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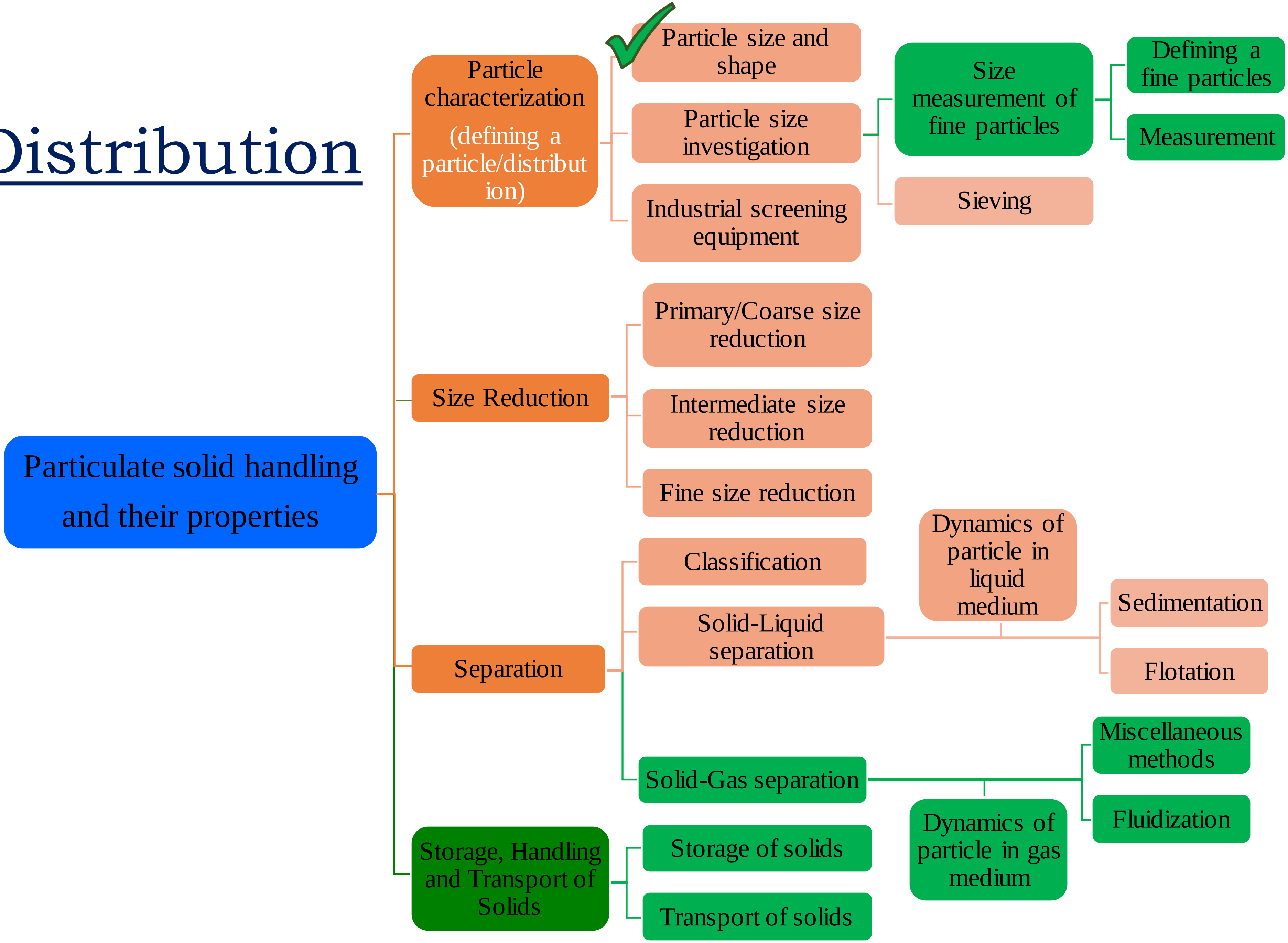
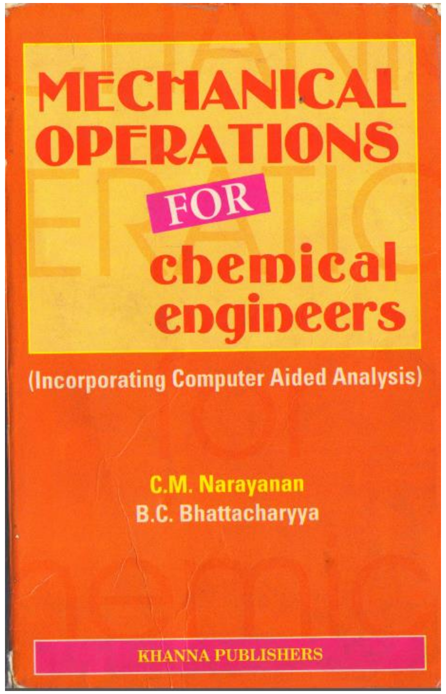


MEASUREMENT OF PARTICLES AND SIEVE ANALYSIS

SIEVING

Resource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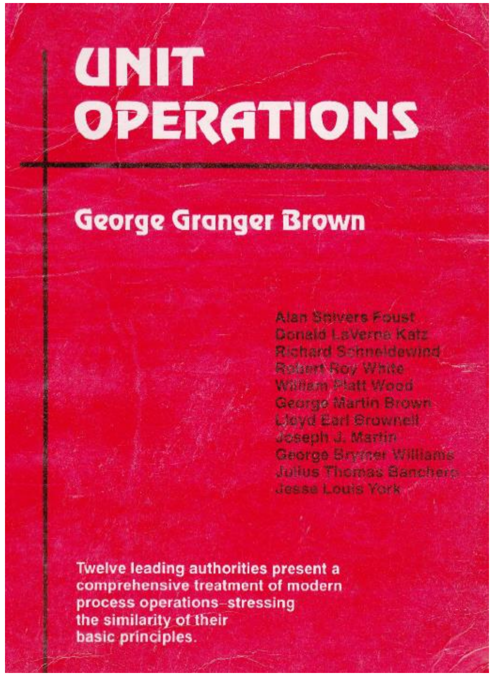
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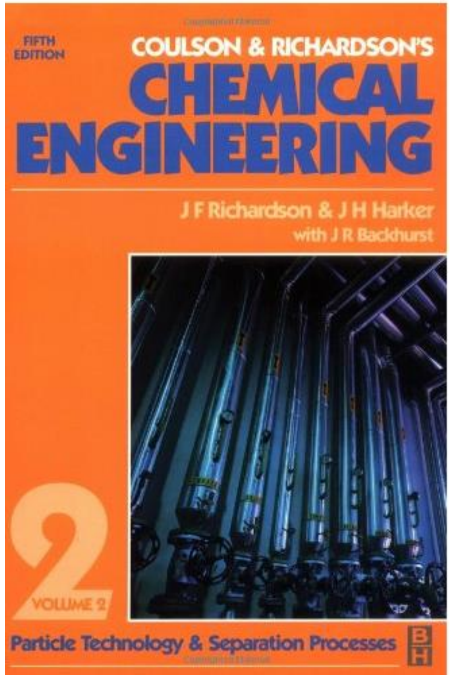
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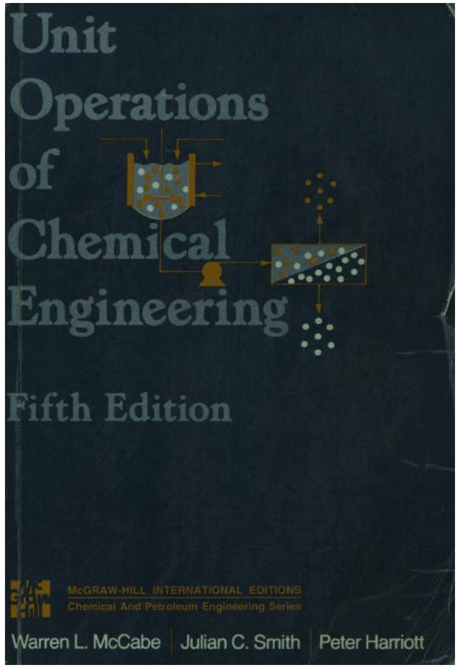
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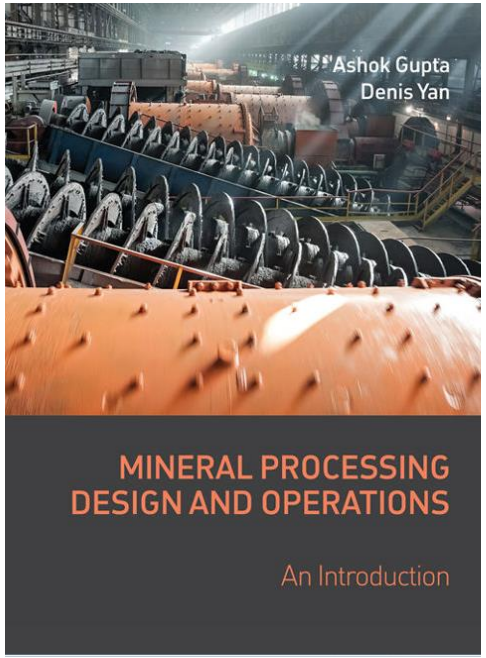
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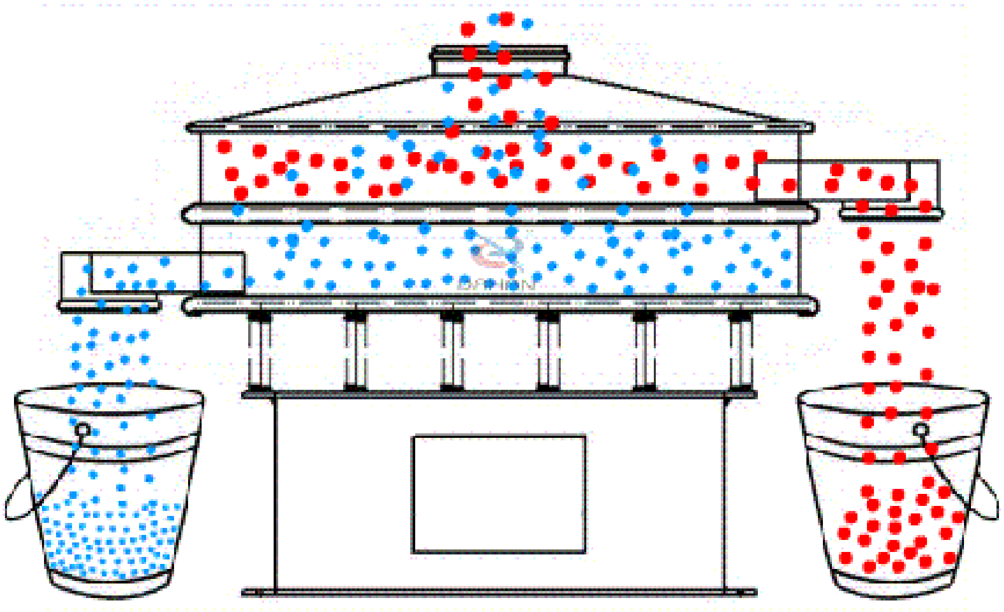
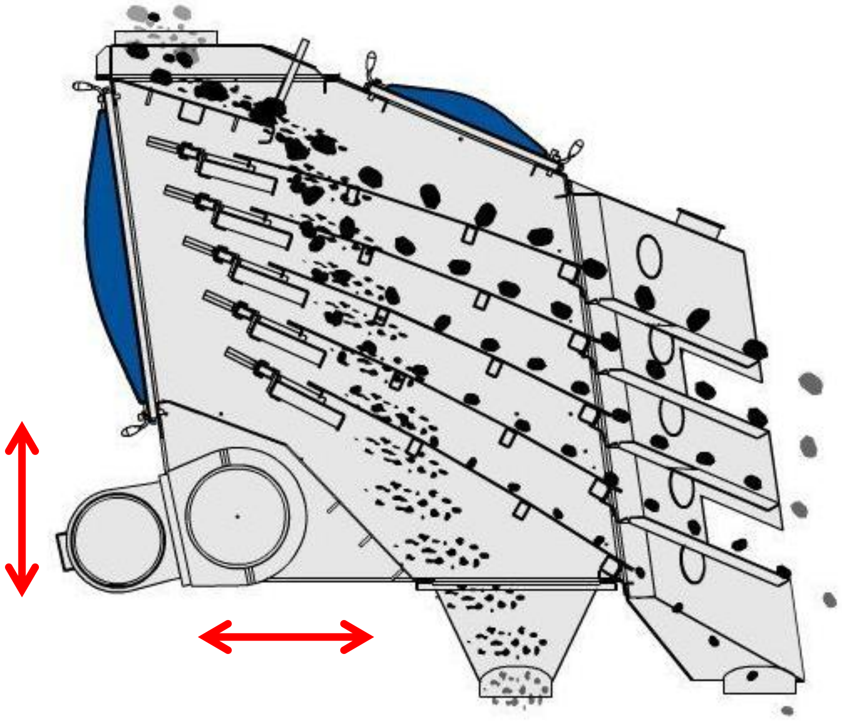
MINERAL PROCESSING DESIGN AND OPERATIONS
An Introduction

Industrial screens



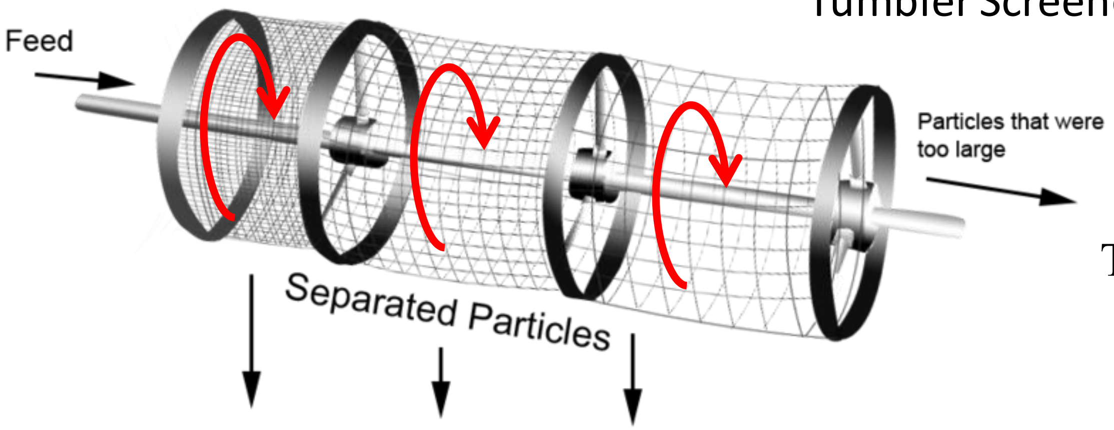
Industrial vibrating screens

Industrial screens



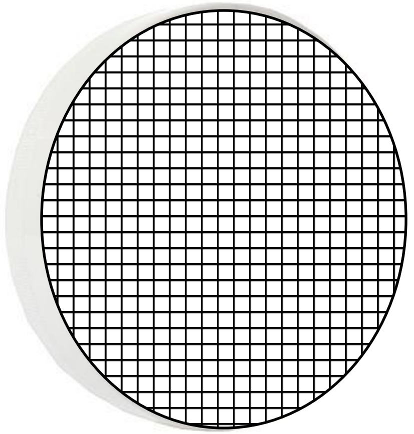
Industrial Screening Process

Tumbler Screener



Trommel

Sieves



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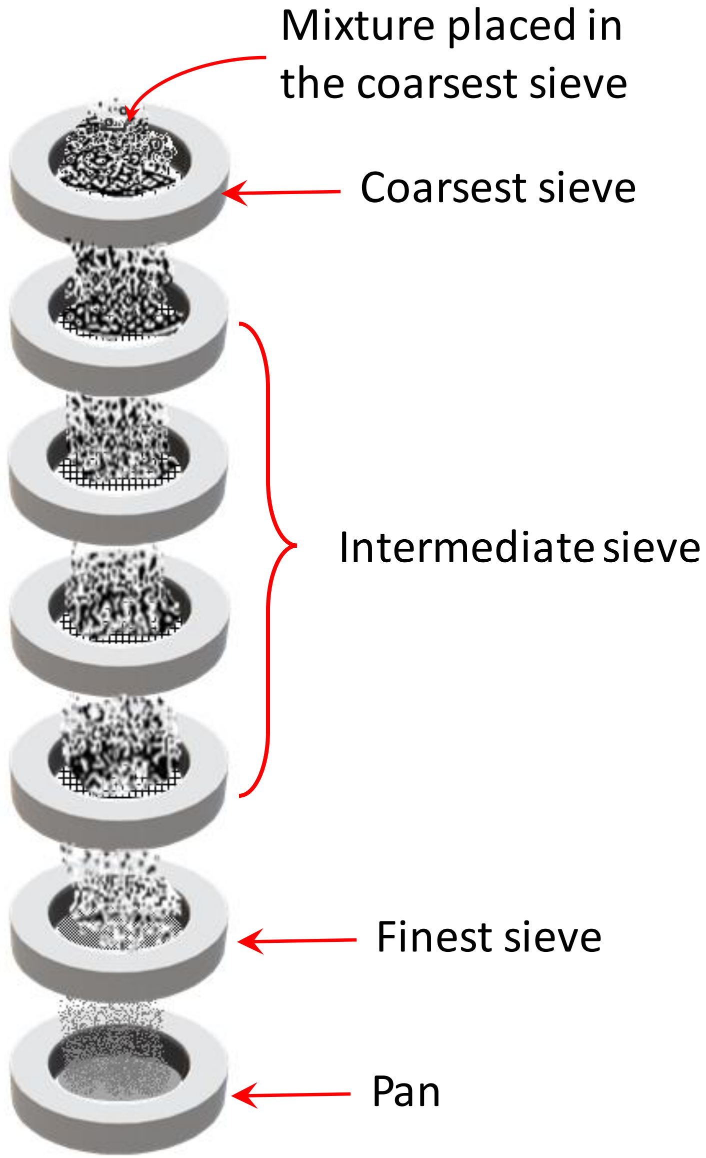


What is the difference between sieve and industrial screen?

- The difference between them is that screening is a continuous operation while sieving is a batch action.
- Sieve wire is usually of small diameter whereas a screen will have relatively large wire thickness.
- Sieves are used for light duty fine separations and screens are used for heavy duty and last longer

Sieves

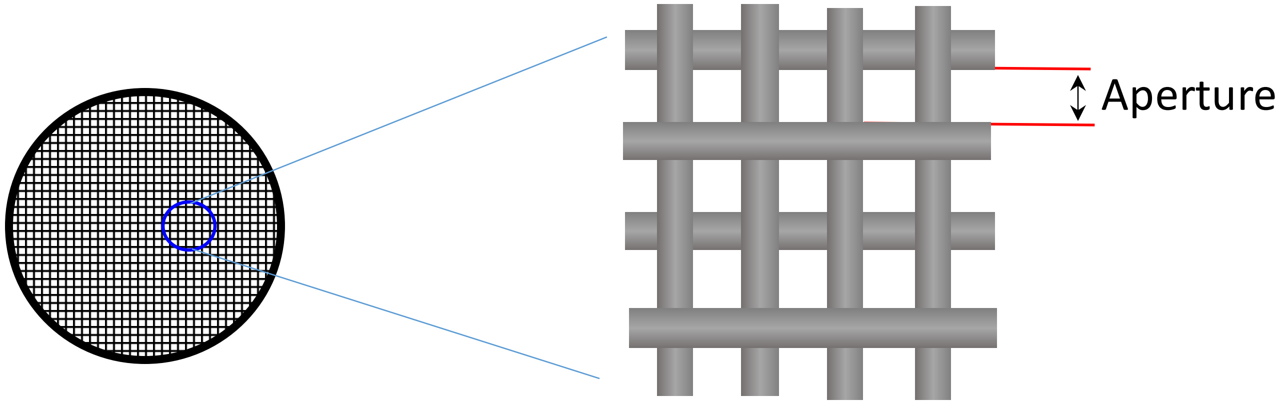
- Undoubtedly, the easiest and most rapid method for obtaining the particle size analysis is by sieving.
- Restricted to powders having the greater proportion coarser than 40 microns.
- For fine powders the method is not generally used because of the high cost of producing sieves.

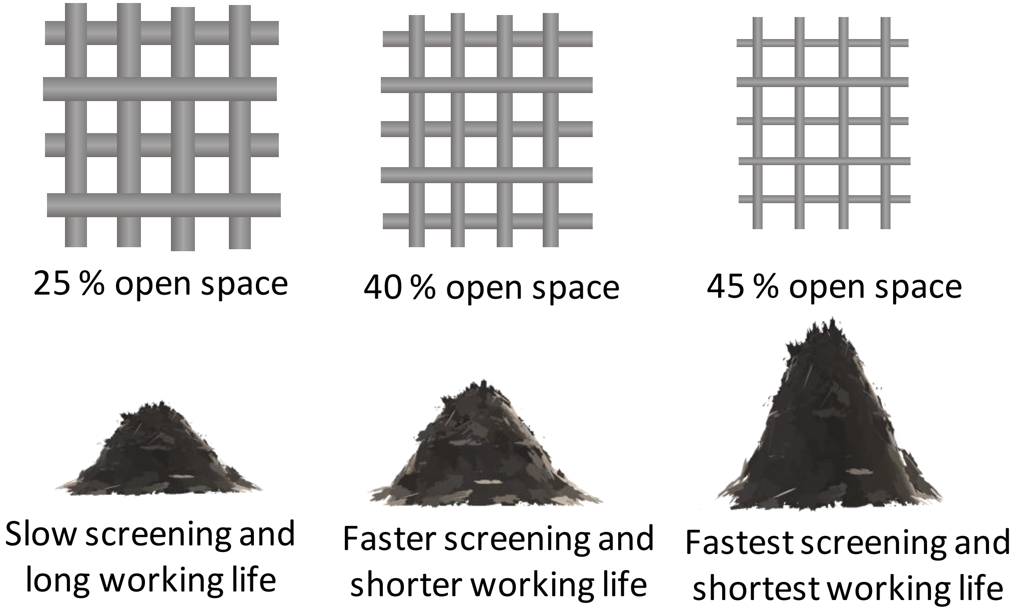
Types of sieves: A variety of sieve aperture ranges are currently being used, the most popular being the

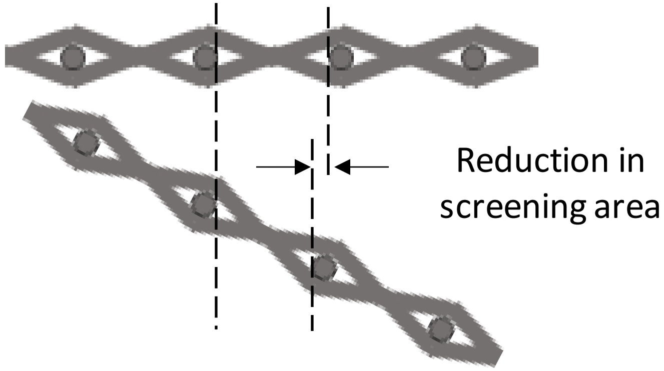
- German Standard DIN 1171 (1934)
- American standard (ASTM standard E 11-61, American Tyler Series)
- French Series AFNOR
- Russian standard Gost 35821-50,
- Institute of Mines and Metallurgy standard and the British standard (BSS).
- Indian standerd screens (ISS)

Aperture

The size of the square opening (the space between the individual wires) is called the aperture size of the screen







Mesh Number

- For (German, American and British standard)
  - Indicates the number of apertures per linear lengh.
- For Indian standard screen (ISS)
  - The mesh number is equal to its aperture size expressed to the nearesd deca-micron (0.01 mm)

Standard screen interval

- The area of opening of any one screen in the series is exactly twice that of the opening in the next smaller screen
- Sometimes intermediate screens with aperture interval $(2)^{\frac{1}{4}}$ is also used.

Material:

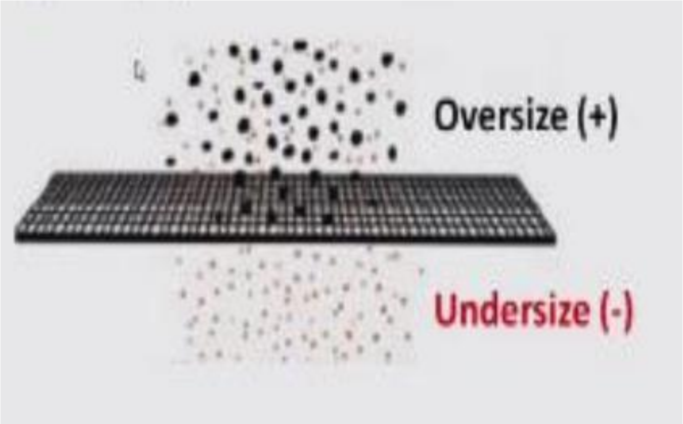
Usually made of phosphor bronze wires. Brass or mild steel wires are used sometimes.

Indian Standard Test Sieves

Sieve Designation Number	Sieve Opening or Width of Aperture		Permissible Variation in Width of Aperture				Wire Diameter			Equivalent Mesh Number of Other Standard Screens		
			Average opening		Maximum opening							
	mm	inch	Microns	Percent	Microns	Percent	mm	inch	SWG	ASTM	BSS	Tyler
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
570	5.660	0.2230	± 170	± 3.0	+ 566	+ 10	2.184	0.086	13.5	3.5	—	3.5
480	4.760	0.1870	± 143	± 3.0	+ 476	+ 10	2.032	0.080	14	4	3/16"	4
400	4.000	0.1570	± 120	± 3.0	+ 400	+ 10	1.829	0.072	15	5	—	5
340	3.353	0.1320	± 108	± 3.2	+ 370	+ 11	1.727	0.068	15.5	6	5	6
320	3.180	0.1252	± 102	± 3.2	+ 350	+ 11	1.829	0.072	15	—	1/8"	—
280	2.818	0.1109	± 97	± 3.4	+ 309	+ 11	1.422	0.056	17	7	6	7
240	2.399	0.0945	± 91	± 3.8	+ 263	+ 11	1.219	0.048	18	8	7	8
200	2.032	0.0800	± 93	± 4.6	+ 244	+ 12	1.118	0.044	18.5	10	8	9
170	1.676	0.0659	± 55	± 3.3	+ 201	+ 12	0.864	0.034	20.5	12	10	—
160	1.600	0.0630	± 54	± 3.4	+ 192	+ 12	0.965	0.038	19.5	—	1/16"	10
140	1.405	0.0553	± 48	± 3.4	+ 168	+ 12	0.711	0.028	22	14	12	12
120	1.201	0.0473	± 46	± 3.8	+ 156	+ 13	0.610	0.024	23	16	14	14
100	1.000	0.0394	± 50	± 5.0	+ 150	+ 15	0.584	0.023	23.5	18	16	16
85	0.842	0.0332	± 44	± 5.2	+ 126	+ 15	0.559	0.022	24	20	18	20
80	0.790	0.0311	± 38	± 4.8	+ 111	+ 14	0.533	0.021	24.5	—	1/32"	—
70	0.708	0.0279	± 38	± 5.4	+ 106	+ 15	0.457	0.018	26	25	22	24

- A set of standard screens is arranged serially in a stack, with the smallest mesh at the bottom and largest at the top. An analysis is conducted by placing the sample on the top screen and shaking the stack mechanically for a definite period.

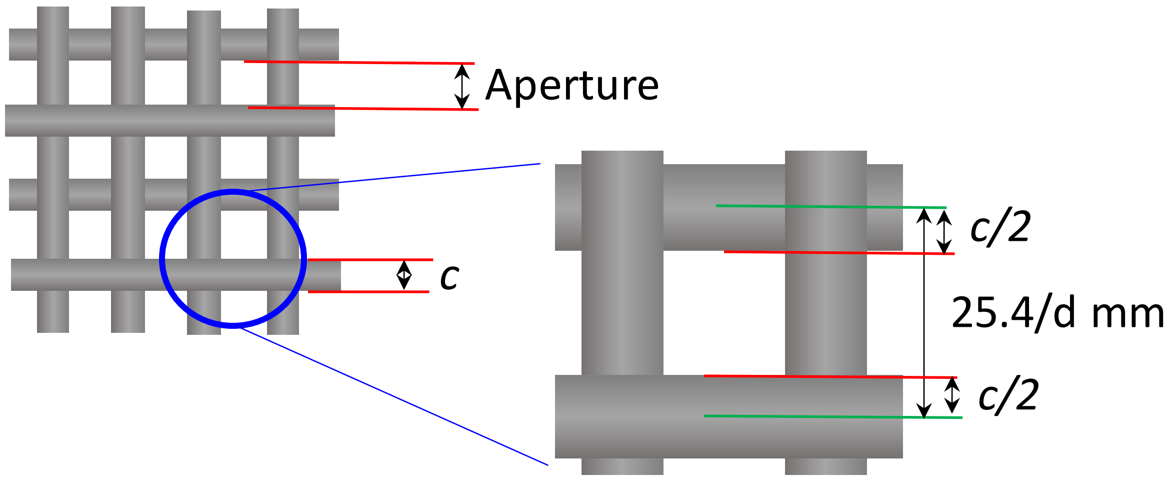
- **The materials that passes through the screen is called the minus (-) material or undersize and the material that is retained on the screen is called the plus (+) material or the oversize. It is designated as (-42+48) or (42/48) in Tyler series.**



- The average size of the particles in a specific fraction will be the arithmetic average of the aperture size of the screens involved.

Problem 1. Calculate the aperture (in mm) of an international standard (ISO 1944) screen with wire diameter *c* (mm) and mesh number *d.*
d is defines as the number of opening per linier inch for ISO 1944 standard screen.

Solution:



Length of *d* opening 25.4 mm (= 1 inch)

So, length of 1 opening 25.4/d mm

Aperture

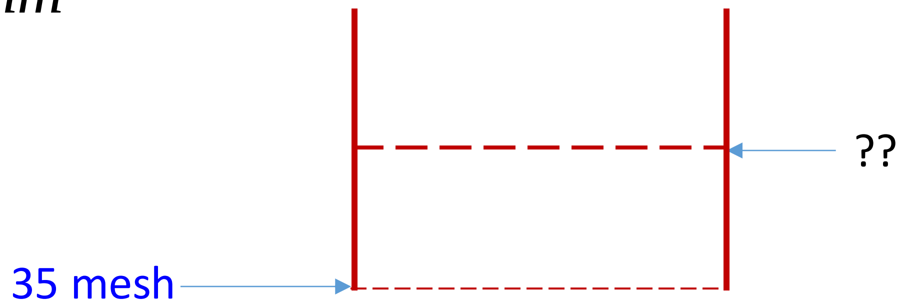
$$a = \left(\frac{25.4}{d}\right) - \left(2 \times \frac{c}{2}\right)$$

$$a = \left(\frac{25.4}{d}\right) - c$$

Problem 2. Find the average size of the particle in mm retained on 35 mesh screen (international standard, ISO 1944). Wire diameter of 35 mesh screen is 0.284 mm. Find the mesh number of the previous screen with wire diameter as 0.417 mm.

Solution: Aperture of 35 mesh screen

$$a_{35} = \left(\frac{25.4}{d_{35}}\right) - c_{35} \quad \Rightarrow a_{35} = \left(\frac{25.4}{35}\right) - 0.284 = 0.442\ mm$$



Aperture of the previous screen = 0.442 × $\sqrt{2}$ = 0.6250 mm

Average particle size =(0.6250+0.442)/2= 0.5335 mm (Ans)

Mesh number of the previous screen

$$a_{i+1} = \left(\frac{25.4}{d_{i+1}}\right) - c_{i+1} \quad \Rightarrow 0.6250 = \left(\frac{25.4}{d_{i+1}}\right) - 0.417 \Rightarrow d_{i+1} = 24.37 \approx 25 \quad \text{(Ans)}$$

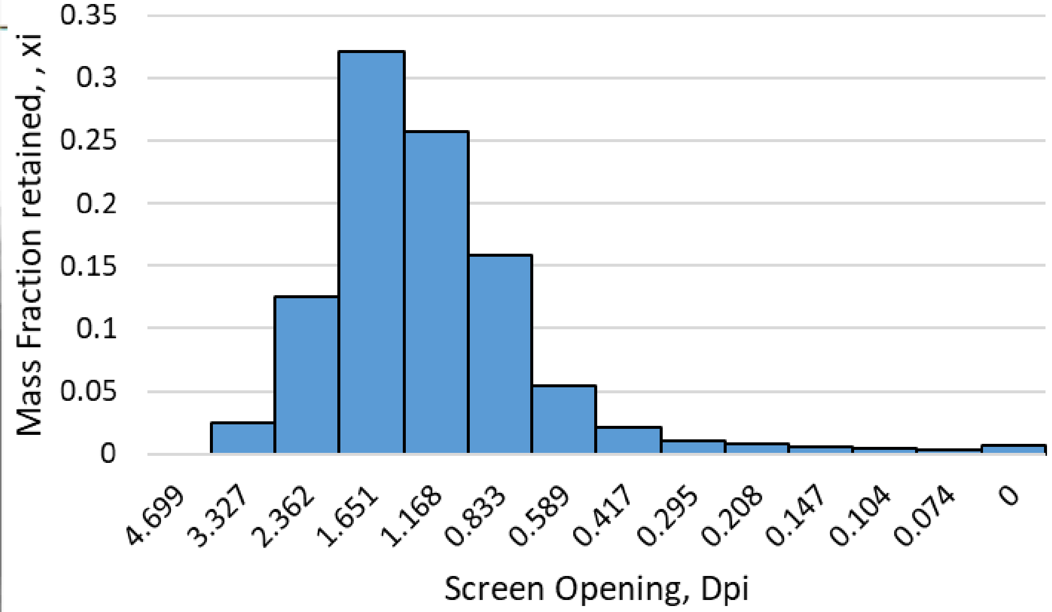
Sieve Analysis

Differencial Analysis

- The results of a screen analysis are tabulated to show the mass fraction of each screen increment as a function of the mesh size range of the increment.
- Since the particles on any one screen are passed by the screen immediately ahead of it, two numbers are needed to specify the size range of an increment.
- Notation 14/20 means, through 14 mesh and on 20 mesh.
- An analysis tabulated in this manner is called a *"differential analysis"*.

Differential Screen Analysis

Mesh	Screen Opening D_{pi}, mm	Mass Fraction Retained, x_i,	Average Particle Diameter in Increment, $\bar{D}_{pi}$, mm
4	4.699	0.0000	–
6	3.327	0.0251	4.013
8	2.362	0.1250	2.85
10	1.651	0.3207	2.007
14	1.168	0.2570	1.409
20	0.833	0.1590	1.001
28	0.589	0.0538	0.711
35	0.417	0.0210	0.503
48	0.295	0.0102	0.356
65	0.208	0.0077	0.252
100	0.147	0.0058	0.178
150	0.104	0.0041	0.126
200	0.074	0.0031	0.089
Pan	–	0.0075	0.037



Differential Screen Analysis

Sieve Analysis

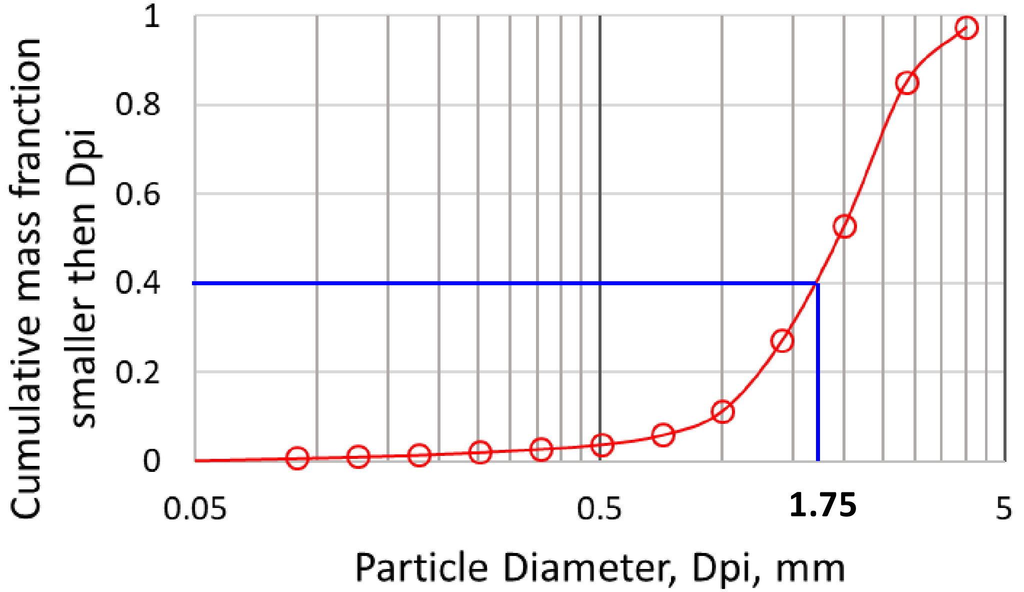
Cumulative Analysis

- A cumulative analysis is obtained from a differential analysis by adding cumulatively.
- The individual differential increments, starting with that retained on the pan and tabulating or plotting the cumulative sums against the mesh dimensions of the retaining screen.
- The cumulative analysis is a relation between Φ and D_{pi} , where D_{pi} is the average particle size retained on screen *i*. The quantity Φ is the mass fraction of the sample that consists of particles smaller than D_{pi} .

$$\Phi = x_1 + x_2 + \ldots\ldots + x_n = \sum x_i$$

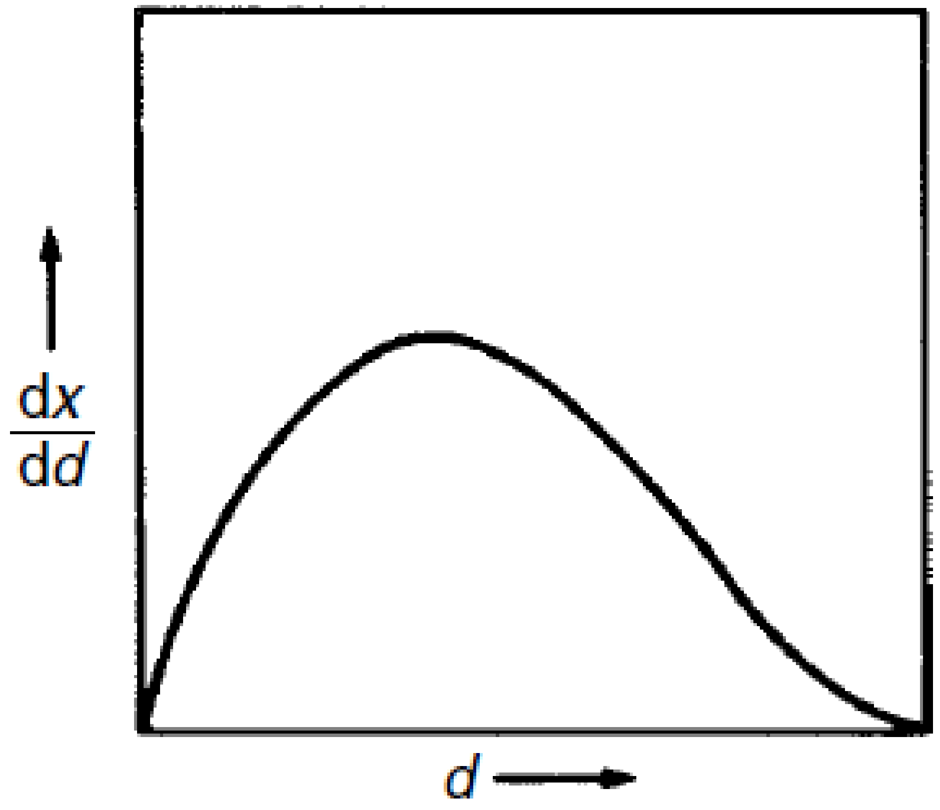
Cumulative Screen Analysis

Mesh	Screen Opening D_{pi}, mm	Mass Fraction Retained, x_i	Average Particle Diameter in Increment, $\bar{D}_{pi}$, mm	Cumulative fraction smaller than D_{pi}, Φ_i
4	4.699	0.0000	–	1.0000
6	3.327	0.0251	4.013	0.9749
8	2.362	0.1250	2.85	0.8499
10	1.651	0.3207	2.007	0.5292
14	1.168	0.2570	1.409	0.2722
20	0.833	0.1590	1.001	0.1132
28	0.589	0.0538	0.711	0.0594
35	0.417	0.0210	0.503	0.0384
48	0.295	0.0102	0.356	0.0282
65	0.208	0.0077	0.252	0.0205
100	0.147	0.0058	0.178	0.0147
150	0.104	0.0041	0.126	0.0106
200	0.074	0.0031	0.089	0.0075
Pan	–	0.0075	0.037	0.0000



Size frequency curve

- The most frequently occurring size is shown by the maximum of the curve.
- For naturally occurring materials the curve will generally have a single peak.
- For mixtures of particles, there may be as many peaks as components in the mixture.
- If the particles are formed by crushing larger particles, the curve may have two peaks, one characteristic of the material and the other characteristic of the equipment.



- The mentioned size distribution is incomplete as the size distribution of the fine particles is not known.

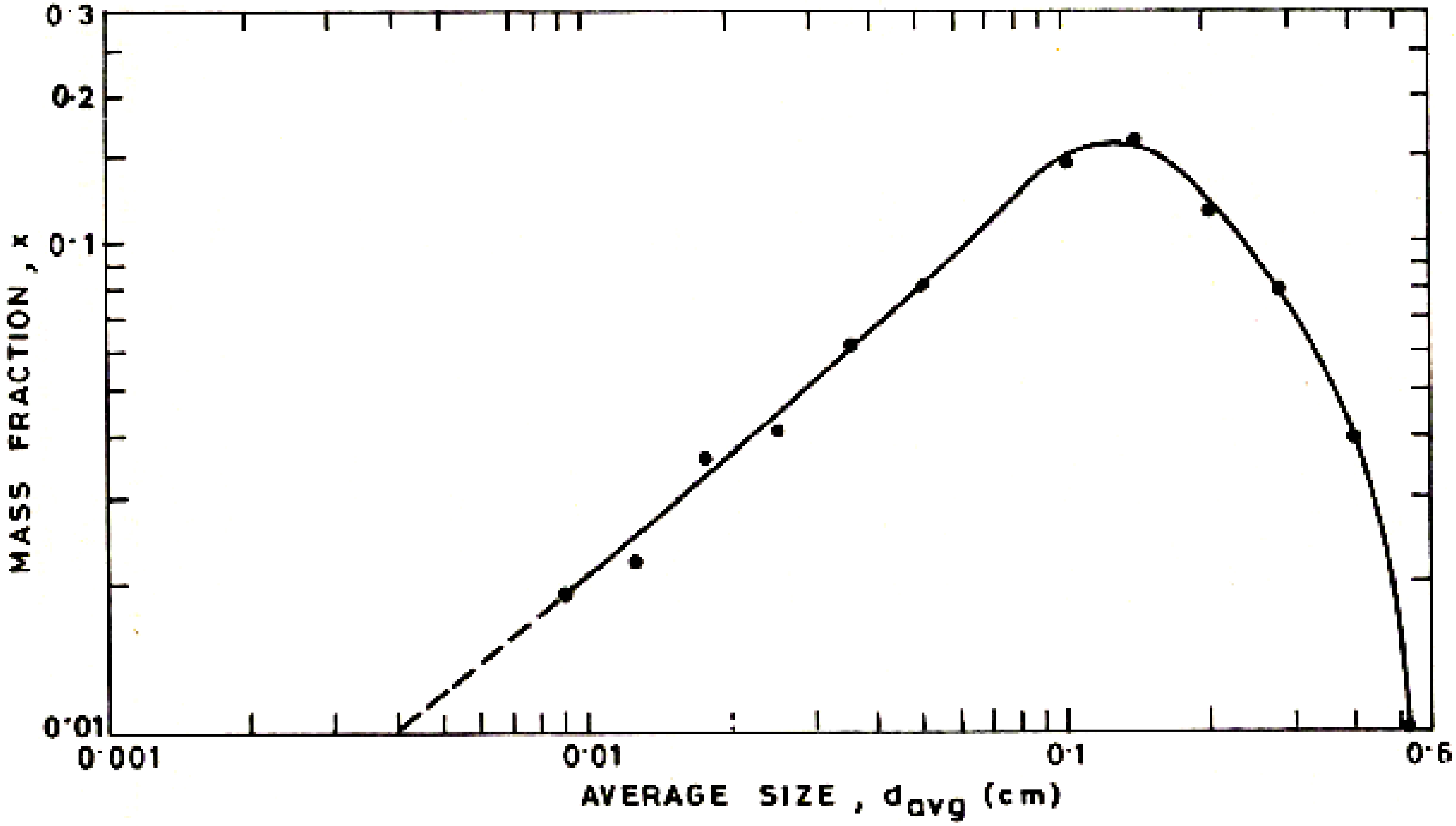
- For estimating the size distribution of such a small particle we can use **<u>Gaudin-Schumann size distribution law</u>**.

According to this law, for very fine particles, a log-log plot of mass fraction x versus average particle (D_{pi} *or* d_{avg}) size shall give a straight line

$$\ln(x) = m\ln(d_{avg}) + \ln B$$

Where, *m* and B are constant

<u>N.B:</u> d_{avg} is the screen size of the particles with screen interval of $(2)^{\frac{1}{4}}$. It is therefore essential that while applying the above equation the values of d_{avg} must confirm to the screen interval employed for the test screens.



Log-log plot of mass fraction vs average particle size

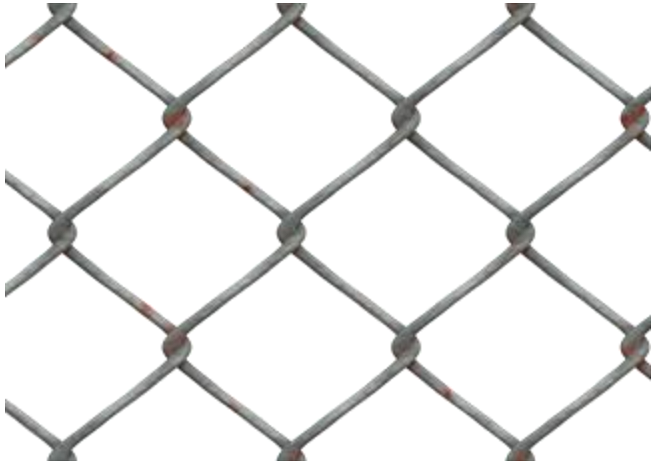
Sieve set

<u>Sieving errors:</u> The possibility for a particle to pass through an aperture depends on the following factors :

1) The particles size distribution of the powder
2) The number of particles on the sieve
3) The physical properties of the particle like surface area, specific gravity *etc.*
4) The method of shaking the sieves
5) The dimensions and shape of the particles
6) Geometry of the sieving surface i.e. open area / Total area

The **sieve distribution** given by sieving operation depends also on the following variables:

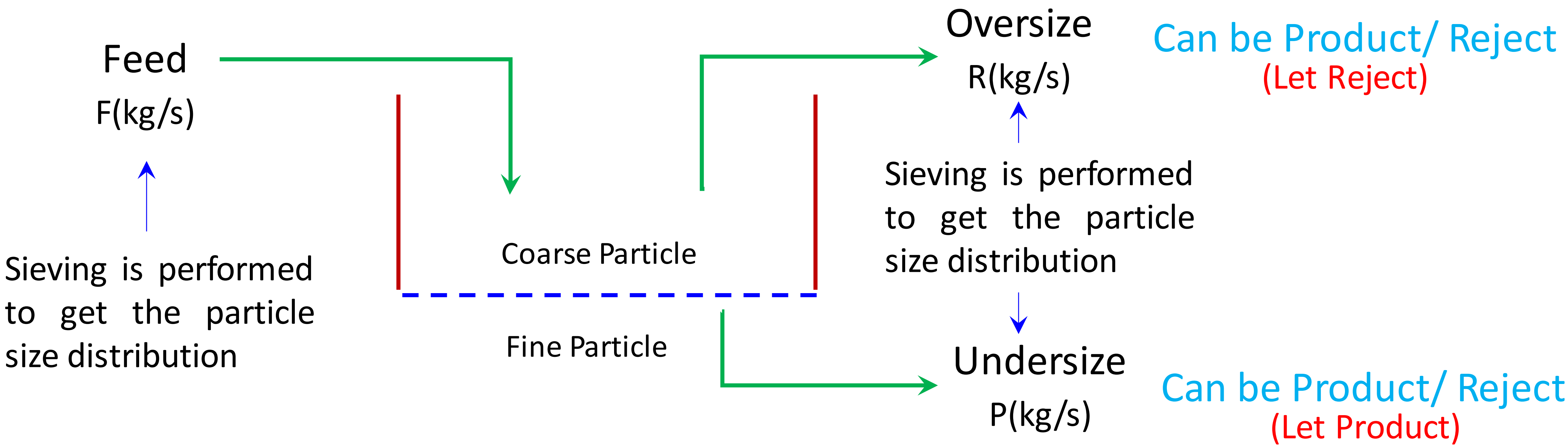
1) Duration of sieving
2) Presence of "near mesh particles"
3) Variation of sieve aperture
4) Errors of observation and experiment
5) Errors of sampling
6) Effect of different equipment and operation



Enlarged view of mesh

Screen Effectiveness

- Screen effectiveness/efficiency mostly depends on two aspects
    1. Recovery of desired product (Represents the ability of the screen to separate all particles of the desired size)
    2. Rejection of Undesired material (Separated product must contain minimal amount of particles having sizes other than the desire size)



The general method of classifying screen effectiveness (E_c) is

$$\mathbf{E_c = (Recovery)\times(Rejection)} \quad .....(1)$$

Where, y_p and y_F are the mass fraction of the desired particle in the product and feed respectively

$$\textbf{Recovery} = \frac{\textbf{Desired material in the product}}{\textbf{Desired material in the feed}} = \frac{Py_p}{Fy_F} \quad .....(2)$$

$$P \times y_P$$

F is the feed rate (kg/s) and P is the product rate

Oversize/Undersize

$$\left(\frac{\text{mass}}{\text{time}}\right) \times \left(\frac{\text{mass of desired size range in the product stream}}{\text{total mass of product stream}}\right)$$

$$\textbf{Rejection} = \frac{\textbf{Undesired material in the reject}}{\textbf{Undesired material in the feed}} = \frac{R(1-y_R)}{F(1-y_F)}$$

$$= \frac{F(1-y_F) - P(1-y_P)}{F(1-y_F)}$$

$$= 1 - \left(\frac{P}{F}\right)\left(\frac{1-y_P}{1-y_F}\right) \quad .....(3)$$

$$\left(\frac{\text{mass of desired size range in the reject stream}}{\text{mass of reject}}\right)$$

$$R \times \underbrace{(1-y_R)}$$

Oversize/Undersize

$$\left(\frac{\text{mass of reject}}{\text{time}}\right) \times \left(\frac{\text{mass of undesired size range in the reject stream}}{\text{mass of reject}}\right)$$

Substituting (2) and (3) in equation (1) we will get

$$E_c = (\text{Recovery}) \times (\text{Rejection}) = \frac{Py_P}{Fy_F} \times \left[1 - \left(\frac{P}{F}\right)\left(\frac{1-y_P}{1-y_F}\right)\right] \quad .....(4)$$

From overall mass balance we have

$$F = P + R \quad \Rightarrow \underbrace{R = (F - P)} \qquad .....(5)$$

From desired material balance we have

$$Fy_F = Py_P + Ry_R = Py_P + (F - P)y_R$$

$$\frac{P}{F} = \frac{y_F - y_R}{y_P - y_R} \qquad .....(6)$$

Substituting (6) in equation (4) we will get

$$\boldsymbol{E_c} = \frac{(y_F - y_R)y_p}{(y_p - y_R)y_F}\left[1 - \frac{(y_F - y_R)(1 - y_p)}{(y_p - y_R)(1 - y_F)}\right] \qquad .....(7)$$

Problem 3:

Anthracite coal from a pulverization unit has been found to contain an excess of fine material (75% by weight). In order to remove these fines, it is screened using a 1.5 mm screen. Estimate the effectiveness of the screen from the following data

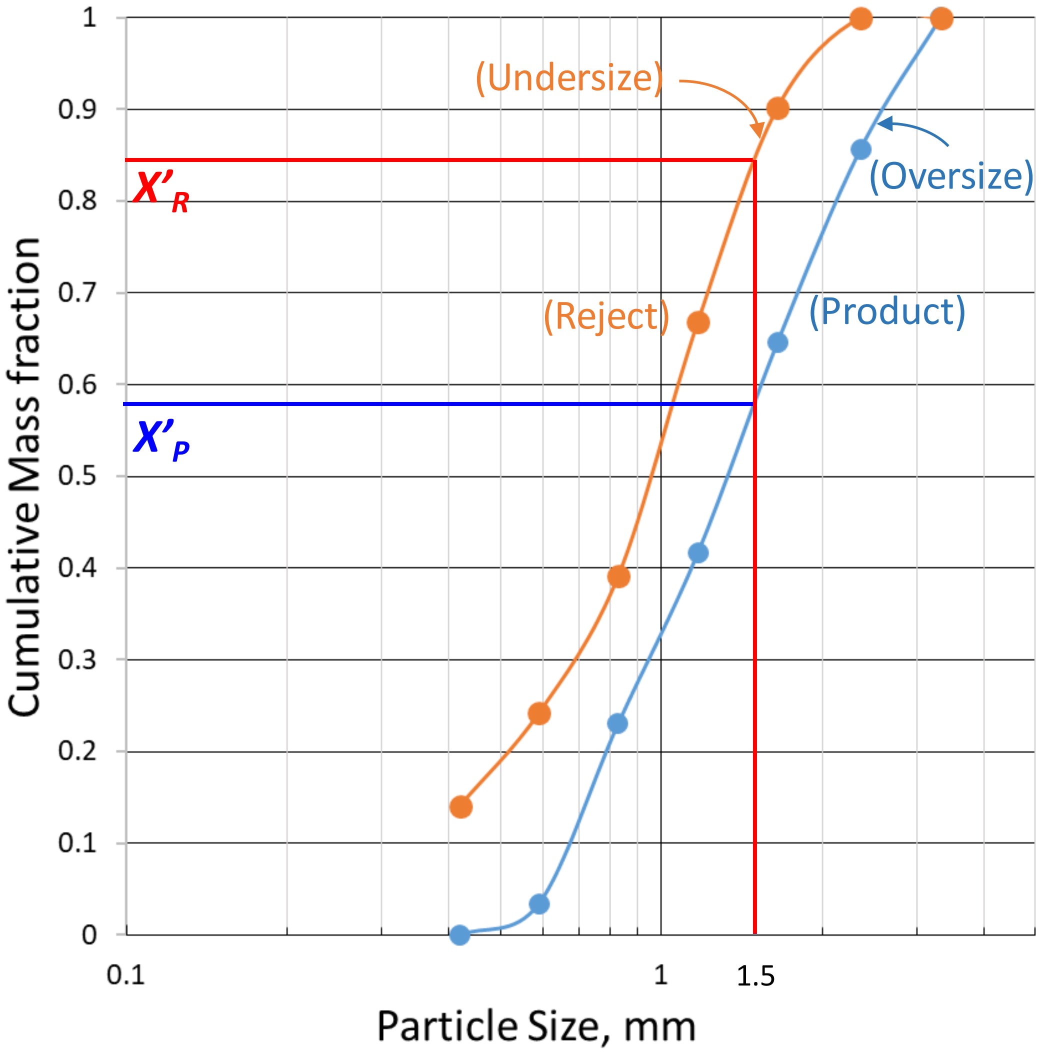
Average particle size (mm)	Mass Fraction	
	Oversize from screen	Undersize from screen
3.33	0.143	0.00
2.36	0.211	0.098
1.65	0.230	0.234
1.17	0.186	0.277
0.83	0.196	0.149
0.59	0.034	0.101
0.42	0.00	0.141

Solution:

- Objective of this screen is to remove the fines. So, undersize should be the reject and oversize should be the product.
- The aperture of the this industrial screen is 1.5 mm and the desired product is +1.5 mm.
- Let X'_P and X'_R be the cumulative mass fraction correspond to the particle size 1.5 mm
- By definition X'_P and X'_R are the total mass fraction of material having size less than 1.5 mm in the product and reject respectively.
- So, the mass total mass fraction of material having size grater than 1.5 mm (+ 1.5) in the product and reject will be $(1 - X'_P)$ $(=y_p)$ and $(1 - X'_R)$ $(=y_R)$ respectively
- The feed contain 75% fine material. So, $y_F = 0.25$.

To find X'_P and X'_R , we have to prepare a cumulative mass fraction table from the given data

Average particle size (mm)	X_P	X_R
3.33	1.0	1.0
2.36	0.857	1.0
1.65	0.646	0.902
1.17	0.416	0.668
0.83	0.230	0.391
0.59	0.034	0.242
0.42	0.00	0.141



From the graph we got $X'_P = 0.57$ and $X'_R = 0.85$

So,

$$y_p = (1 - X'_P) = 0.43 \quad \text{and} \quad y_R = (1 - X'_R) = 0.15$$

Using equation 7 we can find out the effectiveness of the screen as

$$\boldsymbol{E_c} = \frac{(y_F - y_R)y_p}{(y_p - y_R)y_F}\left[1 - \frac{(y_F - y_R)(1 - y_p)}{(y_p - y_R)(1 - y_F)}\right] \times 100$$

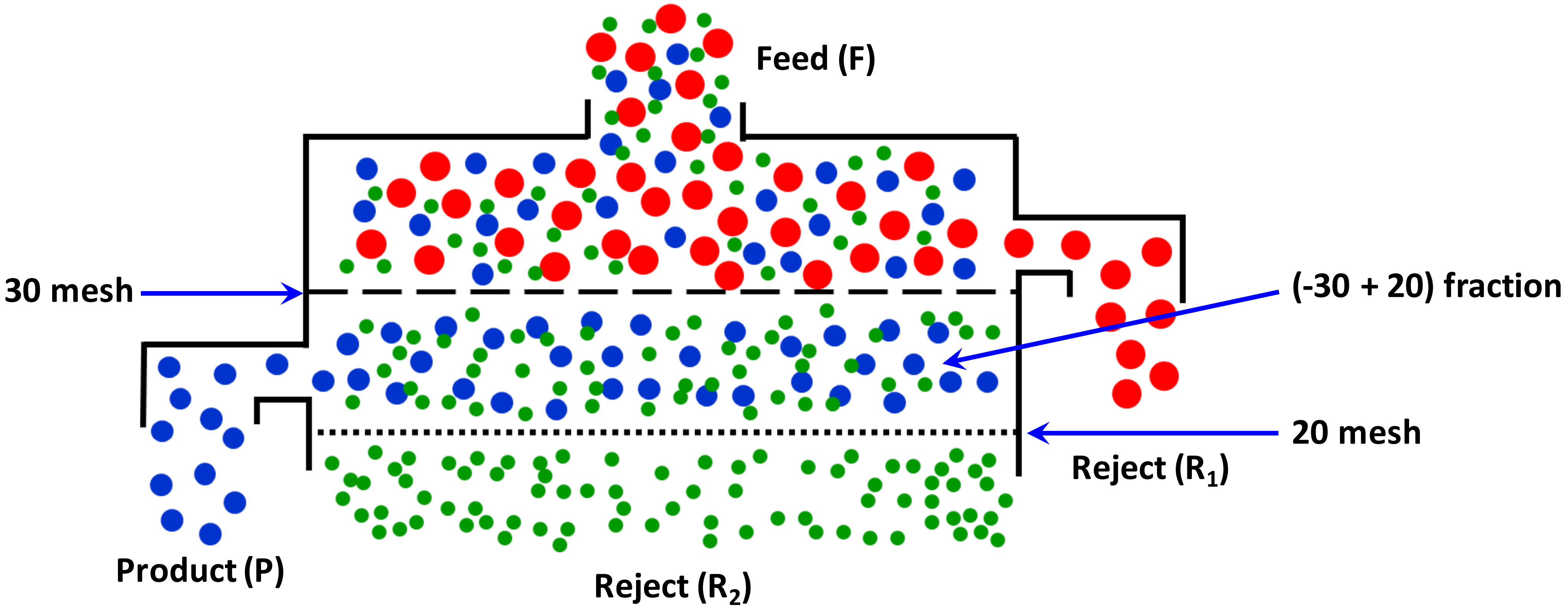
$$= \frac{(0.25 - 0.15) \times 0.1}{(0.43 - 0.15) \times 0.25} \times \left[1 - \frac{(0.25 - 0.15) \times (1 - 0.43)}{(0.43 - 0.15) \times (1 - 0.25)}\right] \times 100$$

$$= 44.75\%$$

Problem 2:

Table salt is being fed to a vibrating screen at the rate of 150 kg/hr. The desired product is -30 +20 mesh fraction. A 30 mesh and a 20 mesh screen are therefore used (double deck), the feed being introduced on the 30 mesh screen. During the operation, it was observed that the average proportion of oversize (from 30 mesh screen): oversize (from 20 mesh screen): undersize (from 20 mesh screen) is 2:1.5:1. Calculate the effectiveness of the screen from the following data:

Mesh	Mass Fraction			
	Feed	Oversize from 30 mesh screen	Oversize from 20 mesh screen	Undersize from 20 mesh screen
-80 + 60	0.097	0.197	0.026	0.0005
- 60 + 40	0.186	0.389	0.039	0.0009
- 40 + 30	0.258	0.337	0.322	0.0036
-30 + 20	0.281	0.066	0.526	0.3490
-20 + 15	0.091	0.005	0.061	0.2990
-15 +10	0.087	0.006	0.026	0.3470



Product (desired material) will be the oversize of 20 mesh and undersize of 30 mesh screen

Mesh y_F	Mass Fraction			
	Feed	Oversize from 30 mesh screen	Oversize from 20 mesh screen	Undersize from 20 mesh screen y_P
-80 + 60	0.097	0.197	0.026	0.0005
- 60 + 40	0.186	0.389	0.039	0.0009
- 40 + 30	0.258	0.337	0.322	0.0036
-30 + 20	0.281	0.066	0.526	0.3490
-20 + 15	0.091	0.005	0.061	0.2990
-15 +10	0.087	0.006	0.026	0.3470

Material balance around the double-deck screen will give

Feed (F) = oversize from 30 mesh (R_1) + oversize from 20 mesh (P)+ Undersize from 20 mesh (R_2)

$$F = R_1 + P + R_2$$

It is given in the problem that $R_1 : P : R_2 = 2:1.5:1$

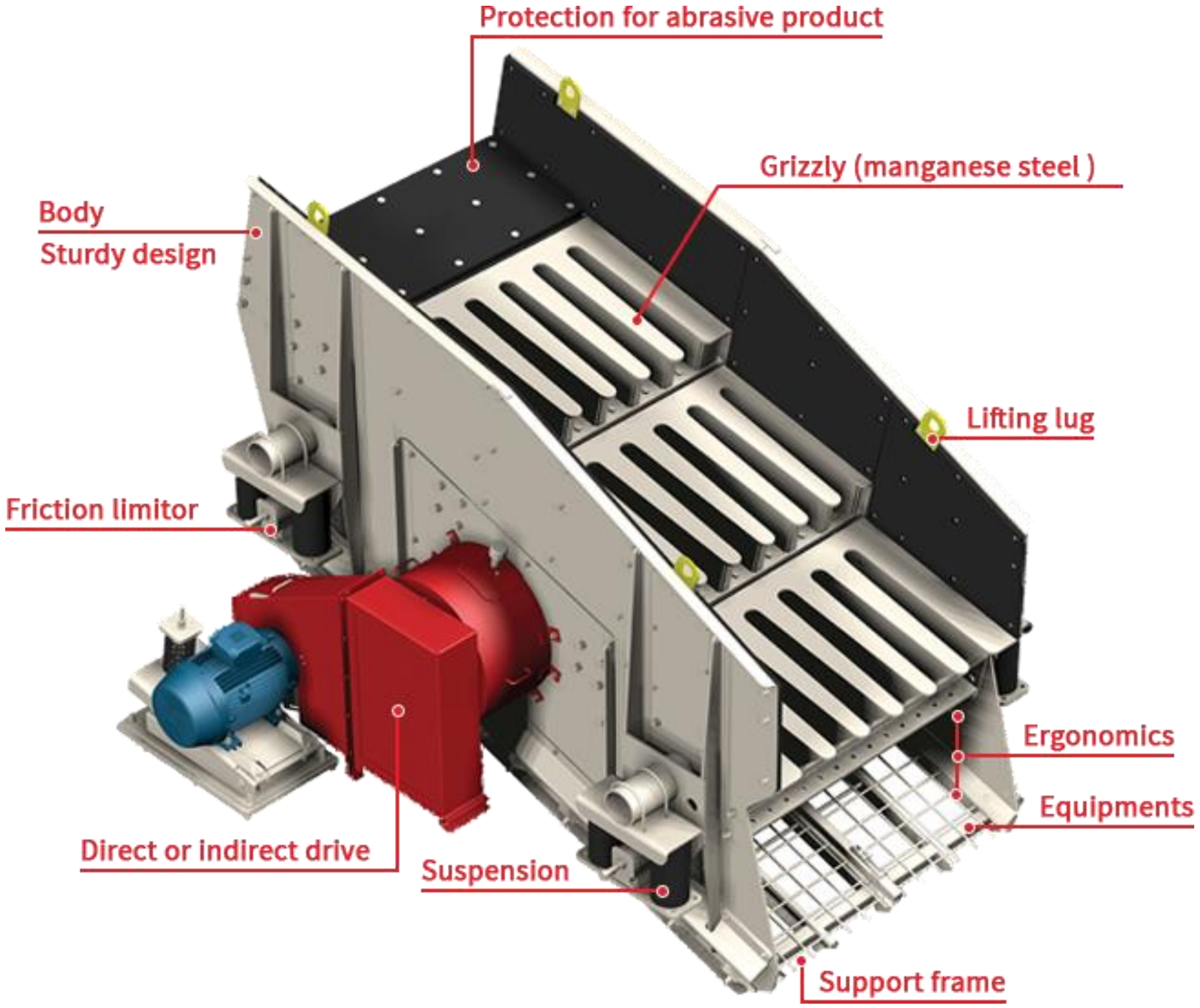
So, $\frac{P}{F} = \frac{P}{P + R_1 + R_2} = \frac{1.5}{4.5} = \frac{1}{3}$

Substituting the relevant values in equation 3, we get

$$E_c = \left(\frac{P}{F}\right) \times \left(\frac{y_P}{y_F}\right) \times \left[1 - \left(\frac{P}{F}\right)\left(\frac{1 - y_P}{1 - y_F}\right)\right] = \left(\frac{1}{3}\right) \times \left(\frac{0.526}{0.281}\right) \times \left[1 - \left(\frac{1}{3}\right)\left(\frac{1 - 0.526}{1 - 0.281}\right)\right] = 0.486$$

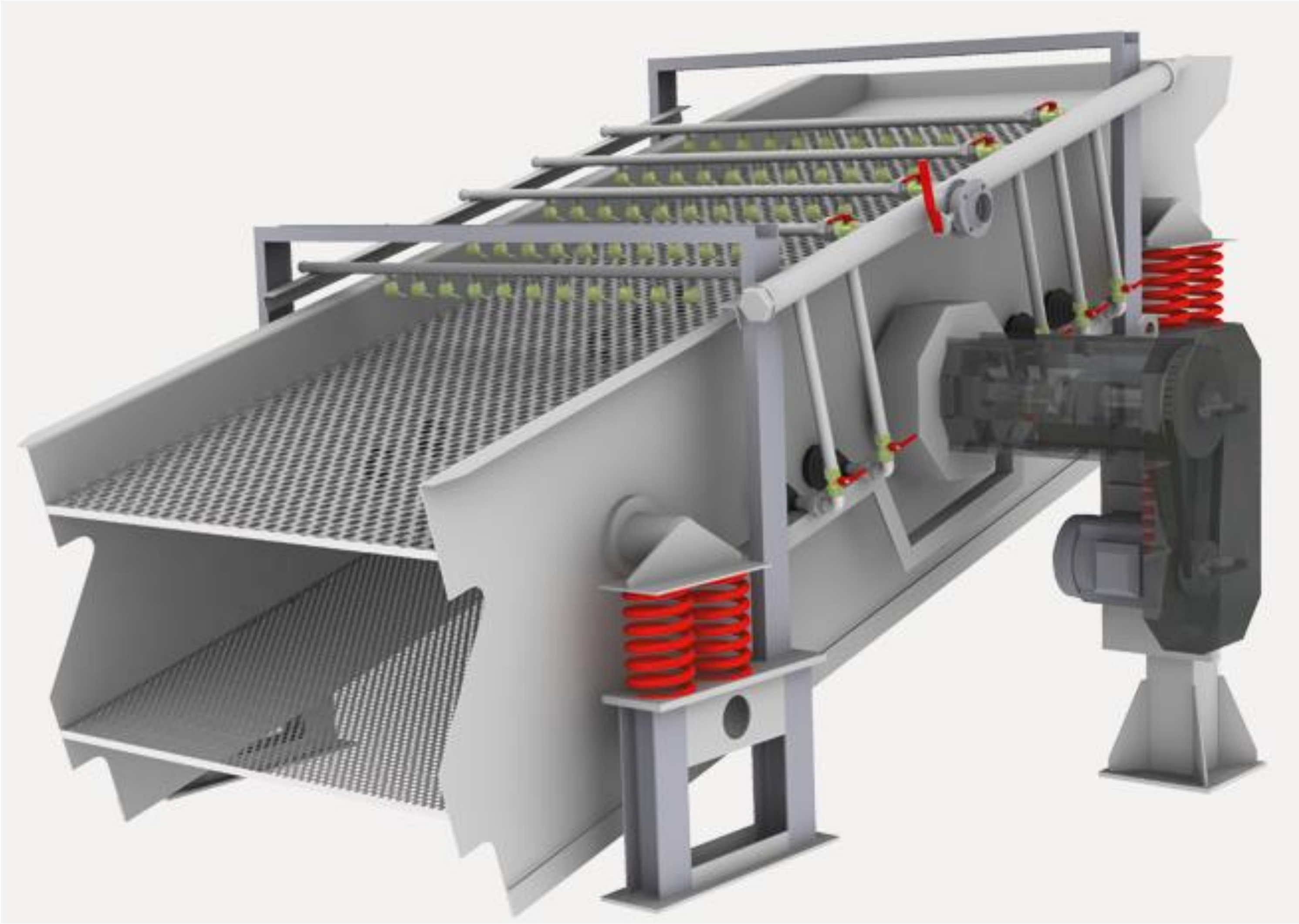
Industrial screening equipment

[Grizzlies]()



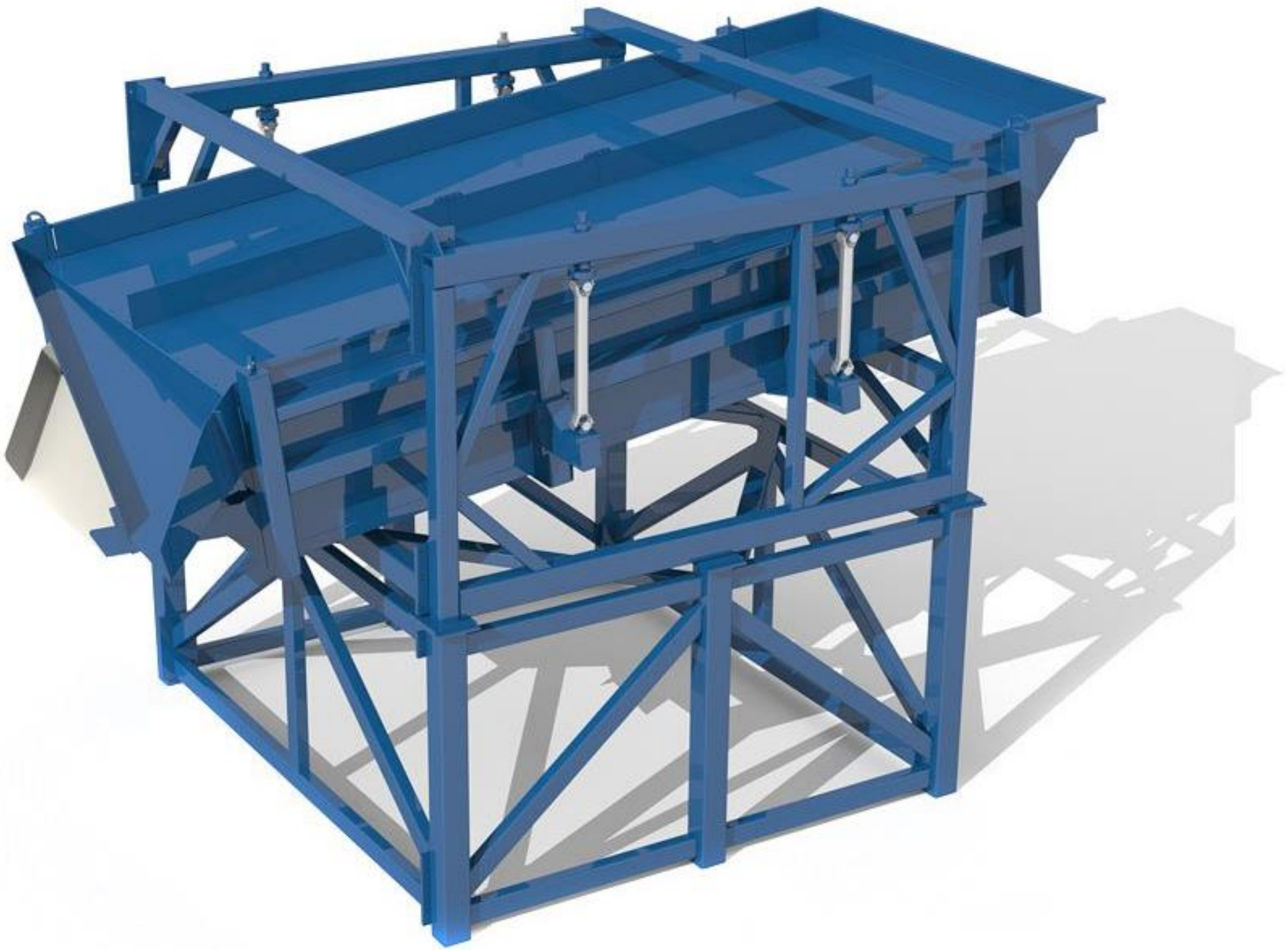
Used to screen large sizes of rocks of 25mm and above

Vibrating screens (most popular)



- The frequency or speed of vibration can vary from 1500 to 7200 per minute.
- Can handle a wide verity of feed from 480 mesh to 4 mesh.

Oscillatory screens



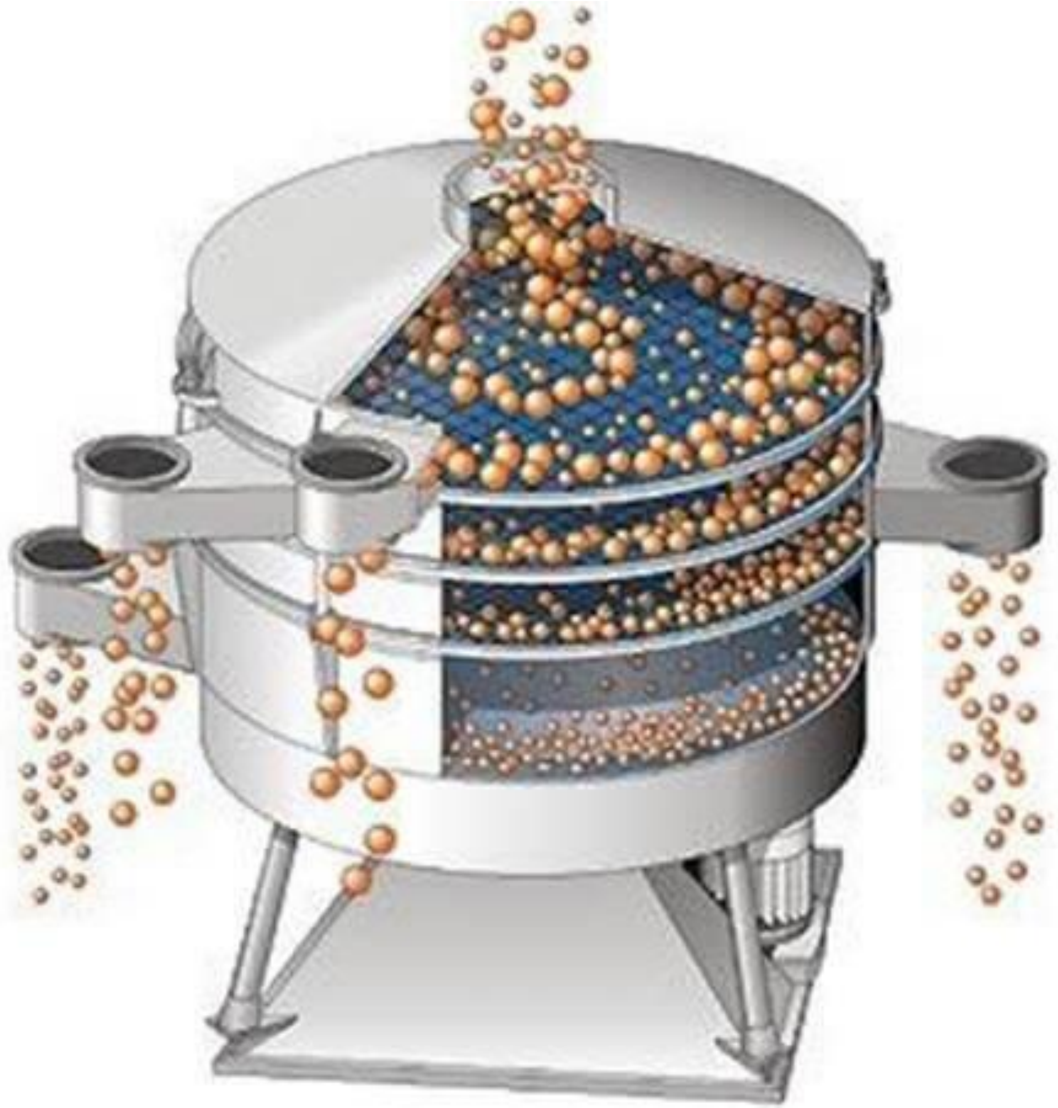
- Relatively low speed oscillations (300 to 400 per minute)

- Mostly used for batch screening of coarse material coarse material of 5 to 15 mm and fine.

Reciprocating screens

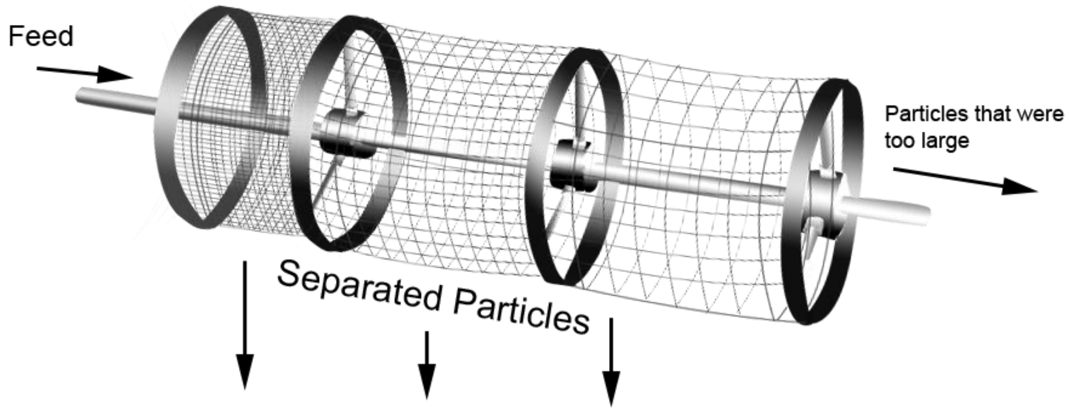
- The speed varies from 500 to 600 per minute
- Used for handling dry chemical, light metal powders, powdered food and granular materials

Gyratory screens



Oscillations in circular or near circular orbits.

Trommel



- Relatively low capacity and low efficiency.
- Very efficient for coarser size
- Rotation speed around 15-20 rpm.