Screening

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Introduction

Solids may be separated from solids (according to size) in the dry state by methods such as screening, magnetic separation and electrostatic separation.

Screening

- A method of separating solid particles according to size alone is called screening.
- It refers to the separation of solid materials based on size using screens of known openings.
- In screening, a mixture of solid particles of various sizes is dropped on a screening surface/screen (a surface provided with suitable openings) which acts as multiple go and no go gage.
- The material that passes through a given screen/screening surface is called the undersize or minus (-) material while the material that remains on the screen/screening surface is called the oversize or plus (+) material.

Screening

- A single screen can make a single separation of the material charged into two fractions.
- These are called unsized fractions as only the upper limit or lower limit of the particle sizes they contain is known and the other limit is not known.
- The material can be separated into sized fractions in which both the maximum and minimum particle sizes are known, by passing it through a series of screens of different sizes.
- Screening is commonly adopted for dry particulate solids and occasionally for wet particulate solids.

Materials for Screens

- Metal bars,
- woven wire cloth,
- silk bolting cloth,
- perforated or
- slotted metal plates.

Importance of Screening Operations

- Remove the fines from a feed material before a reduction equipment such as Jaw crusher, Ball Mill or Rod Mill
- Prevent an incompletely crushed material (oversize) from entering into other unit operations.
- Produce a commercial or process grade material to meet specific particle size limits.
- Remove the fines from a finished product prior to shipping.

Types of standard screen series

Usually, for carrying out the analysis, standard screens of either Tyler standard screen series, U.S. sieve series or British standard sieves are used.

The testing sieves with square opening are constructed of woven wire screens, the mesh and dimensions of which are standardized.

Types of standard screen series

Every screen is identified in meshes per inch.

In coarse screens, the term mesh refers to the distance between adjacent wires or rods.

While in fine screens, the mesh is the number of openings per linear inch counting from the center of any wire to a point exactly one inch distance.

Example: A 200 mesh screen will have 200 openings per linear inch.

The minimum clear space between the edges of the opening in the screening surface is termed as screen aperture or screen size opening.

Types of standard screen series

https://www.sepor.com/laboratory-testing-sieve-screens/

https://www.espimetals.com/index.php/faq/327-technical-data/stainless-steel/334-understanding-mesh-sizes

Mesh sizing

Appendix C-8. TYLER STANDARD SCREEN SIZES

Foust, et.al 1960

Standard Interval = $\sqrt{2}$, Aperture, in.	Interval = $\sqrt[4]{2}$			
	Aperture, in.	Aperture, mm	Mesh Number	Wire Diameter, in.
1.050	1.050	26.67	...	0.148
	0.883	22.43	...	0.135
0.742	0.742	18.85	...	0.135
	0.624	15.85	...	0.120
0.525	0.525	13.33	...	0.105
	0.441	11.20		0.105
0.371	0.371	9.423	...	0.092
	0.312	7.925	$2\frac{1}{2}$	0.088
0.263	0.263	6.680	3	0.070
	0.221	5.613	$3\frac{1}{2}$	0.065
0.185	0.185	4.699	4	0.065
	0.156	3.962	5	0.044
0.131	0.131	3.327	6	0.036
	0.110	2.794	7	0.0326
0.093	0.093	2.362	8	0.032
	0.078	1.981	9	0.033
0.065	0.065	1.651	10	0.035
	0.055	1.397	12	0.028
0.046	0.046	1.168	14	0.025
	0.0390	0.991	16	0.0235
0.0328	0.0328	0.833	20	0.0172
	0.0276	0.701	24	0.0141
0.0232	0.0232	0.589	28	0.0125
	0.0195	0.495	32	0.0118
0.0164	0.0164	0.417	35	0.0122
	0.0138	0.351	42	0.0100
0.0116	0.0116	0.295	48	0.0092
	0.0097	0.248	60	0.0070
0.0082	0.0082	0.208	65	0.0072
	0.0069	0.175	80	0.0056
0.0058	0.0058	0.147	100	0.0042
	0.0049	0.124	115	0.0038
0.0041	0.0041	0.104	150	0.0026
	0.0035	0.088	170	0.0024
0.0029	0.0029	0.074	200	0.0021
	0.0024	0.061	230	0.0016
0.0021	0.0021	0.053	270	0.0016
	0.0017	0.043	325	0.0014
0.0015	0.0015	0.038	400	0.0010

US SIEVE to TYLER MESH CONVERSION

US Sieve Size	Tyler Mesh	Opening mm	Opening in
-	2½ Mesh	8.00	0.312
-	3 Mesh	6.73	0.265
No. 3½	3½ Mesh	5.66	0.233
No. 4	4 Mesh	4.76	0.187
No. 5	5 Mesh	4.00	0.157
No. 6	6 Mesh	3.36	0.132
No. 7	7 Mesh	2.83	0.111
No. 8	8 Mesh	2.38	0.0937
No.10	9 Mesh	2.00	0.0787
No. 12	10 Mesh	1.68	0.0661
No. 14	12 Mesh	1.41	0.0555
No. 16	14 Mesh	1.19	0.0469
No. 18	16 Mesh	1.00	0.0394
No. 20	20 Mesh	0.841	0.0331
No. 25	24 Mesh	0.707	0.0278
No. 30	28 Mesh	0.595	0.0234
No. 35	32 Mesh	0.500	0.0197
No. 40	35 Mesh	0.420	0.0165
No. 45	42 Mesh	0.354	0.0139
No. 50	48 Mesh	0.297	0.0117
No. 60	60 Mesh	0.250	0.0098
No. 70	65 Mesh	0.210	0.0083
No. 80	80 Mesh	0.177	0.0070
No.100	100 Mesh	0.149	0.0059
No. 120	115 Mesh	0.125	0.0049
No. 140	150 Mesh	0.105	0.0041
No. 170	170 Mesh	0.088	0.0035
No. 200	200 Mesh	0.074	0.0029
No. 230	250 Mesh	0.063	0.0025
No. 270	270 Mesh	0.053	0.0021
No. 325	325 Mesh	0.044	0.0017
No. 400	400 Mesh	0.037	0.0015

Types of Screen Analysis

Two methods of screen analysis: Differential and Cumulative

Differential Analysis: The screen analysis in which the weight fraction of the material retained on each screen is reported in tabular or graphical form as a function of the mesh size/screen opening.

The fine particles are generally specified according to their screen analysis.

A screen analysis of a material is carried out by using testing sieves.

A set of standard screens is arranged serially in a stack in such way that the coarsest of the screens is at the top and the finest of the screens is at the bottom.

Types of Screen Analysis

The analysis is carried out by placing the sample on the top screen and shaking the stack in a definite manner, either manually or mechanically for a definite length of the time.

The material remained in each screen is removed and weighed.

For reporting the screen analysis, the amount of material retained on each screen is expressed as the weight fraction of the total sample as a function of the mesh size.

The screen analysis of a sample is reported either in a tabular form or graphs.

Types of Screen Analysis

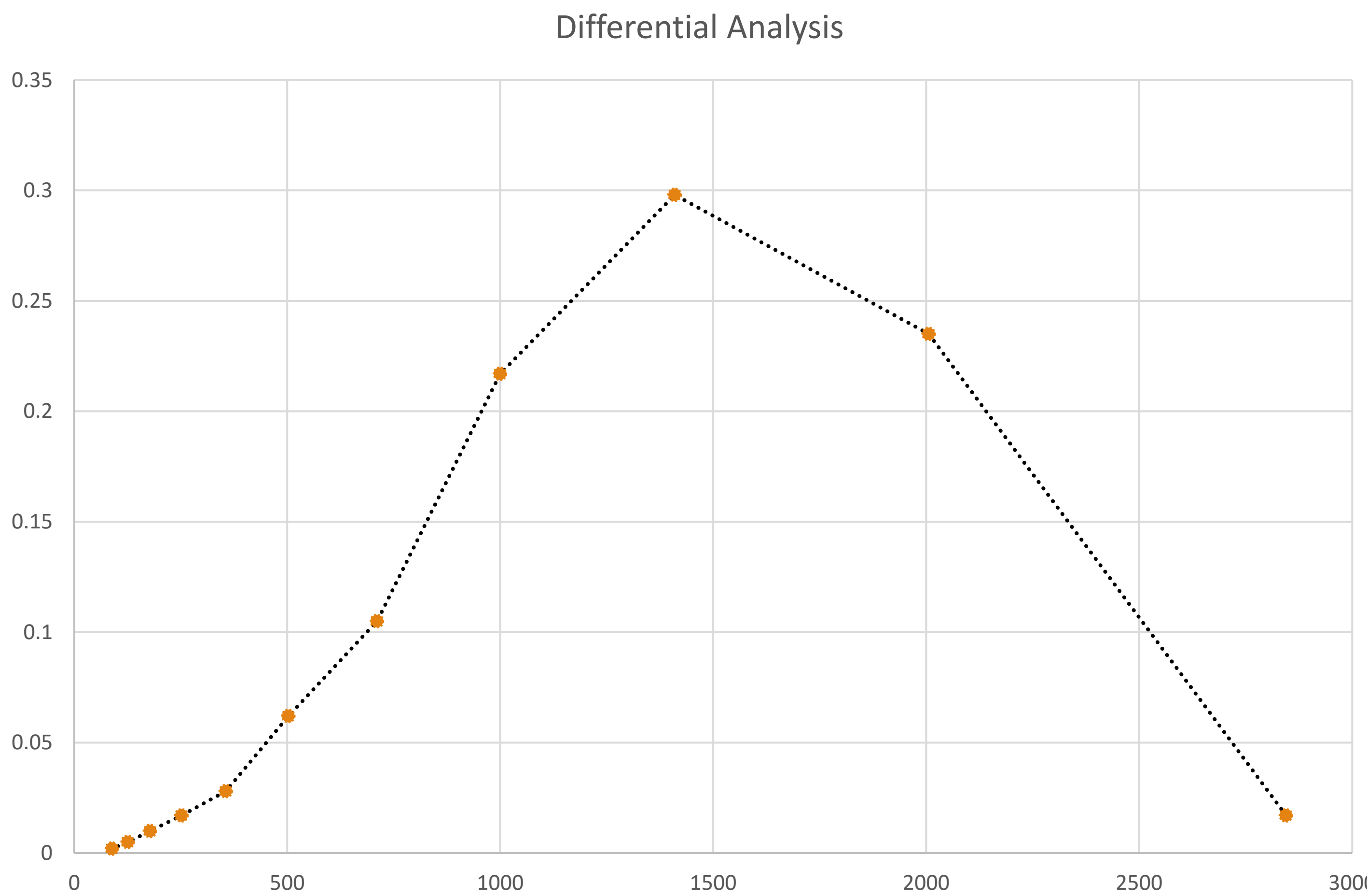
As the particles retained on any one screen are passed through the screen immediately above it, two numbers are needed to specify the size, one for the screen through which the fraction passes and the other for the screen on which that fraction retained.

Hence, the notation 10/14 means through 10 mesh and on 14 mesh.

An analysis reported in a tabular form in this manner is called a differential analysis.

Differential Screen Analysis

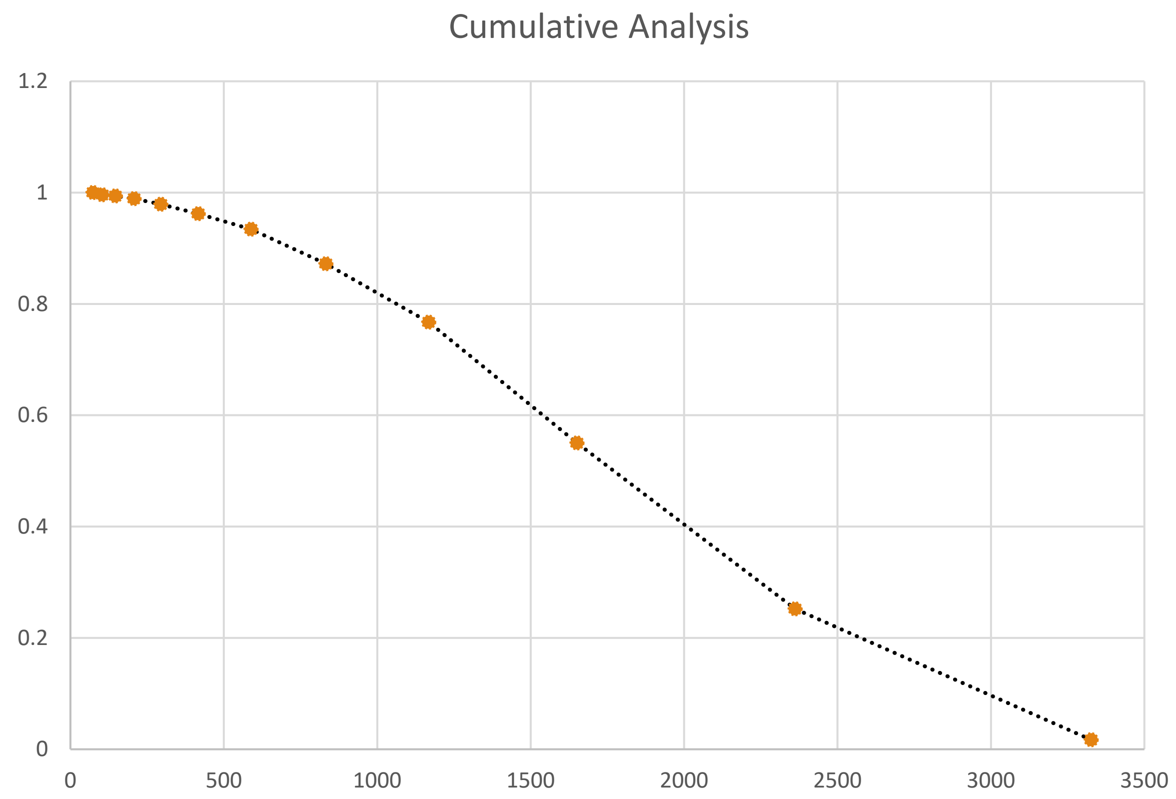
Mesh	Screen Opening (Microns)	Average Particle Size (Microns)	Weight Fraction Retained
6/8	2362	2845	0.017
8/10	1651	2006	0.235
10/14	1168	1410	0.298
14/20	833	1000	0.217
20/28	589	711	0.105
28/35	417	503	0.062
35/48	295	356	0.028
48/65	208	252	0.017
65/100	147	178	0.010
100/150	104	126	0.005
150/200	74	89	0.002
Pan			0.004



The average size of the particle retained on any particular screen is calculated as the arithmetic mean of two screen openings used to obtain the fraction.

Cumulative Analysis

Mesh	Screen Opening (Microns)	Weight Fraction Retained	Cumulative Weight Fraction
6	3327	0	0
8	2362	0.017	+ 0.017
10	1651	0.235	+ 0.252
14	1168	0.298	0.550
20	833	0.217	0.767
28	589	0.105	0.872
35	417	0.062	0.934
48	295	0.028	0.962
65	208	0.017	0.979
100	147	0.01	0.989
150	104	0.005	0.994
200	74	0.002	0.996
Pan		0.004	1



The cumulative analysis is obtained from the differential analysis by adding cumulatively, the individual weight fractions of material retained on each screen, starting with that retained on the largest mesh.

Capacity and Effectiveness of Screens

The capacity and effectiveness are measures of the performance in industrial screening.

The **Capacity** of a screen is the mass of material that can be fed per unit time to a unit area of the screen.

For obtaining maximum effectiveness the capacity must be small and vice versa.

Capacity and Effectiveness of Screens

As the capacity and effectiveness are opposing factors, a reasonable balance must be done between them in actual practice.

The factors which tend to reduce the capacity and lower effectiveness are:

- Blinding,
- Cohesion,
- Motion or speed of the screen,
- Moisture content of the feed

Screen Efficiency

Measuring the success of the screen in closely separating undersize and oversize materials.

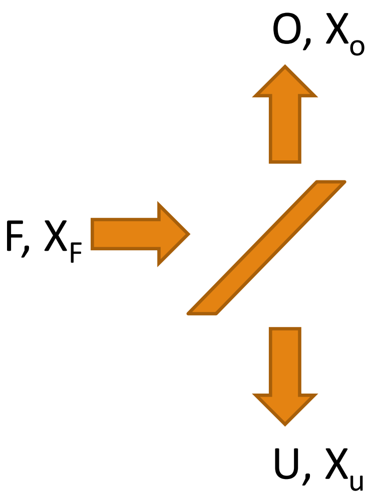
In the case of perfectly functioned screen, all the oversize material would be in the overflow and vice versa.

The screen effectiveness based on the oversize material is the ratio of the amount of oversize material that is actually in the overflow to the amount of oversize material in the feed.

$$\text{Screen effectiveness based on oversize material} = \frac{\text{Quantity of oversize in the overflow}}{\text{Quantity of oversize in the feed}}$$

$$\text{Screen effectiveness based on undersize material} = \frac{\text{Quantity of undersize in the overflow}}{\text{Quantity of undersize in the feed}}$$

Screen Efficiency



Consider that the feed to a screen consist of materials A and B.

Let F = mass flow rate of feed (kg/h)

O = mass flow rate of overflow

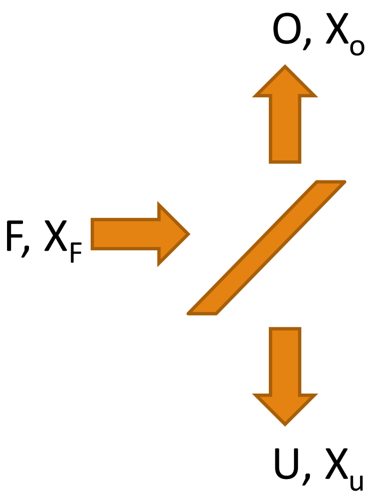
U = Mass flow rate of underflow

X_F = mass fraction of material A in the feed

X_O = mass fraction of material A in the overflow

X_U = mass fraction of material A in the underflow

Screen Efficiency



Overall material balance over the screen:

$$F = O + U$$

A-component balance:

$$X_F \cdot F = X_O \cdot O + X_U \cdot U$$

Overall efficiency of the screen:

$$\boxed{E = \frac{OUX_O\left(1 - X_U\right)}{F^2 X_F\left(1 - X_F\right)}}$$

Foust, et.al 1960

$$\boxed{E = \frac{\left(X_F - X_U\right)\left(X_O - X_F\right)X_O\left(1 - X_U\right)}{\left(X_O - X_U\right)^2\left(1 - X_F\right)X_F}}$$

Factors Effecting the Performance of Screens

Method of Feeding: Fed the material properly, Spread the material evenly over a full width of the screening surface, Must fed at low flow rate.

Screening surfaces: Depends on speed and amplitude of vibration for best performance

Screen Slope: Depends on slope of the screen however slope cannot be increased beyond a certain value because beyond that value material will travel down the screen much faster without getting screened and the screening efficiency reduces drastically.

Factors Effecting the Performance of Screens

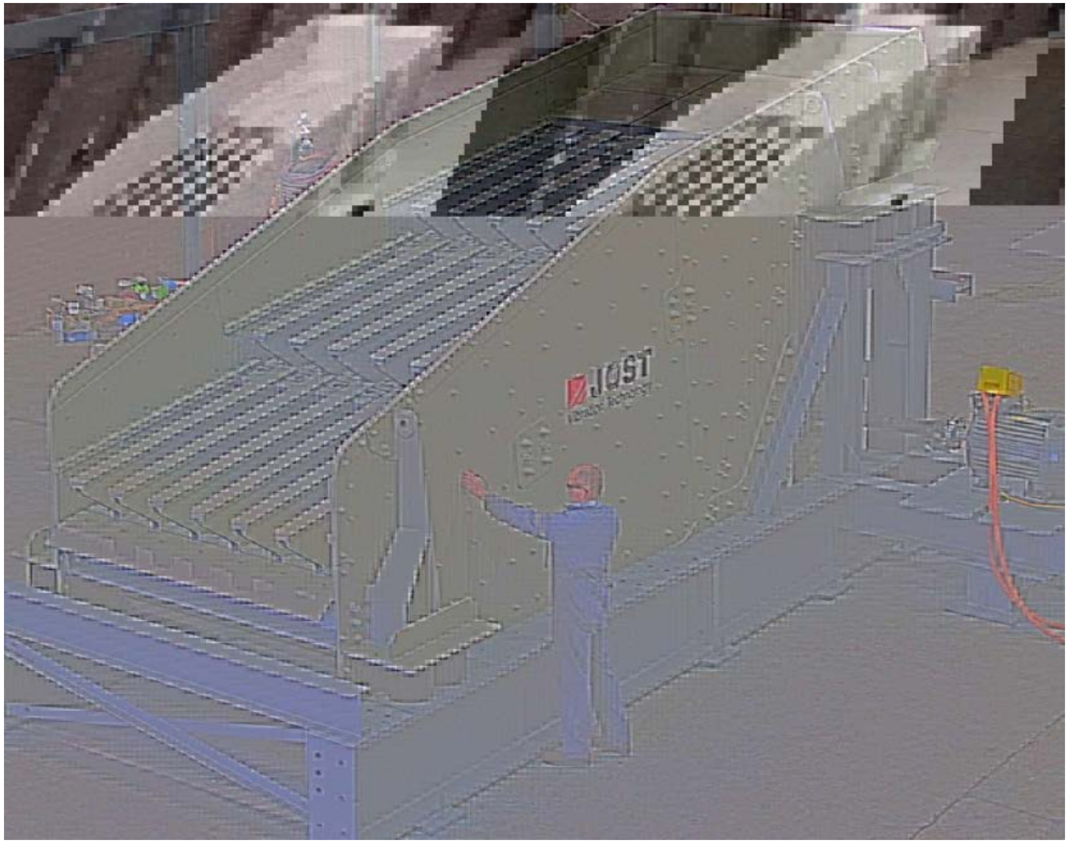
Vibration and Frequency: One has to select proper amplitude and vibration to prevent blinding of the screening cloth and for long bearing life. The frequency of vibration affects the capacity of the screening equipment by regulating the number of contacts between the material and the screening surface.

Moisture in Feed: The moisture associated with feed material adversely affects the screening operation and should be removed.

Screening Equipment

- Grizzlies
- Trommels
- Gyratory Screens
- Vibrating Screens

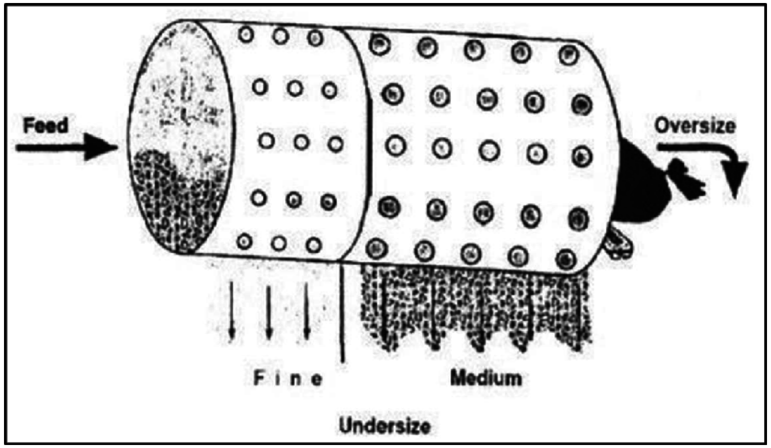
Grizzlies



https://elektromag-joest.com/products/screening/grizzly-screen/

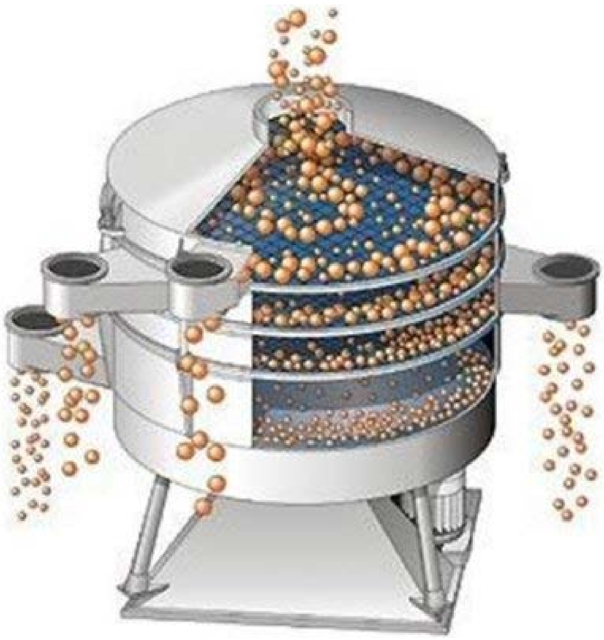
Trommel

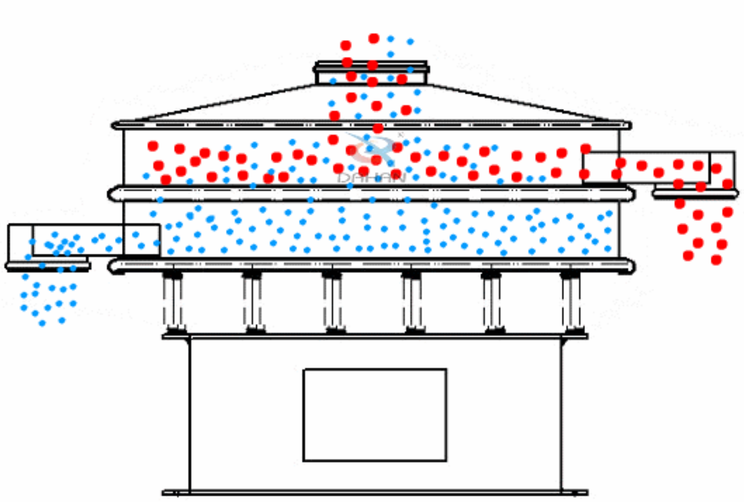
https://westsalem.com/products/trommel-screens/



Al-Blooshi, et.al

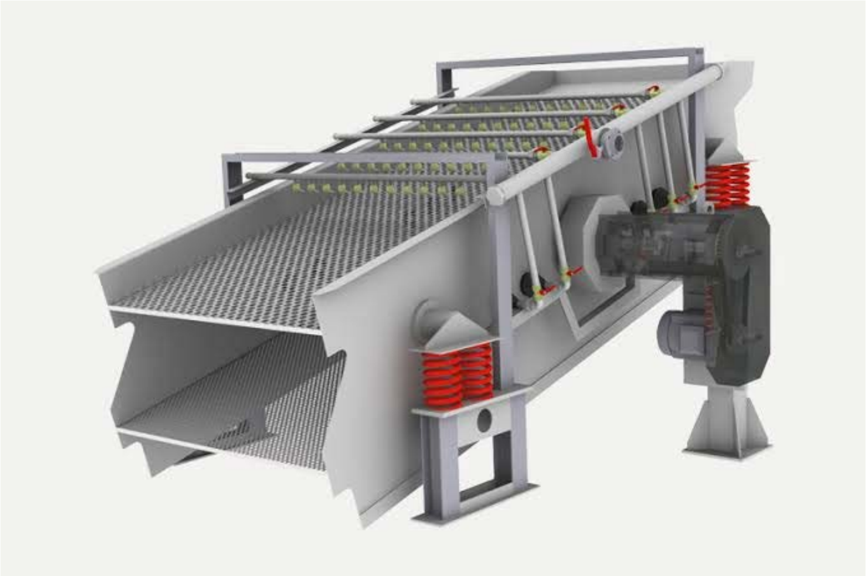
Gyratory Screen



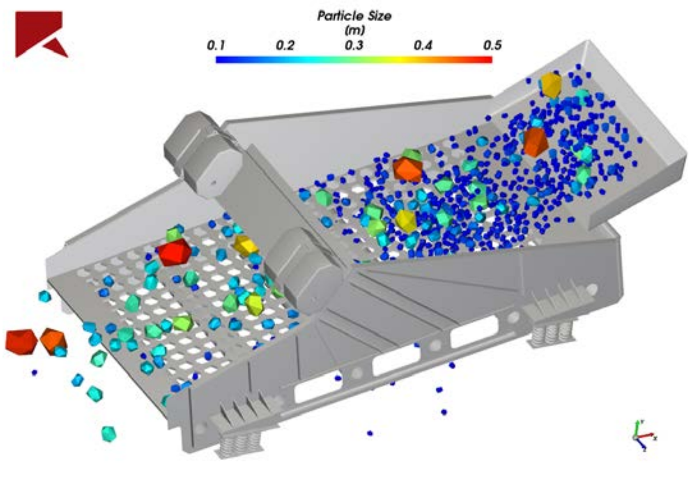


https://www.911metallurgist.com/gyratory-screens/

Vibrating Screen



https://www.microwiremesh.com/advantages-and-common-design-of-vibrating-screen/



https://rocky.esss.co/blog/evaluating-vibrating-screen-efficiency-by-using-the-discrete-element-method/

Example 1

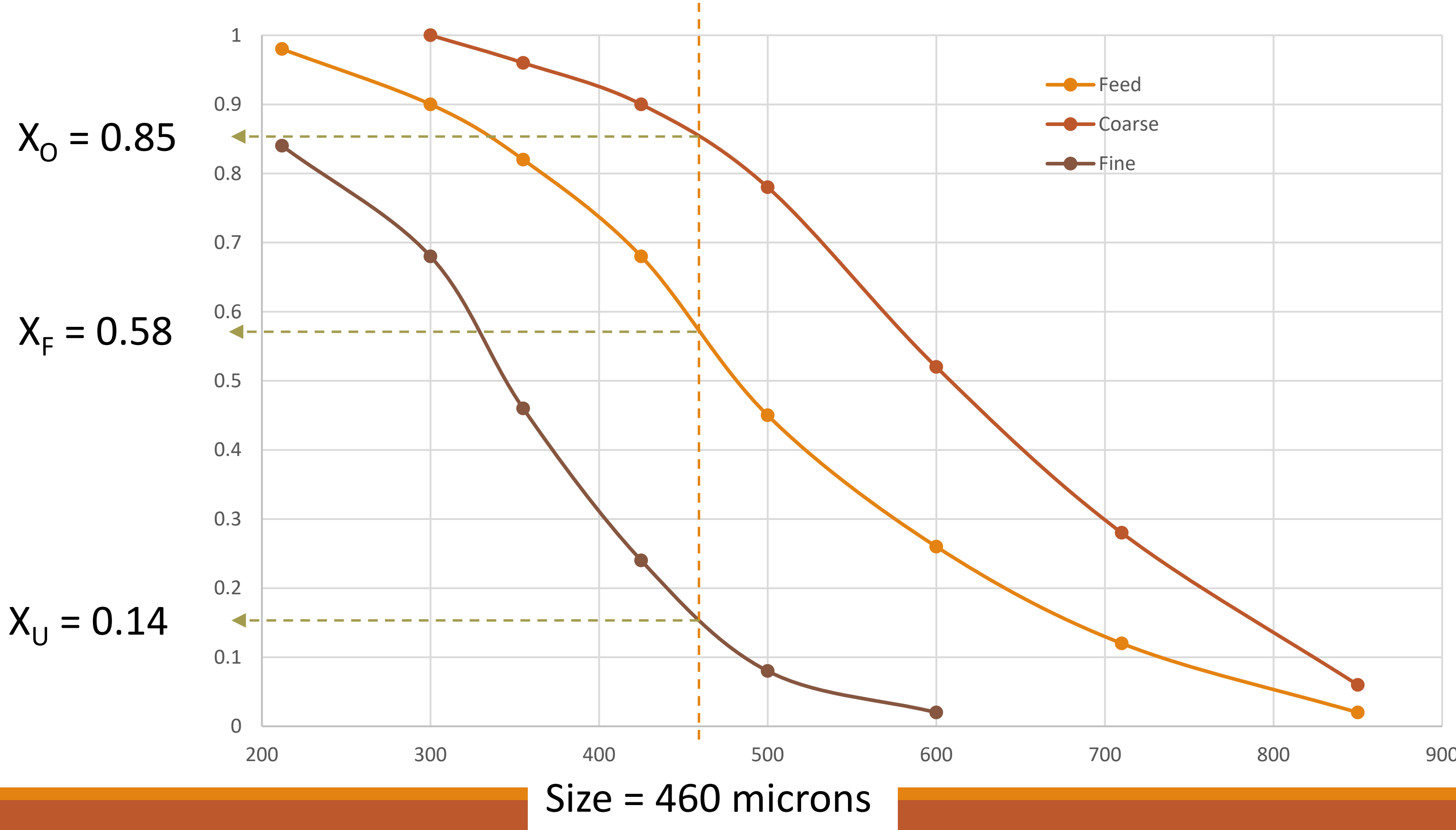
Data on a screening operation is presented in Table 1. Particle size distributions of feed, overflow, and underflow are given as cumulative frequency. The screen used for separation has an aperture size of 460 μm, and 1000 kg/h of feed are processed obtaining 650 kg/h of overflow. Calculate the efficiency of the operation.

Sieve Size (μm)	**Cumulative *Fraction***		
	Feed	Coarse	Fine
850	0.02	0.06	-
710	0.12	0.28	-
600	0.26	0.52	0.02
500	0.45	0.78	0.08
425	0.68	0.90	0.24
355	0.82	0.96	0.46
300	0.90	1.00	0.68
212	0.98	-	0.84

Table 1

Example 1: Solution

Plot the cumulative fraction to get the actual X_F, X_O, X_U:



Example 1: Solution

$X_U = 0.85$, $X_F = 0.58$, $X_O = 0.14$

F = 1000 kg/hr, O = 650 kg/hr

OMB:

$$F = O + U$$
$$1000 = 650 + U$$
$$U = 350$$

U = 350 kg/hr

Overall Efficiency:

$$E = \frac{OUX_O\left(1 - X_U\right)}{F^2 X_F\left(1 - X_F\right)}$$

$$E = 0.683$$

$\boxed{\mathbf{E = 68.3\%}}$

Example 2

The fine fraction of a catalyst retained on a **7-mesh screen (Tyler)** is to be separated to be used in a melting process. The particle size analysis of fractions obtained is given in Table 2. Calculate the efficiency of the screening operation.

Mesh	**Cumulative *Fraction***		
	Feed	Coarse	Fine
4	0.00	0.03	-
6	0.07	0.56	-
8	0.43	0.84	0.02
10	0.85	0.92	0.20
14	0.97	0.96	0.58
20	0.99	1.00	0.83
28	1.00	-	0.91
35	-	-	0.94
65	-	-	0.96
Pan	-	-	1.00

Table 2

Aperture, mm	Mesh Number
26.67	...
22.43	...
18.85	...
15.85	...
13.33	...
11.20	
9.423	...
7.925	2½
6.680	3
5.613	3½
4.699	4
3.962	5
3.327	6
2.794	7
2.362	8
1.981	9
1.651	10
1.397	12
1.168	14
0.991	16
0.833	20
0.701	24
0.589	28
0.495	32
0.417	35
0.351	42
0.295	48
0.248	60
0.208	65
0.175	80

Mesh	Aper. (mm)	Cumulative *Fraction*		
		Feed	Coarse	Fine
4	4.699	0.00	0.03	-
6	3.327	0.07	0.56	-
8	2.362	0.43	0.84	0.02
10	1.651	0.85	0.92	0.20
14	1.168	0.97	0.96	0.58
20	0.833	0.99	1.00	0.83
28	0.589	1.00	-	0.91
35	0.417	-	-	0.94
65	0.208	-	-	0.96
Pan		-	-	1.00

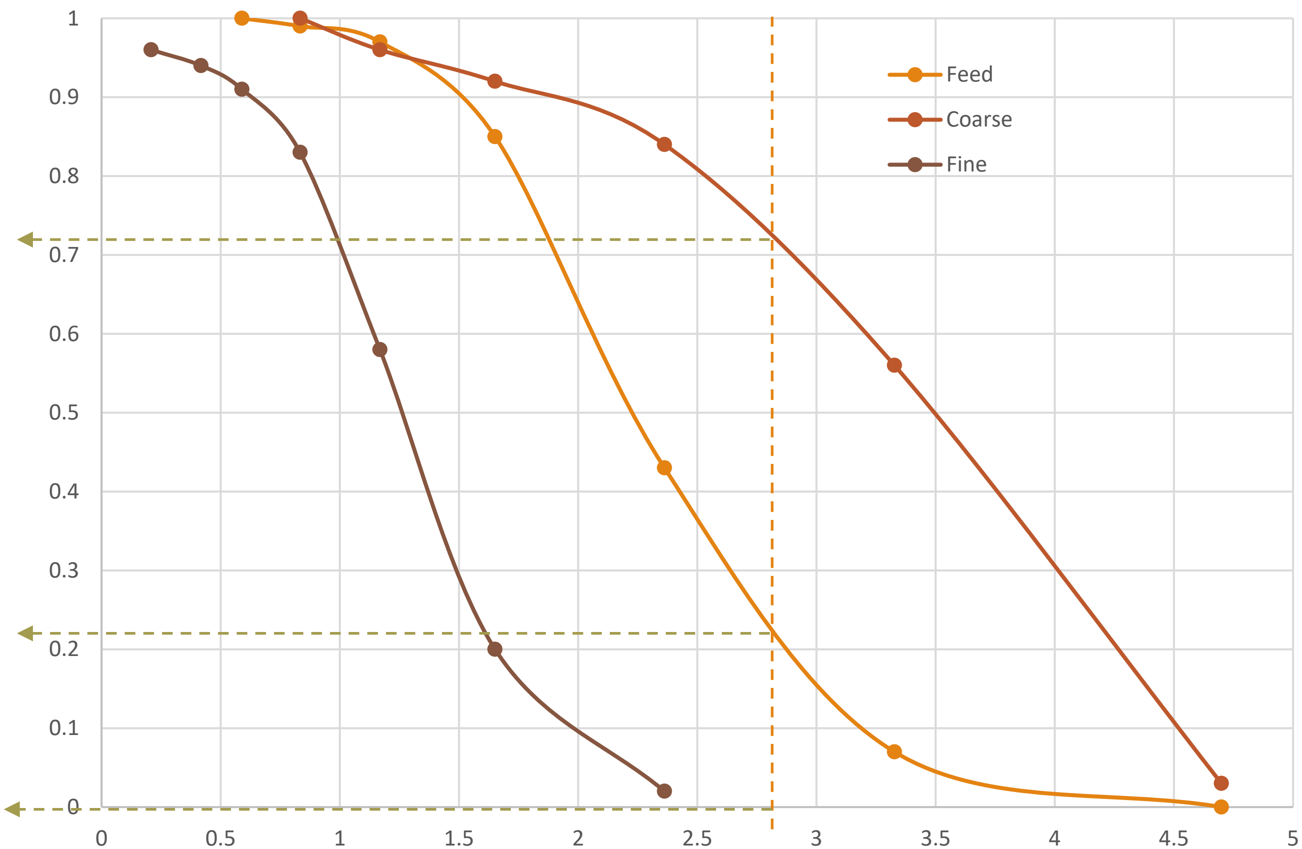
Example 2: Solution

Plot the cumulative fraction to get the actual X_F, X_O, X_U:

$X_O = 0.72$

$X_F = 0.22$

$X_U = 0$



Mesh 7 = 2.794 mm

Example 2: Solution

$X_U = 0$, $X_F = 0.22$, $X_O = 0.72$

Overall Efficiency:

$$E = \frac{\left(X_F - X_U\right)\left(X_O - X_F\right)X_O\left(1 - X_U\right)}{\left(X_O - X_U\right)^2\left(1 - X_F\right)X_F}$$

$$E = \frac{(0.22)(0.72 - 0.22)0.72(1)}{(0.72)^2(1 - 0.22)0.22}$$

$$E = 0.8503$$

E = 85.03%

References:

Principles of unit operations, 2nd edition (Foust, Alan S.; Wenzel Leonard A.; Clump, Curtis W.; Maus, Lois; Anderson, L. Bryce)

Unit Operations of Particulate Solids, Theory and Practice (Ortega-Rivas, Enrique) https://doi.org/10.1201/b11059