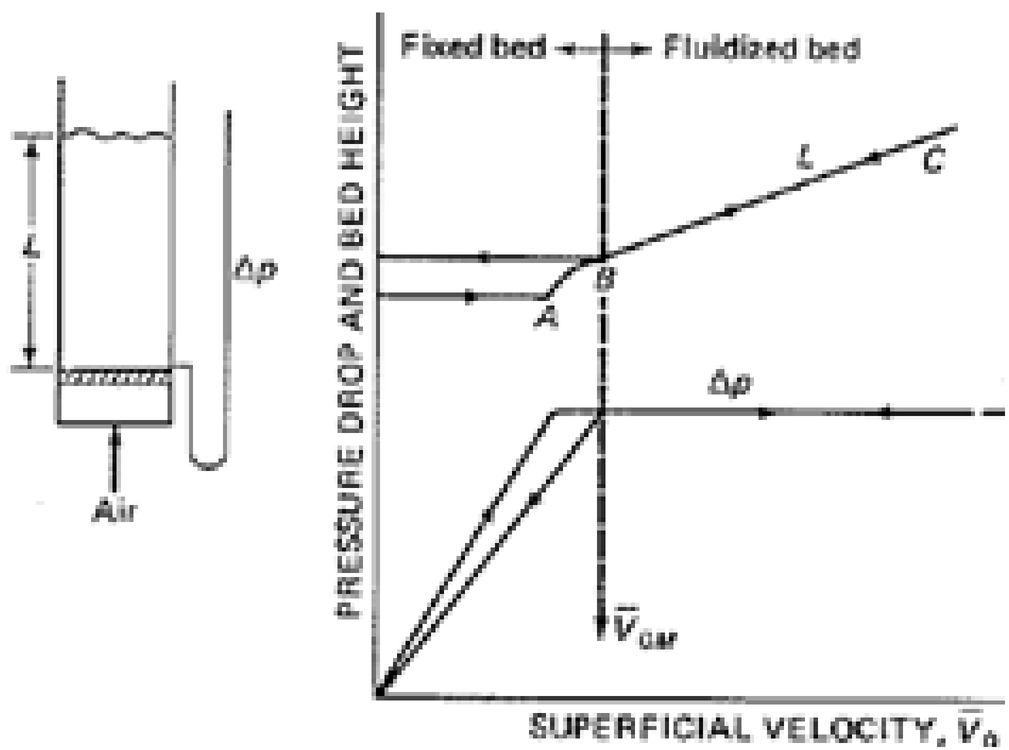


(b) Vacuum

(c) Pressure-vacuum

FLUIDIZATION





- Gas flow between 15 to 30m/s in pipes ranging from 50 to 400 mm diameter.
- Particle size range from fine powder to 6.5mm, Bulk density from 16 to 3200kg/m3
- Pressure System
  - 1-5 atm gauge
  - Free flowing material for any particle size – 5-6 mm
  - Flow rates more than 9000kg/hr
  - Pressure loss in the system 0.5 atm
  - Rotary Air lock valve required
- Vacuum System
  - Lower flow rates 7000kg/hr and 300m
  - Fine powders
  - No Rotary air lock valve required.
- Pressure Vacuum system

HYDRAULIC CONVEYING /SLURRY TRANSPORTATION

- Generally particles less than 50 micron
- Main application in Mining industry
- Fluid used is water
- Velocity more than settling velocity of particles,
- Critical velocity , below which particles will settle out range between 1-5m/s,
- Pressure drop calculated using same equation with allowance for increase in density and viscosity.

STORAGE OF SOLIDS

- BULK STORAGE

Coarse large quantity solids like gravel and coal outside in large piles.

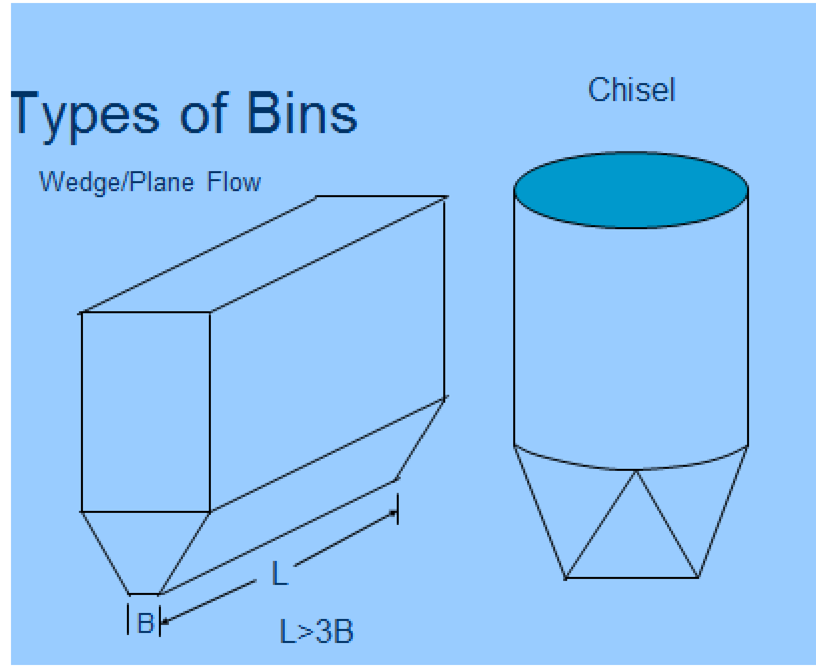
Protection from

- BIN STORAGE -

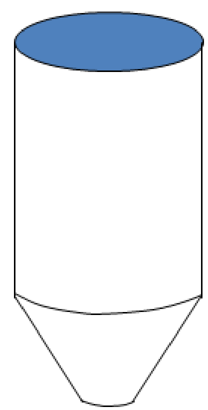
✓ Silos – tall and small diameter

✓ Bins – fairly wide and Not tall

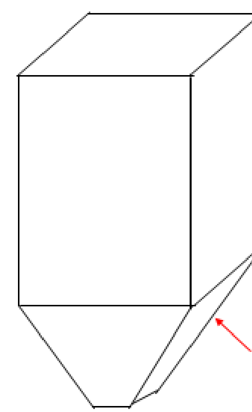
✓ Hoppers – Small vessel with sloping bottom, generally temporary storage before feeding solids to a process.



Conical



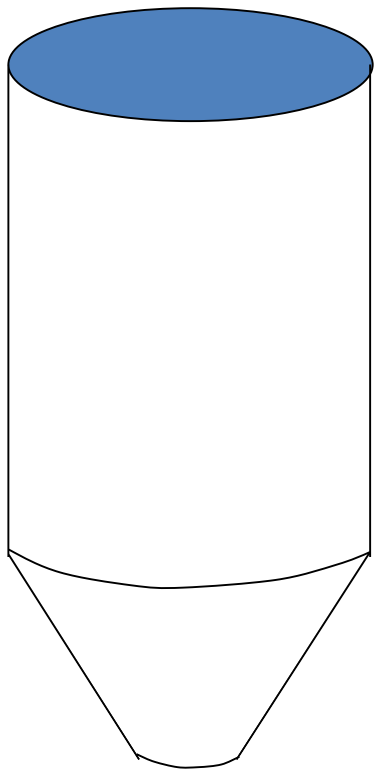
Pyramidal



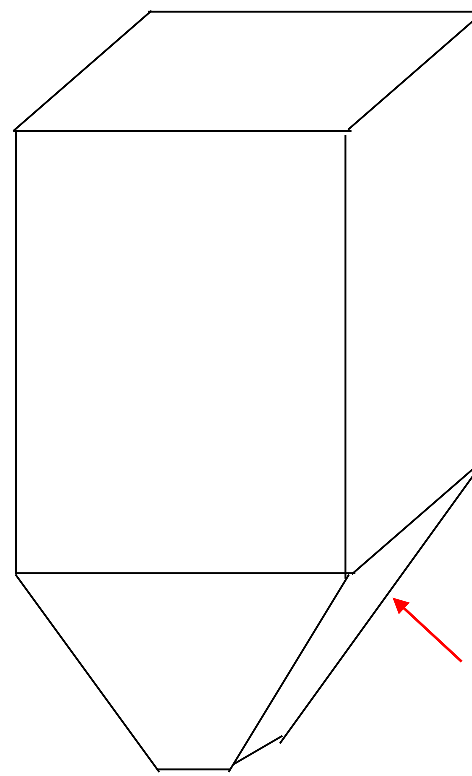
Watch for in-flowing valleys in these bins!

Types of Bins

Conical



Pyramidal



Watch for in-flowing valleys in these bins!

PRESSURE IN BINS AND SILOS

Janssen Equation: Pressure at any height h, from the base

$$P = \frac{\rho_b g D}{4 f_w \; k}\left[1 - exp\,\frac{4 f_w \; K(h - H)}{D}\right]$$

If value of H is sufficiently large which is the case at the base of the base of the cylindrical portion of the hopper:

$$P_O = \frac{\rho_b g D}{4 f_w \; K}$$

ρ_b=Bulk density

H= level of solid bed,

g = acceleration due to gravity

D = Diameter of hopper

f_w = Coefficient of friction between solids and wall

$$K' = \frac{normal\ pressure}{applied\ pressure} = \frac{1 - sin\alpha_m}{1 + sin\alpha_m}$$

α_m= effective angle of internal friction.

Pressure at the base of a vertical bin filled with particulate solids

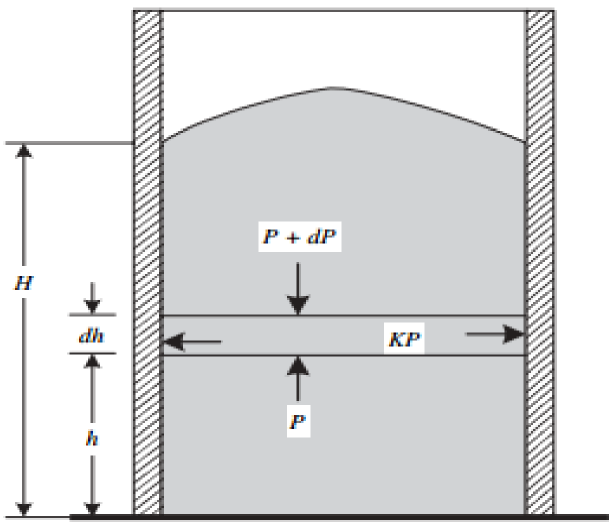
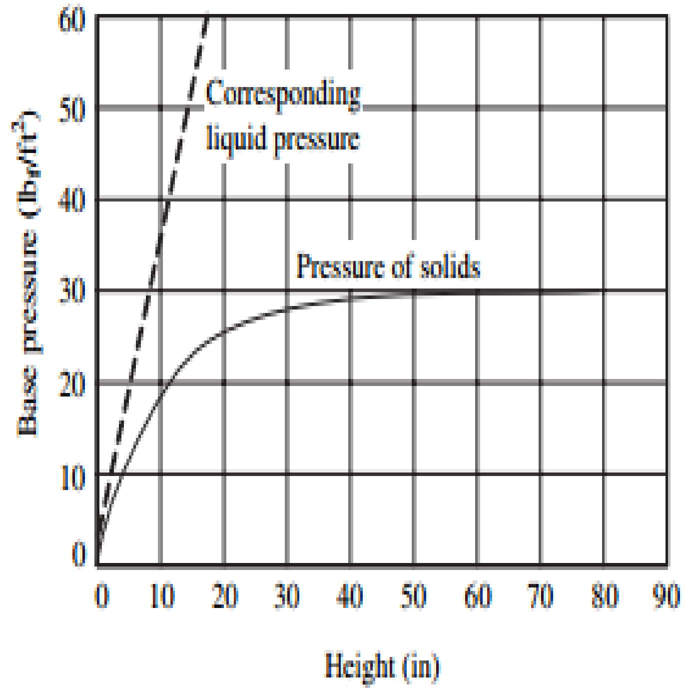


Fig. 4.5 A Vertical bin filled with particulate solids.



$$P = \frac{\rho_b g D}{4 f_w \; k}\left[1 - exp\,\frac{4 f_w \; K(h-H)}{D}\right]$$

FLOW OUT OF BINS

- Mass Flow - all the material in the hopper is in motion, but not necessarily at the same velocity [Cone angle from vertical axis=0-40o]
- Funnel Flow - centrally moving core, dead or non-moving annular region
- Expanded Flow - mass flow cone with funnel flow above it

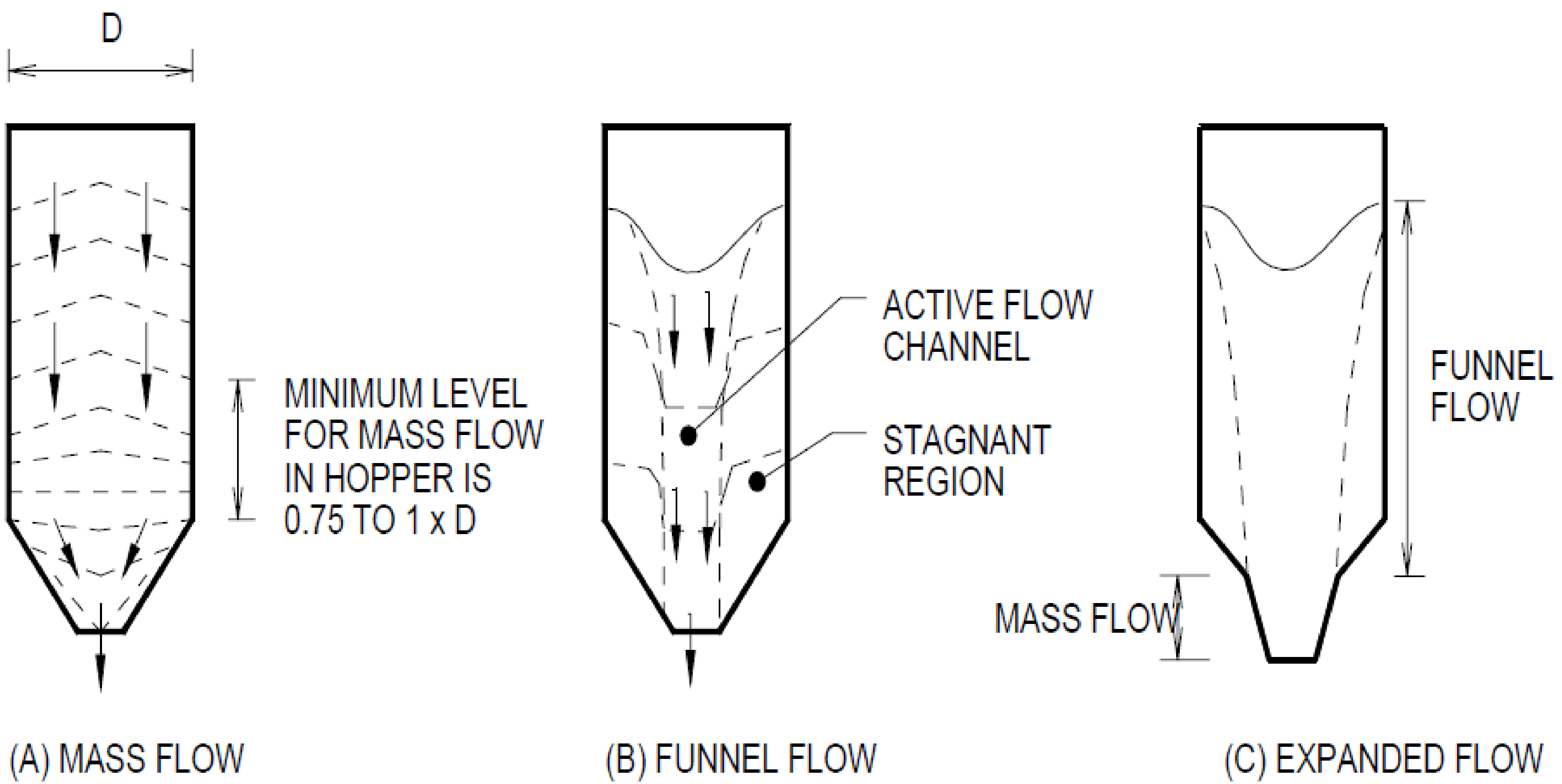
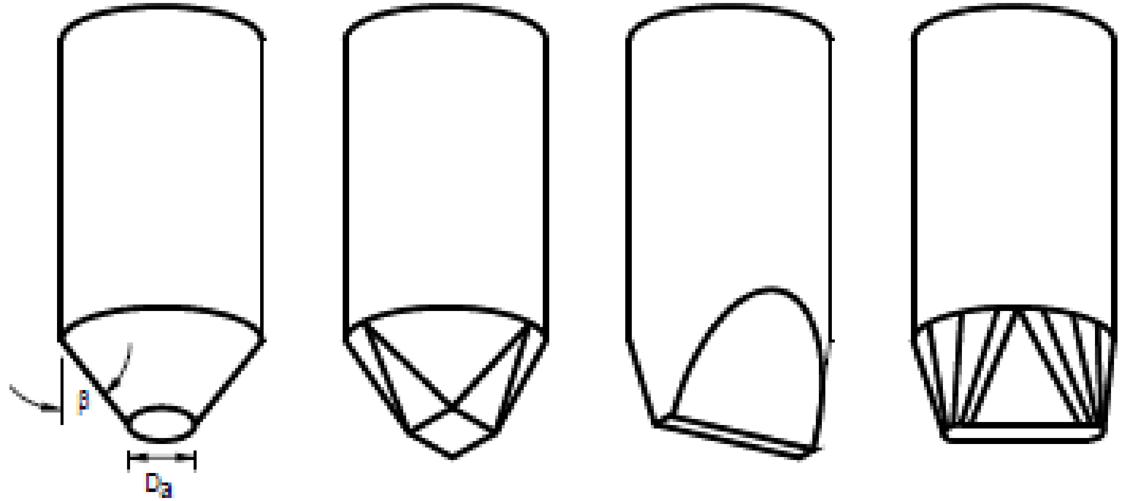
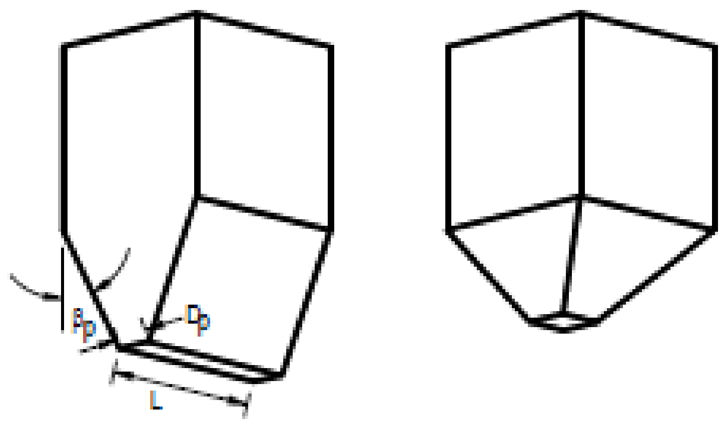


Figure 10-1. In mass flow (A) all material moves in the bin including near the walls. In funnel flow (B) the material moves in a central core with stagnant material near the walls. Expanded flow (C) is a combination of mass flow in the hopper exit and funnel flow in the bin above the hopper (normally used in retrofit situations).

COMMON DESIGNS FOR MASS FLOW HOPPERS

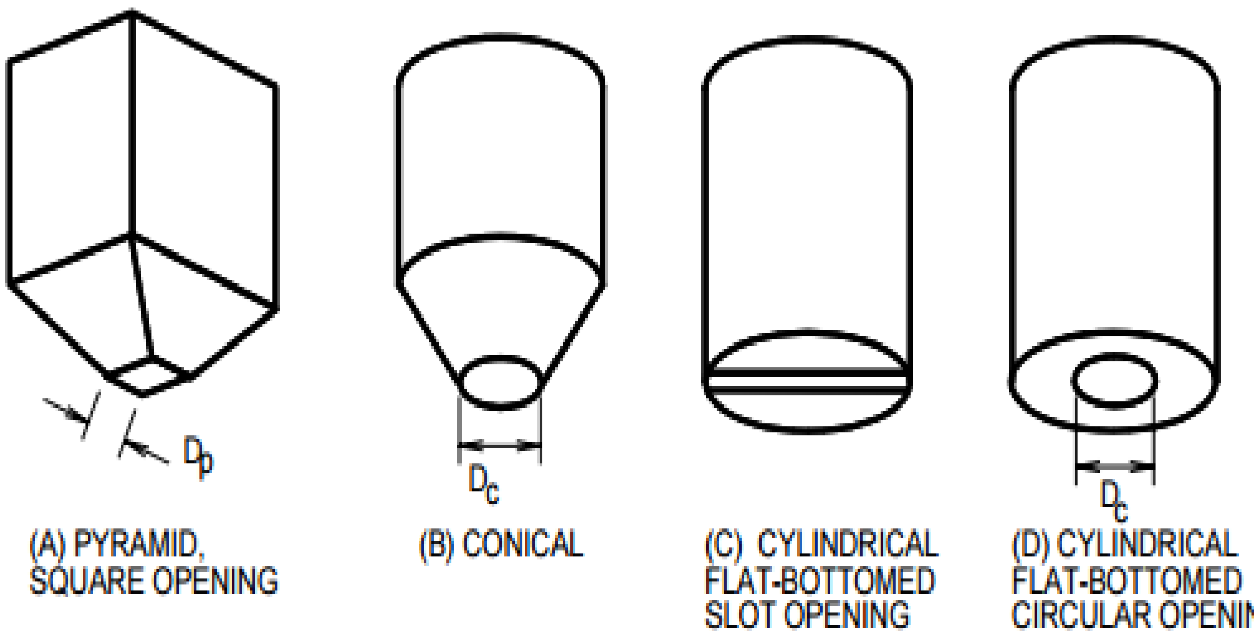


(A) CONICAL HOPPER (B) SQUARE OPENING (C) CHISEL

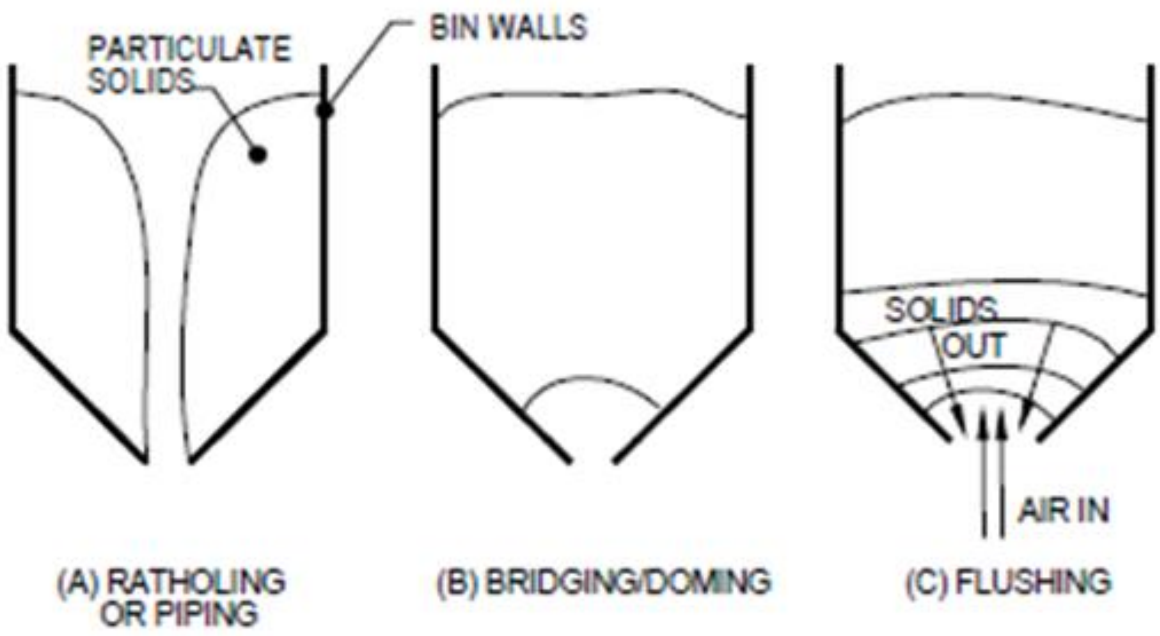


(E) WEDGE (F) PYRAMID

Design for Funnel Flow



HOPPER DESIGN PROBLEMS



HOPPER DESIGN PROBLEMS

- ***RATHOLING/PIPING***. Ratholing or piping occurs when the core of the hopper discharges (as in funnel flow) but the stagnant sides are stable enough to remain in place without flowing, leaving a hole down through the center of the solids stored in the bin
- ***FLOW IS TOO SLOW***. The material does not exit from the hopper fast enough to feed follow on processes.
- ***NO FLOW DUE TO ARCHING OR DOMING***. The material is cohesive enough that the particles form arch bridges or domes that hold overburden material in place and stop the flow completely.
- ***FLUSHING***. Flushing occurs when the material is not cohesive enough to form a stable dome, but strong enough that the material discharge rate slows down while air tries to penetrate into the packed material to loosen up some of the material. The resulting effect is a sluggish flow of solids as the air penetrates in a short distance freeing a layer of material and the process starts over with the air penetrating into the freshly exposed surface of material.

HOPPER DESIGN PROBLEMS

- I***NCOMPLETE EMPTYING***. Dead spaces in the bin can prevent a bin from complete discharge of the material.
- ***SEGREGATION*****.** Different size and density particles tend to segregate due to vibrations and a percolation action of the smaller particles moving through the void space between the larger particles
- ***TIME CONSOLIDATION.*** For many materials, if allowed to sit in a hopper over a long period of time the particles tend to rearrange themselves so that they become more tightly packed together. The consolidated materials are more difficult to flow and tend to bridge or rat hole.
- ***CAKING****.* Caking refers to the physiochemical bonding between particles what occurs due to changes in humidity. Moisture in the air can react with or dissolve some solid materials such as cement and salt. When the air humidity changes the dissolved solids re-solidify and can cause particles to grow together.