CHBE 344: Course Overview

Unit 1: Characterization and Creation of Particles

Unit 2: Mechanical Separations

Unit 3: Thermal Separations and Other Unit Operations

Unit 2: Mechanical Separations

Topics:

- Screening and Classification
  - batch vs. continuous, effectiveness, other considerations
- Sedimentation (Decanting)
  - settling velocity of single particles, hindered settling, batch data, ideal continuous sedimentation, elutriation, design considerations
- Filtration
  - types of filters, flow through porous media, filter cakes, constant pressure filtration, constant flux filtration
- Centrifugation
  - settling velocity of single particles, design considerations
- Chromatography
  - operation, types of columns, surface area measurements, adsorption isotherms
- Others

Unit 2: Mechanical Separations

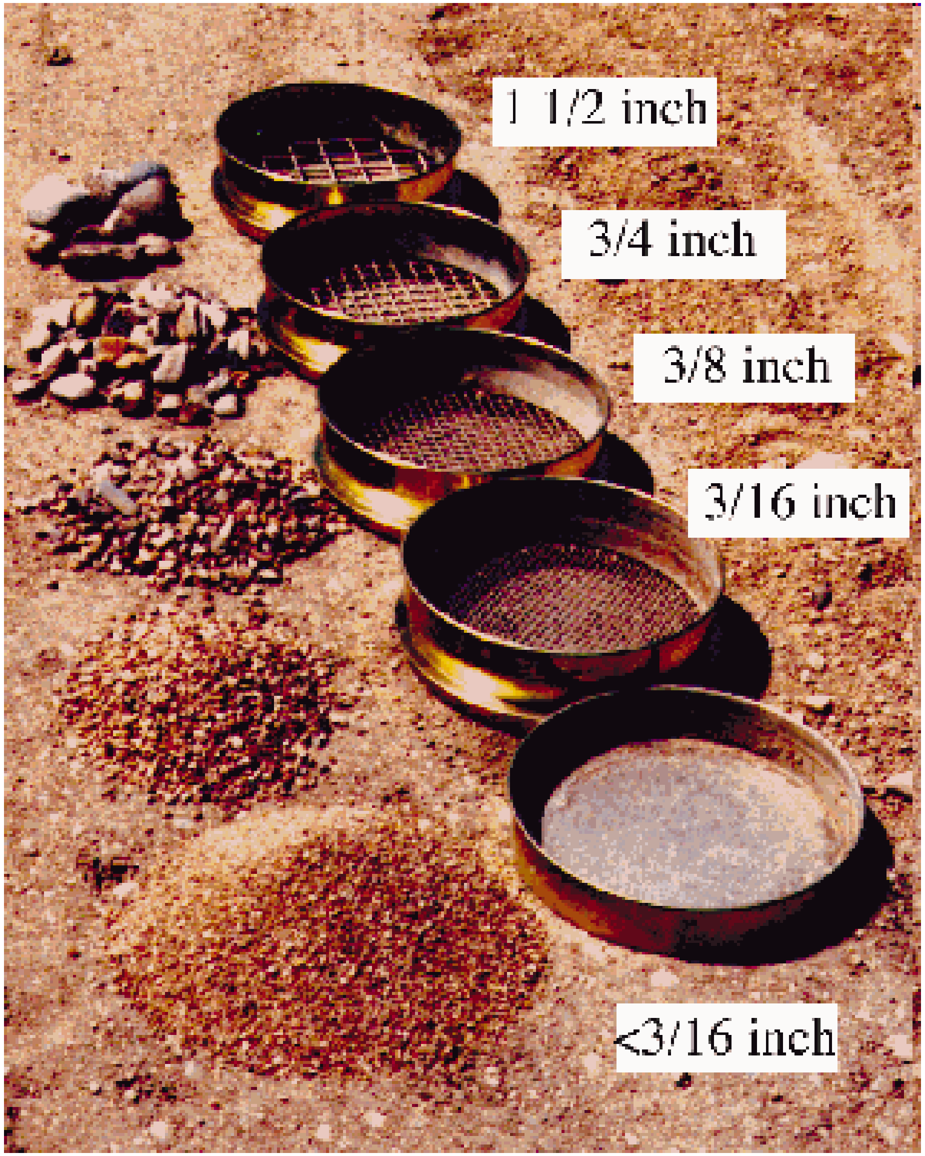
Objectives:

- **Describe** the fundamental physics underlying several separations processes including
  - sedimentation, filtration, centrifugation and chromatography
- **Apply** basic process design equations for the separations processes listed above to **calculate** some process parameters such as
  - screening efficiency, sedimentation velocity, separation performance, pressure drop, filtration time, centrifugation capacity, adsorption parameters
- **Apply** computing programming to carry out processing calculations using the following techniques in Matlab or Python
  - functions, plotting, solving systems of ODE's, root finding, curve fitting

Importance of Screening in Engineering

- **Mineral Processing Industry**
  - Ores are taken from mines in the form of rocks that must be reduced in size for further processing
- **Pulp and Paper Industry**
  - Wood chips, which are the source of fiber, must be in the correct size range for the pulping process
- **Fertilizer Industry**
  - Fertilizer pellets should be of a certain size so as to give the optimum rate of release of nutrients to the soil
- **Wastewater Treatment.**
  - Sewers discharge a lot of stuff like rocks, stones, sticks, rags, cans, bottles, broken glass, etc., which could damage process equipment such as pumps. So the sewage flow is screened prior to processing it to remove such oversized materials.

Sieving – Batch Process



Mesh Sizes

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 in.	Nominal aperture µm	Sieve no.	Nominal aperture in.	Nominal aperture µm	Sieve no.	Nominal aperture in.	Nominal aperture µm	Sieve no.	Nominal aperture in.	Nominal aperture 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
85	0.0070	178	80	0.0062	157	65	0.0082	208	70	0.0083	210
			70	0.0071	180				60	0.0098	250
72	0.0083	211	60	0.0083	211	60	0.0097	246	50	0.0117	297
60	0.0099	251							45	0.0138	350
52	0.0116	295	50	0.0100	254	48	0.0116	295	40	0.0165	420
			40	0.0125	347	42	0.0133	351	35	0.0197	500
44	0.0139	353				35	0.0164	417	30	0.0232	590
36	0.0166	422	30	0.0166	422	32	0.0195	495			
30	0.0197	500				28	0.0232	589			
25	0.0236	600									
22	0.0275	699	20	0.0250	635	24	0.0276	701	25	0.0280	710
18	0.0336	853	16	0.0312	792	20	0.0328	833	20	0.0331	840
16	0.0395	1003				16	0.0390	991	18	0.0394	1000
14	0.0474	1204	12	0.0416	1056	14	0.0460	1168	16	0.0469	1190
12	0.0553	1405	10	0.0500	1270	12	0.0550	1397			
10	0.0660	1676	8	0.0620	1574	10	0.0650	1651	14	0.0555	1410
8	0.0810	2057				9	0.0780	1981	12	0.0661	1680
7	0.0949	2411				8	0.0930	2362	10	0.0787	2000
6	0.1107	2812	5	0.1000	2540	7	0.1100	2794	8	0.0937	2380
5	0.1320	3353				6	0.1310	3327			
						5	0.1560	3962	7	0.1110	2839
						4	0.1850	4699			
									6	0.1320	3360
									5	0.1570	4000
									4	0.1870	4760

Types of Screening Equipment

Vibrating Screen

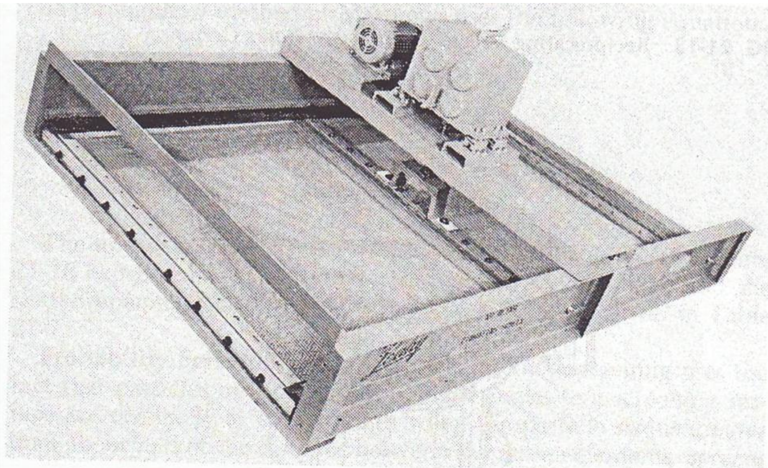
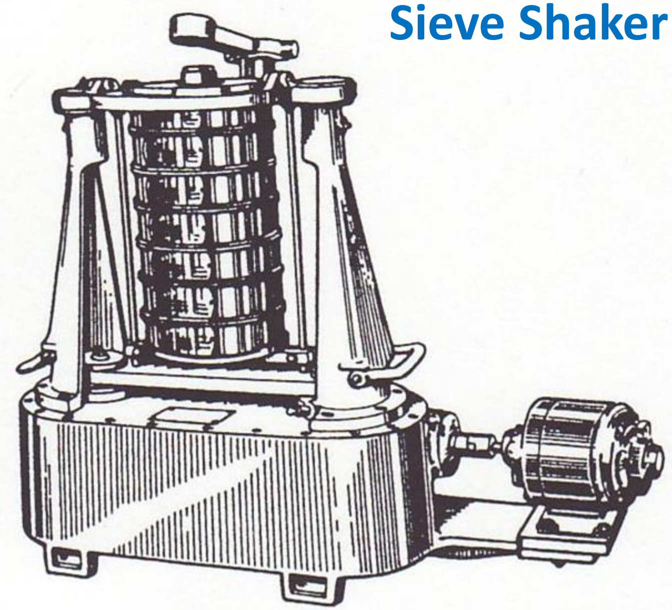


FIG. 21-11 Mechanically vibrated horizontal screen. *(Courtesy of Diester Concentrator Company, Inc.)*

Sieve Shaker



Reciprocating Screen

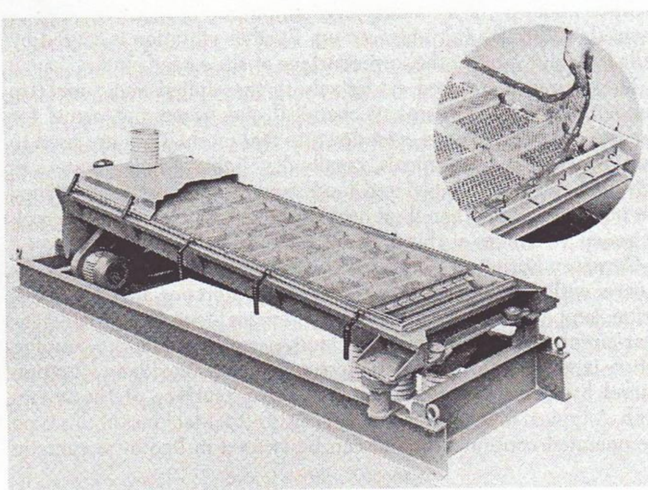


FIG. 21-13 Reciprocating screen. *(Courtesy of Rotex Corp.)*

Inclined Screen

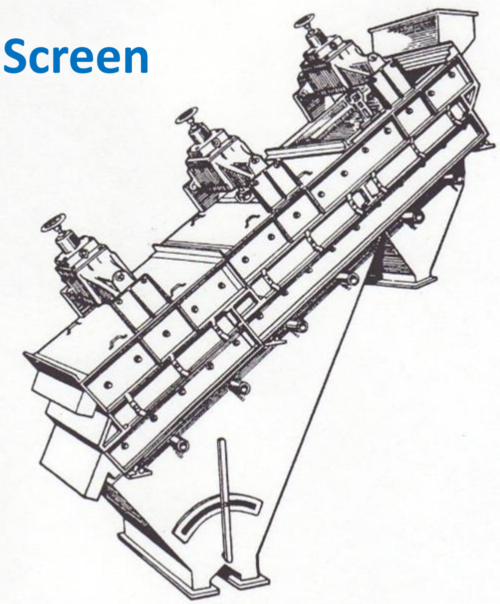
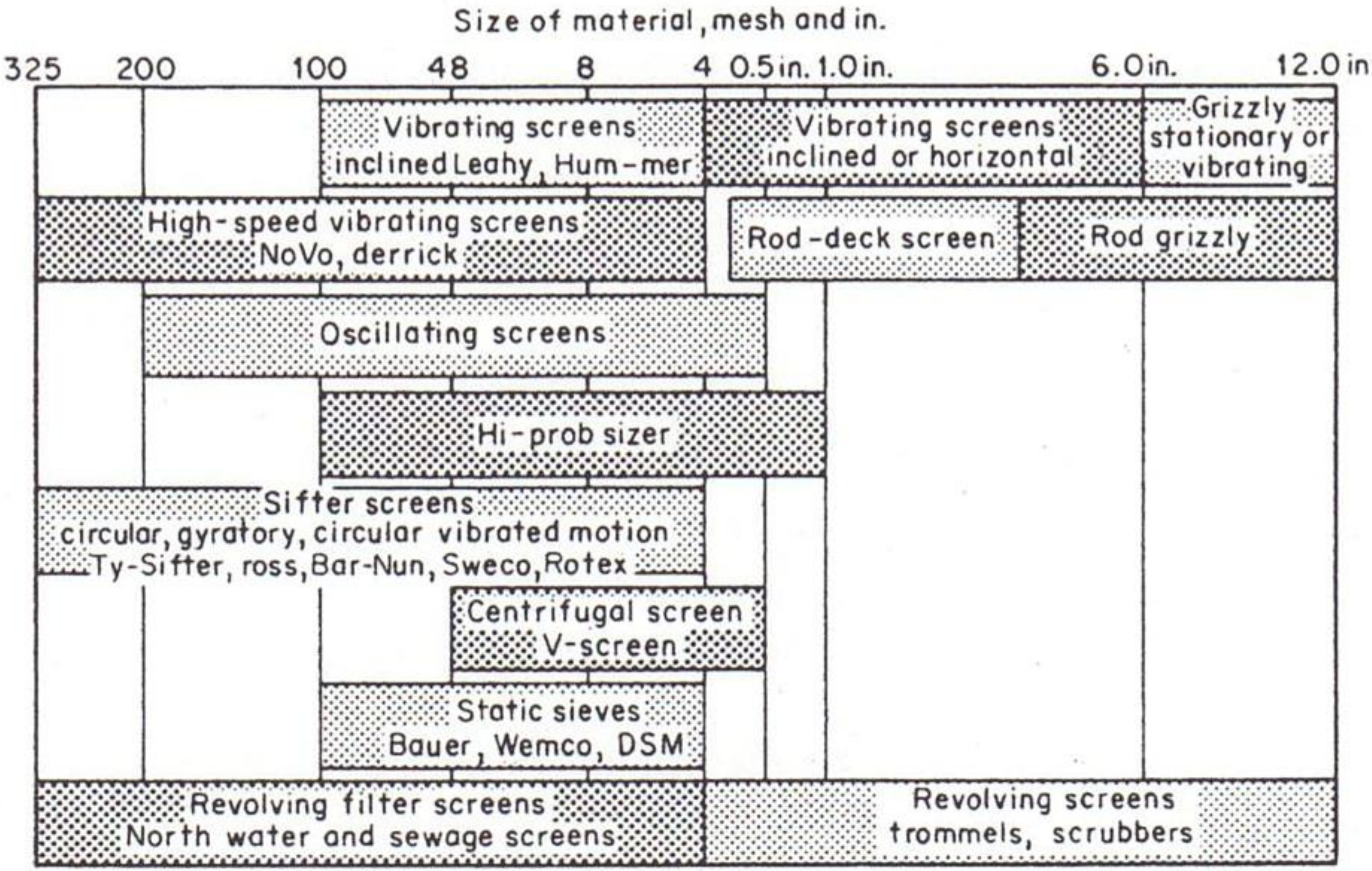
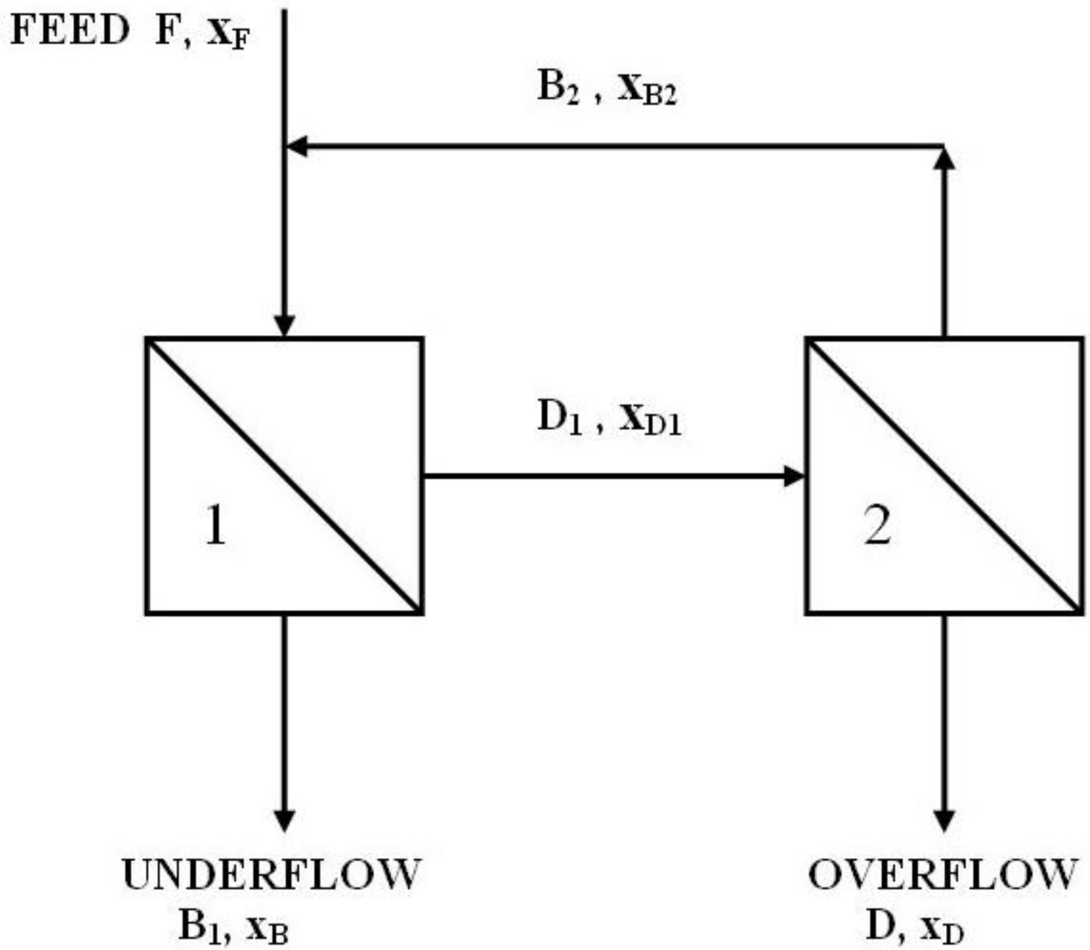


FIG. 21-12 Type 38 Hum-mer screen. *(W. S. Tyler, Inc.)*

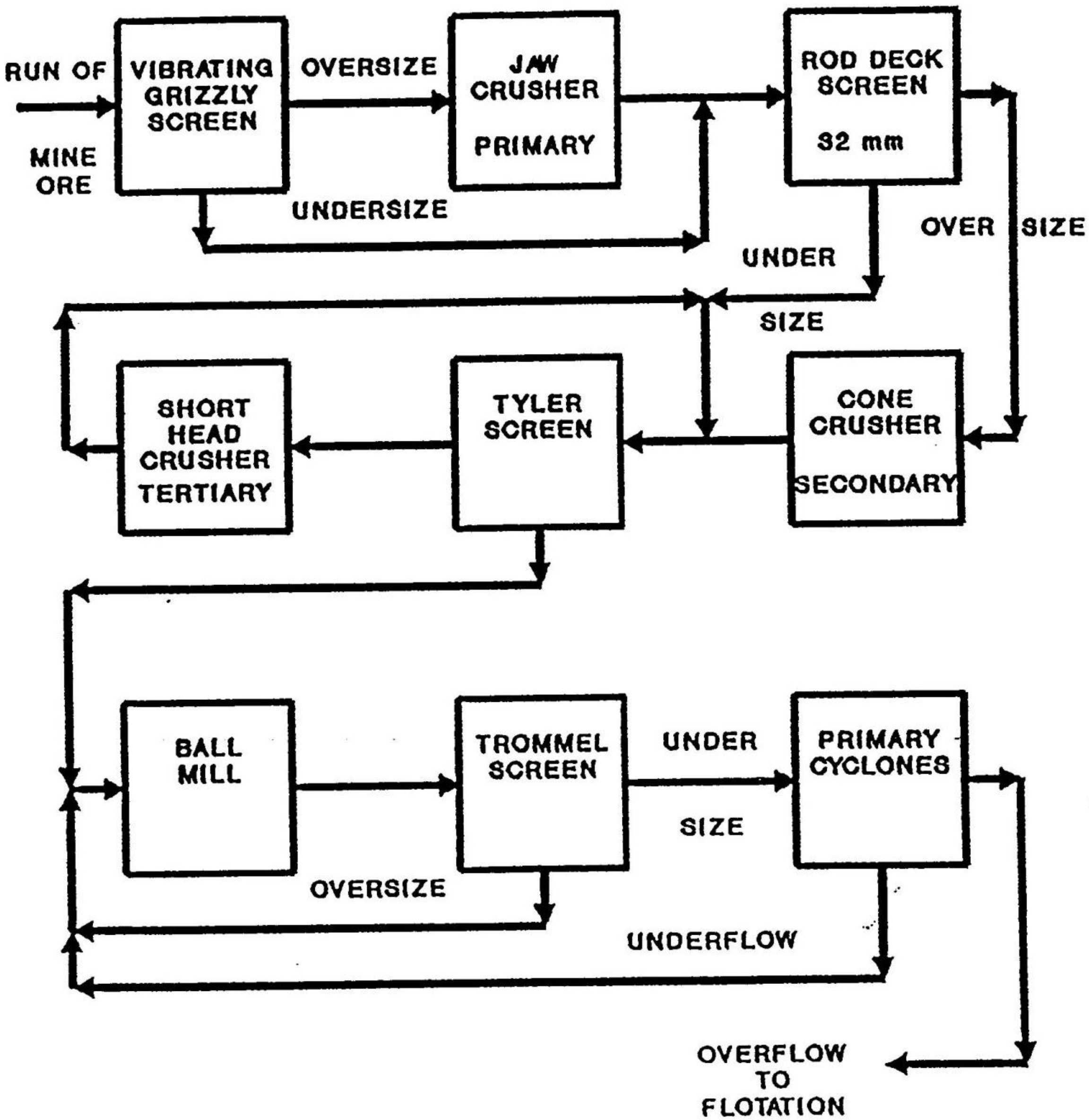
Selection of Screening Equipment



Cascades of Screens



Typical Mineral Processing Flow Sheet



Cloud Harvesting in the Andes

https://www.newyorker.com/tech/elements/could-harvesting-fog-help-solve-the-worlds-water-crisis

Sedimentation

Thickener

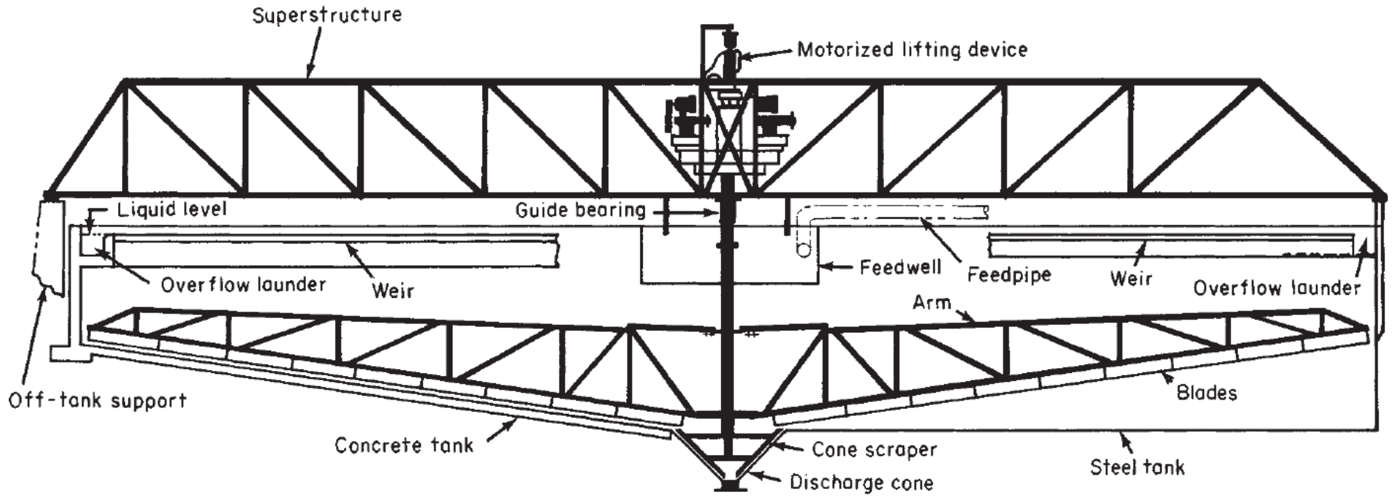


FIG. 18-86 Unit thickener with bridge-supported mechanism. (*EIMCO Process Equipment Co.*)

Perry's chemical engineers' handbook. — 7th ed.

Clarifier

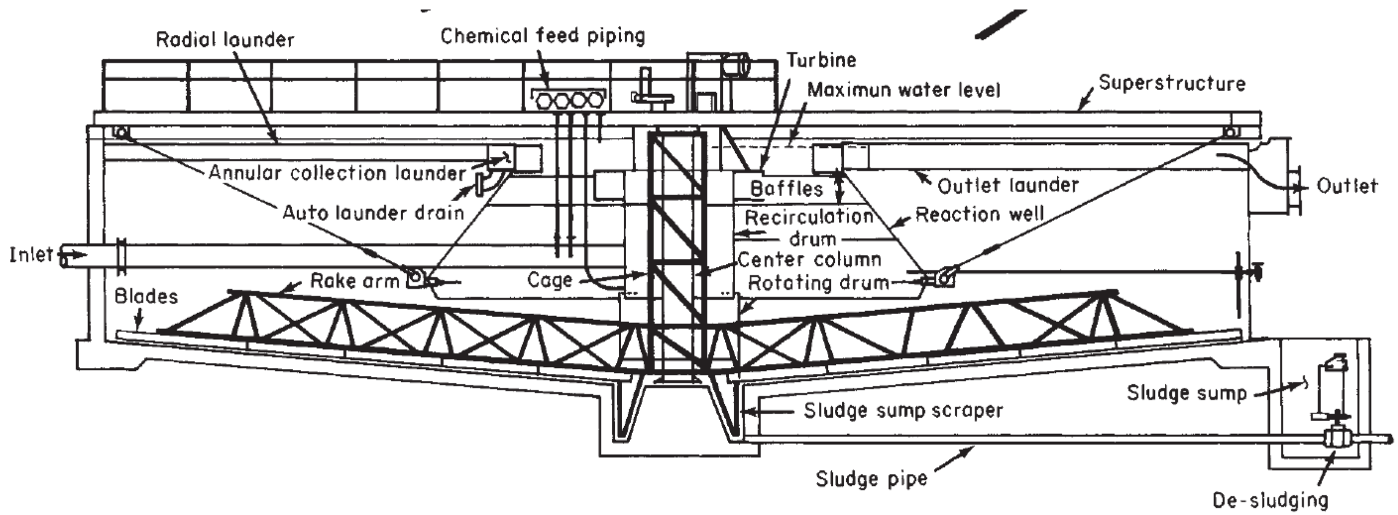
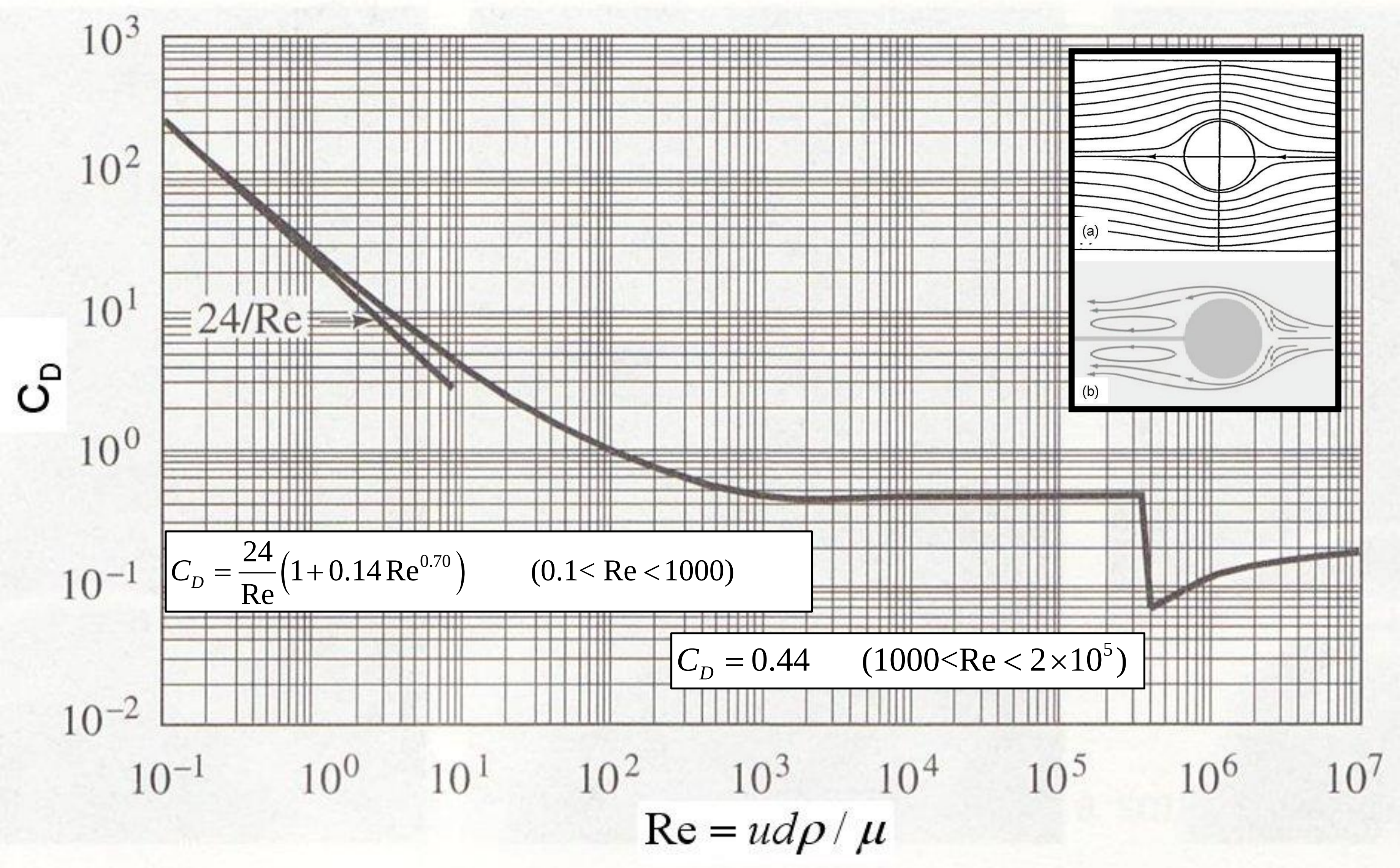


FIG. 18-89 Reactor-clarifier of the high-rate solids-contact type. (*EIMCO Process Equipment Co.*)

Waste water treatment (0 – 1:55 min)

Drag Coefficient on Spherical particles



Drag Coefficient for Non-spheres

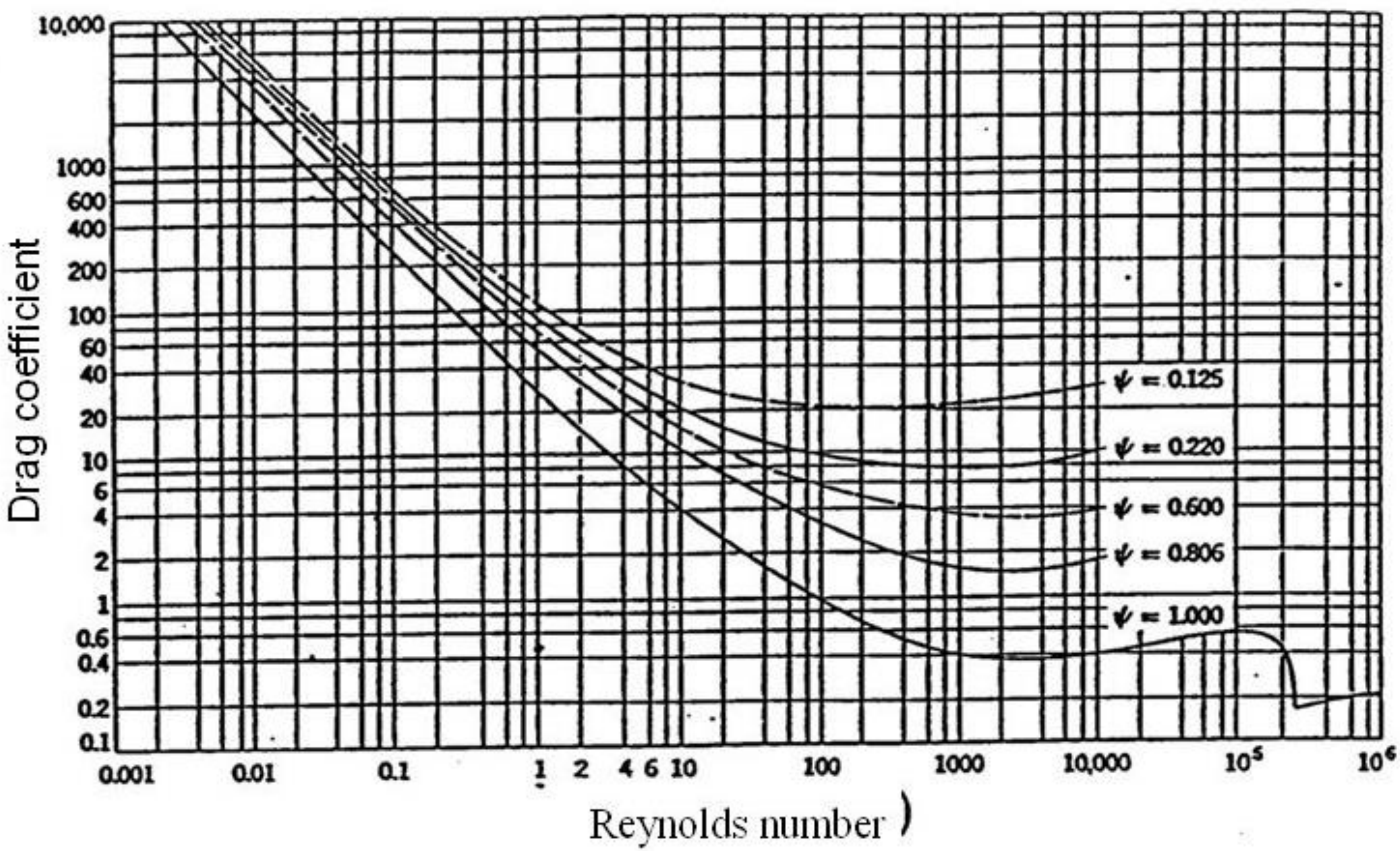


Figure 4.10: Drag coefficient as a function of Re and sphericity

Some values of sphericity

Material	Nature of grain	Ψ
Arnould's wire spirals	. . . .	0.2
Berl saddles	. . . .	.3
Coal dust, natural (up to $\frac{3}{8}$ in.)	. . . .	.65
Coal dust, pulverized	. . . .	.73
Cork	. . . .	.69
Flue dust	Fused, spherical	.89
Flue dust	Fused, aggregates	.55
Fusain fibers	. . . .	.38
Glass, crushed	Jagged	.65
Mica flakes	. . . .	.28
Raschig rings	. . . .	.3
Sand:		
Average for various types	. . . .	.75
Flint sand	Jagged	.65
Flint sand	Jagged flakes	.43
Ottawa sand	Nearly spherical	.95
Sand	Rounded	.83
Sand	Angular	.73
Wilcox sand	Jagged	.60
Tungsten powder	. . . .	.89

Drag Coefficient on Disks and Cylinders

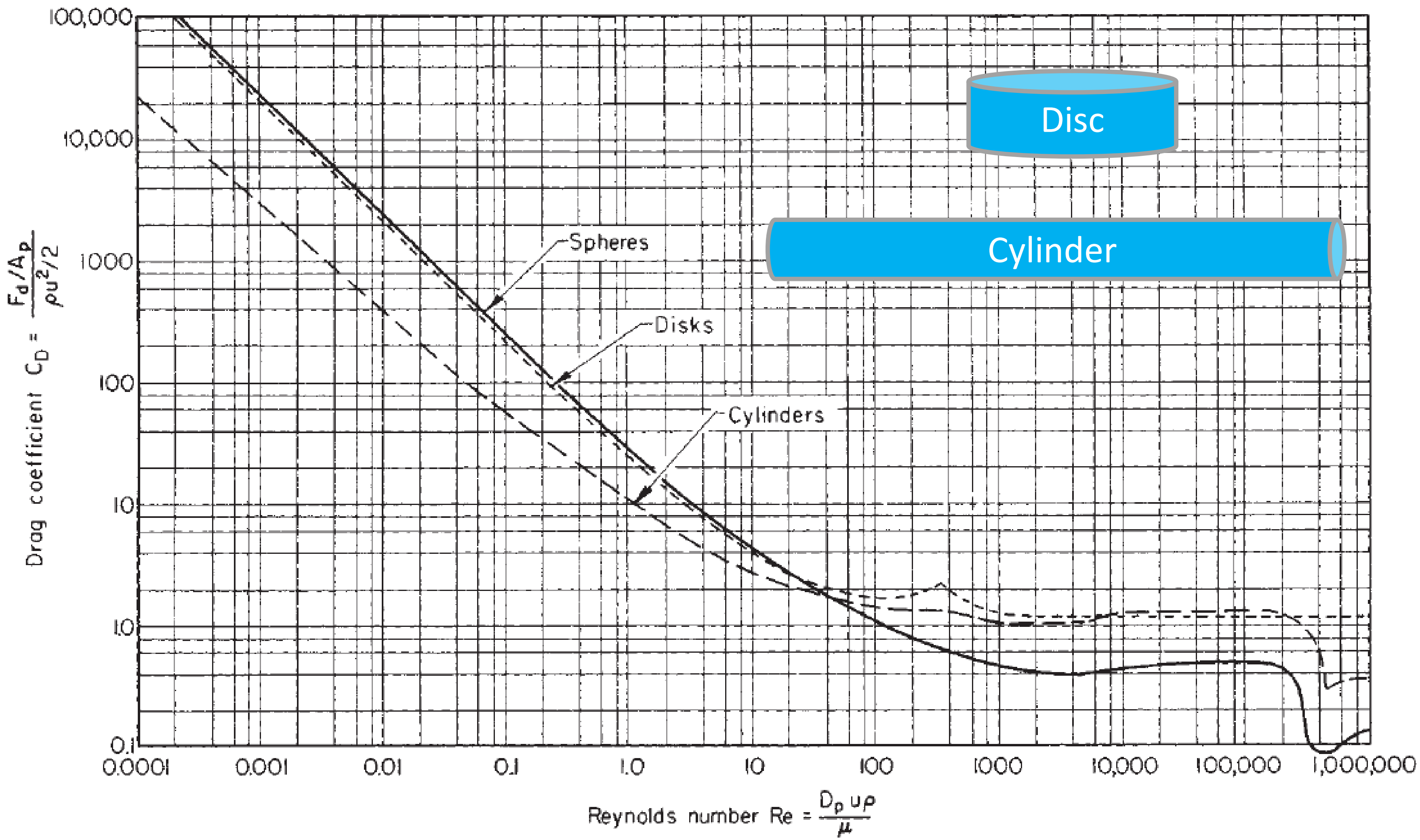


FIG. 6-57 Drag coefficients for spheres, disks, and cylinders: A_p = area of particle projected on a plane normal to direction of motion; C = overall drag coefficient, dimensionless; D_p = diameter of particle; F_d = drag or resistance to motion of body in fluid; Re = Reynolds number, dimensionless; u = relative velocity between particle and main body of fluid; μ = fluid viscosity; and ρ = fluid density. (*From Lapple and Shepherd,* Ind. Eng. Chem., **32**, *605* [*1940*].)

Hindered Settling

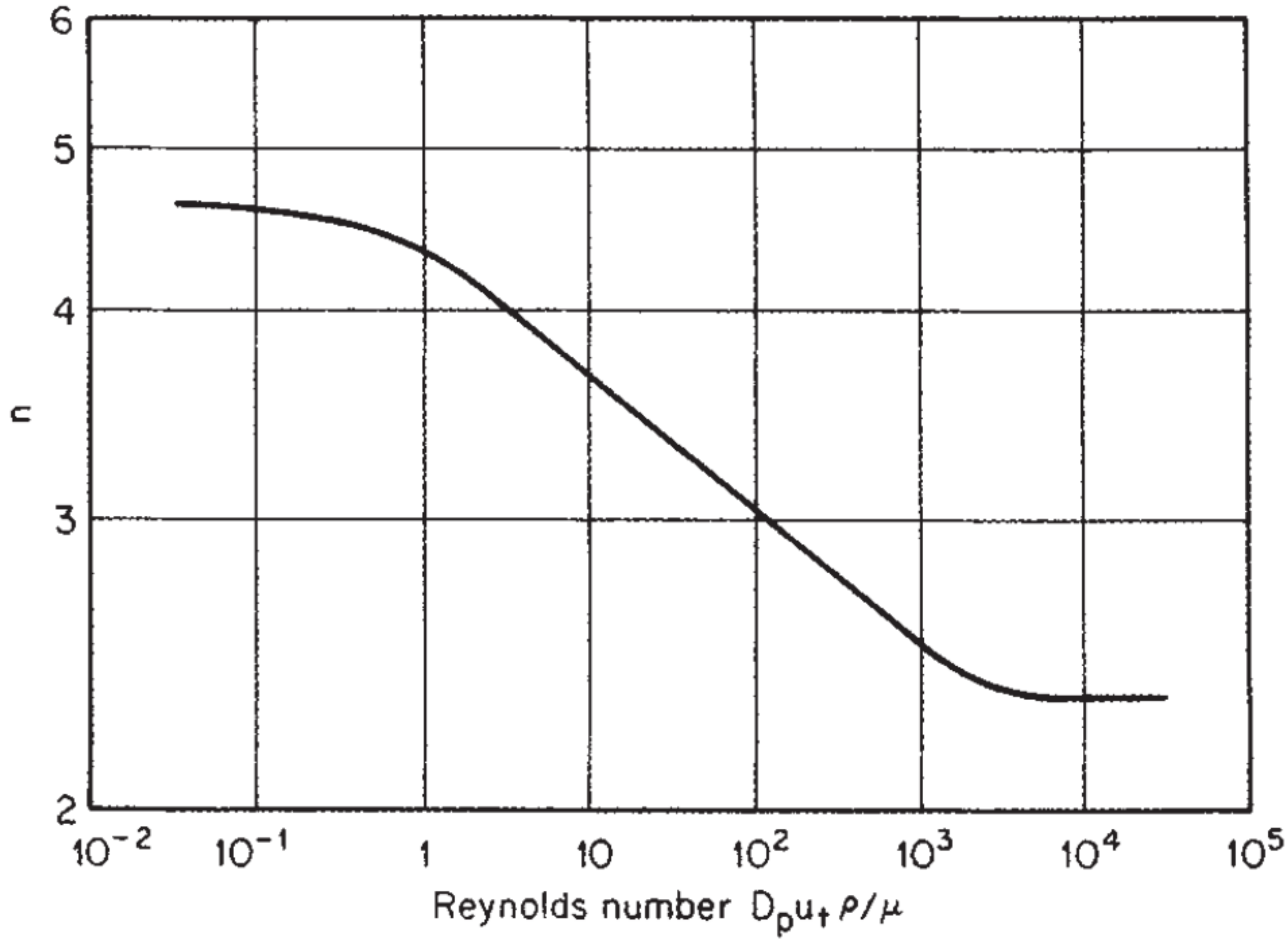
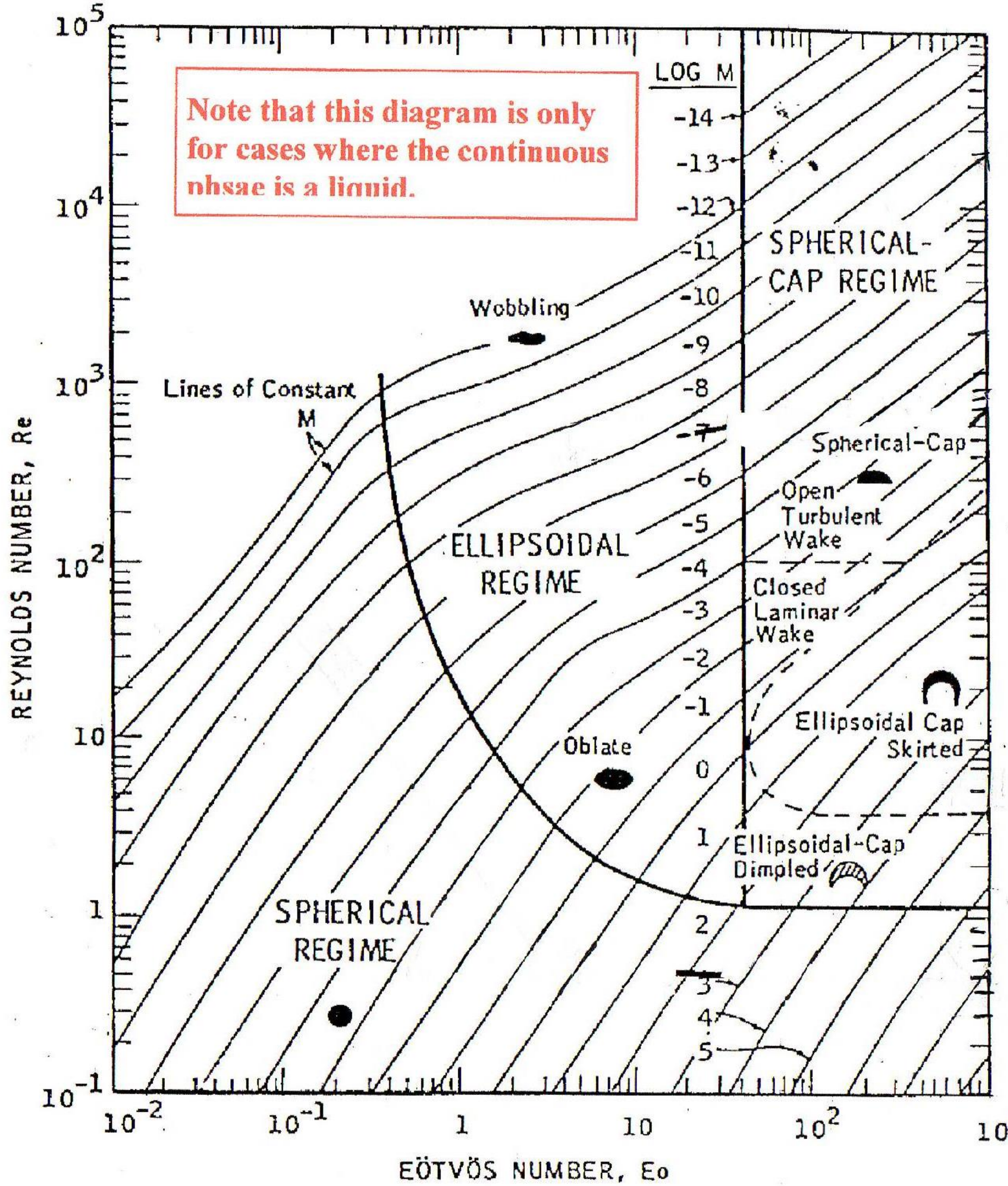


FIG. 6-58 Values of exponent n for use in Eq. (6-240). (*From Maude and Whitmore,* Br. J. Appl. Phys., **9,** *481* [*1958*]. *Courtesy of the Institute of Physics and the Physical Society.*)

Boycott effect

Estimates for Bubble and Drops



Terminal Velocity of Bubbles in Water

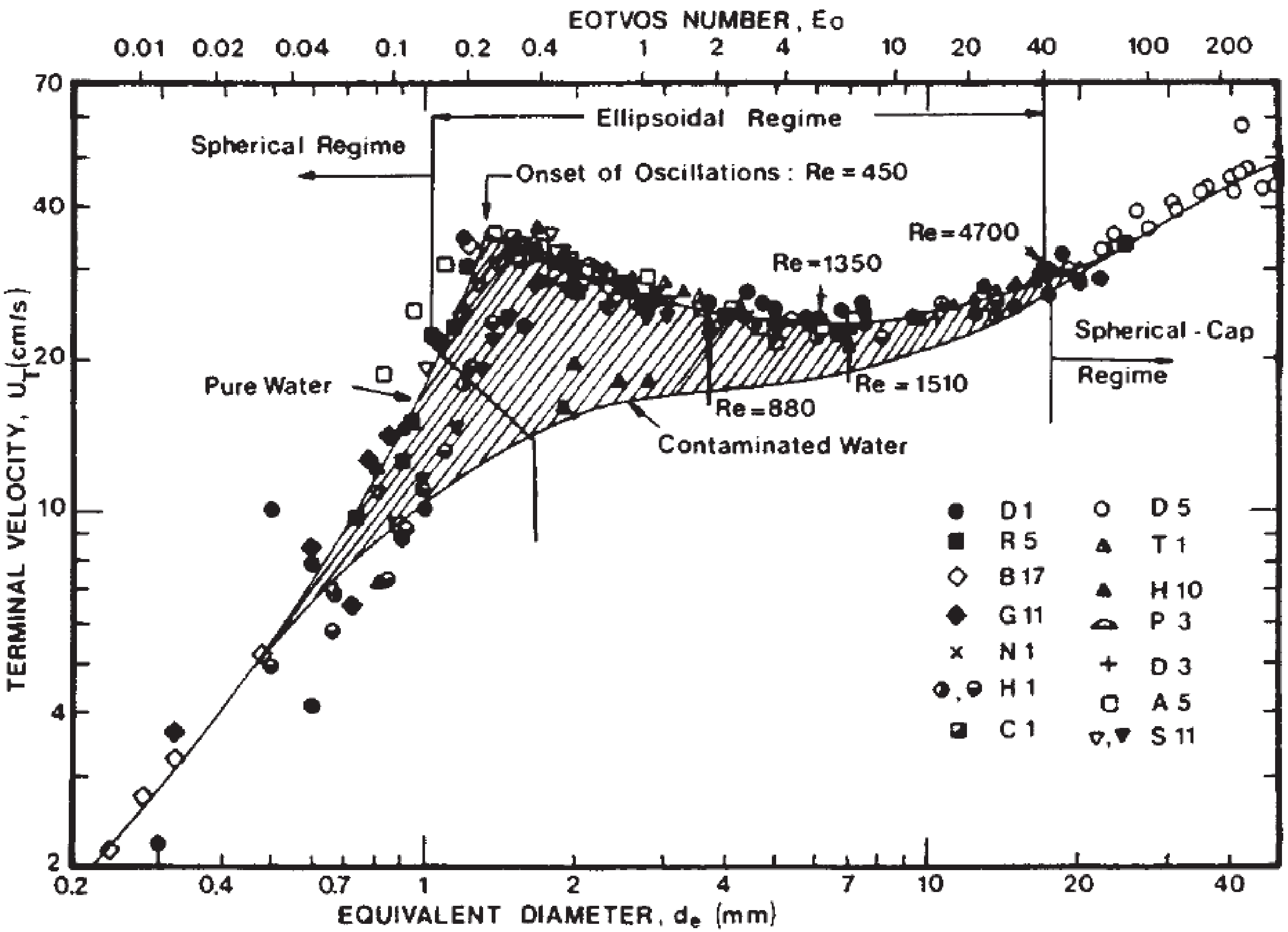
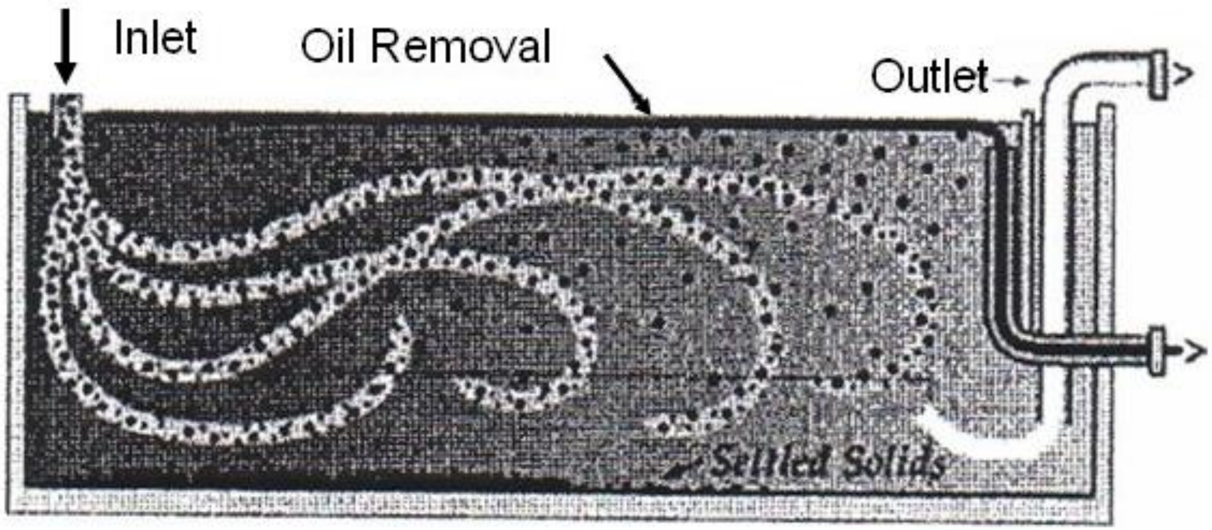
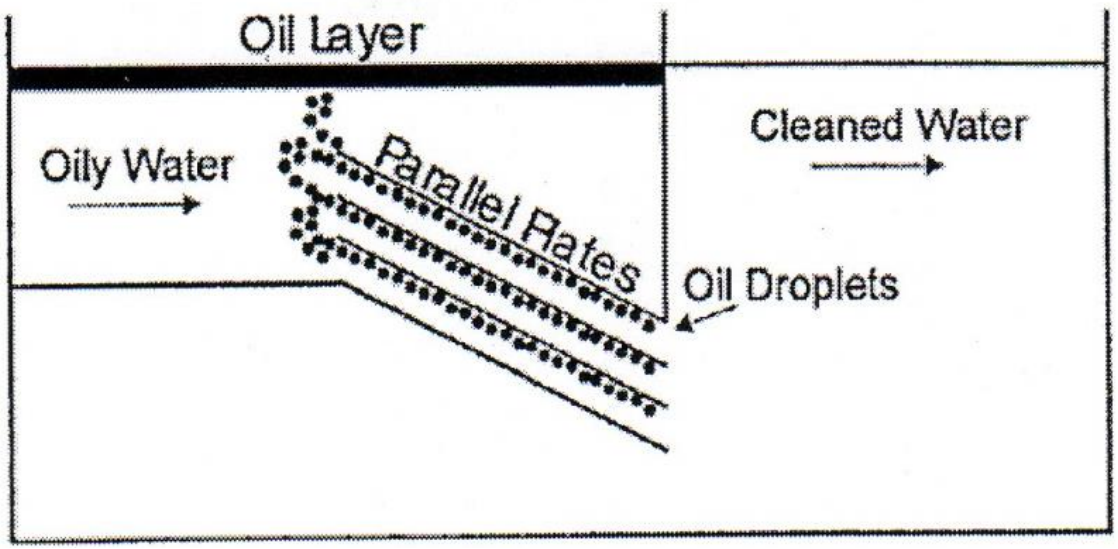


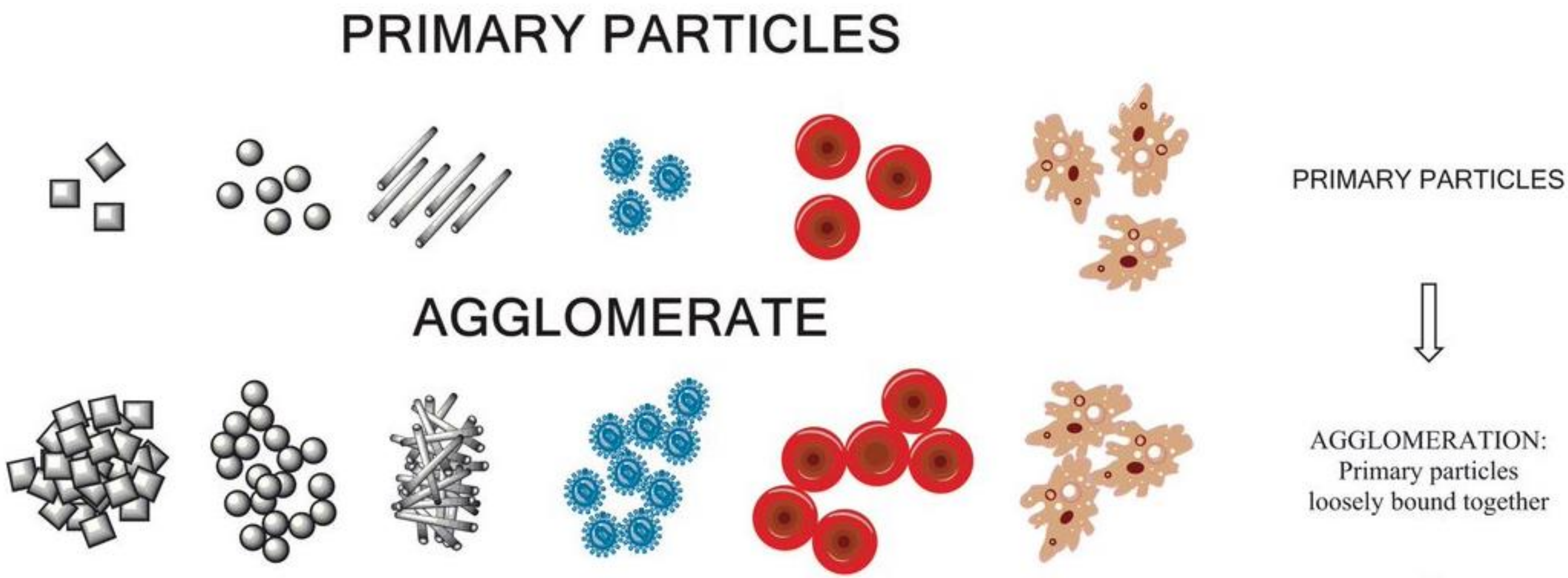
FIG. 6-59 Terminal velocity of air bubbles in water at 20°C. (*From Clift, Grace, and Weber,* Bubbles, Drops and Particles, *Academic, New York, 1978*).

Gravity Separation of Oil Droplets from Water

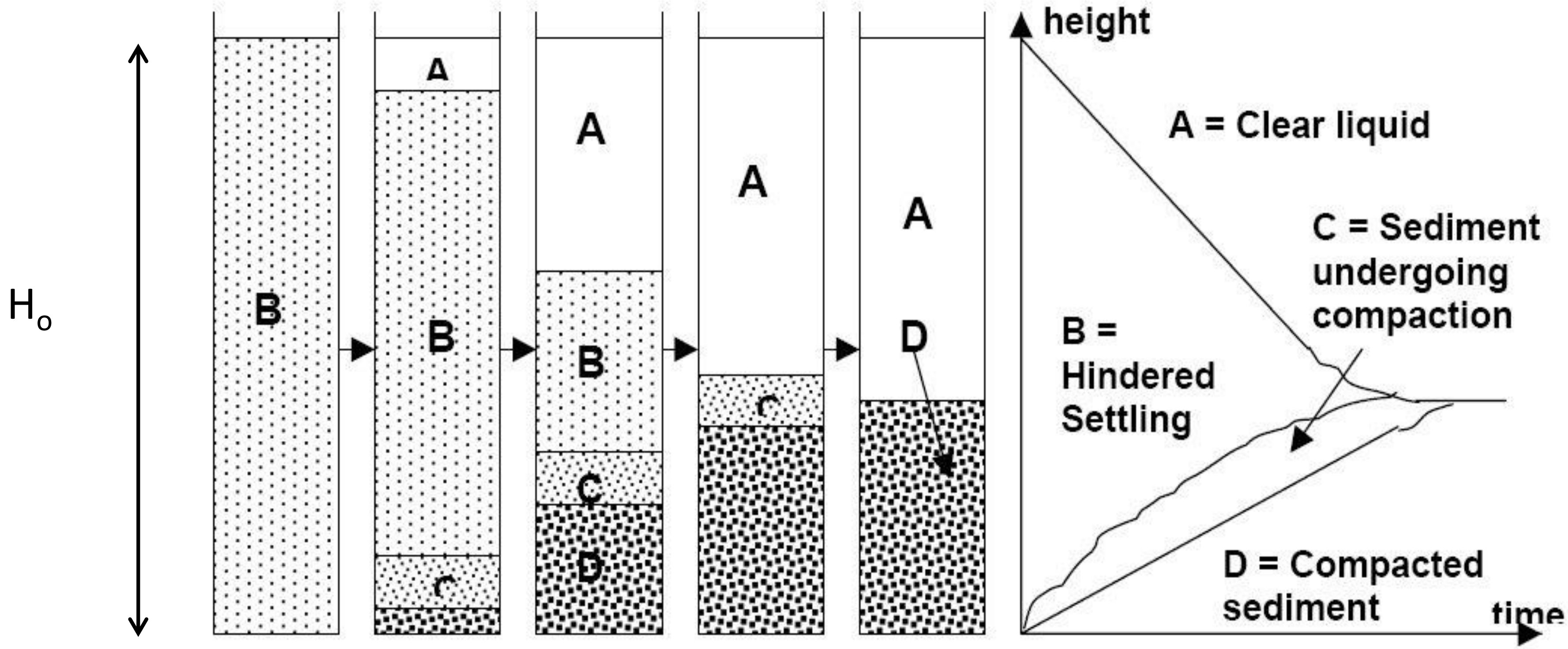




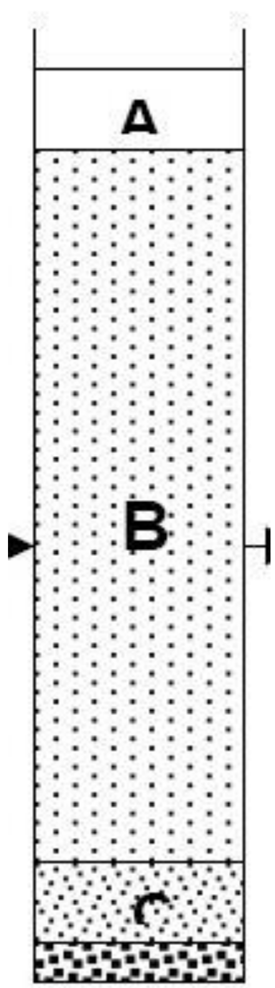
Particle Aggregation

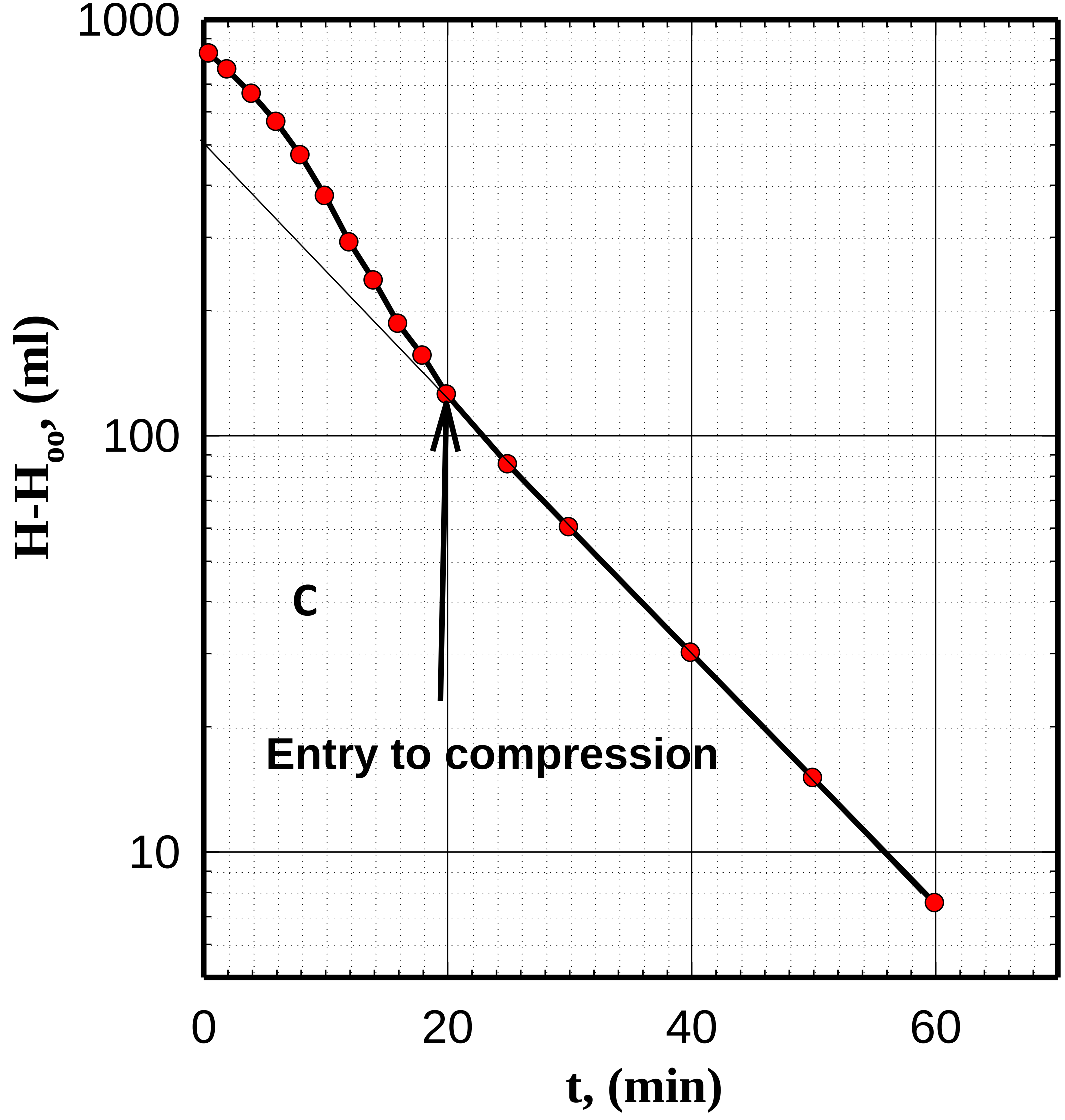


Batch Sedimentation



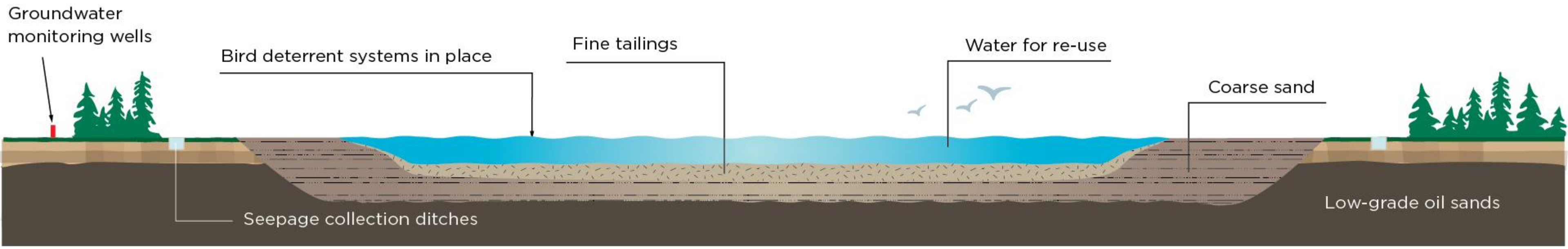
Beginning of Compression Phase





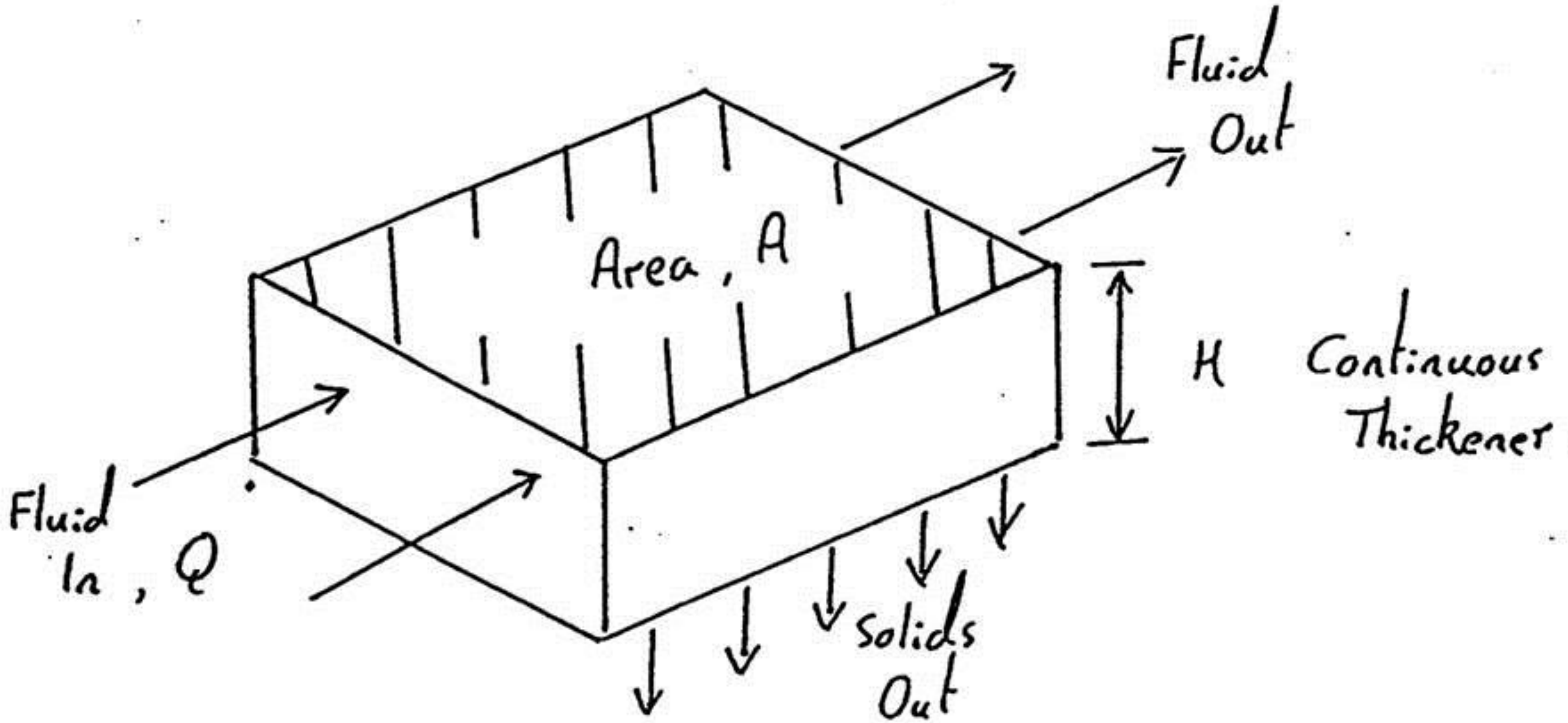
Tailings Ponds

https://canadians.org/blog/nafta-compounds-12-trillion-litres-toxic-petrochemical-waste-tar-sands-tailings-ponds

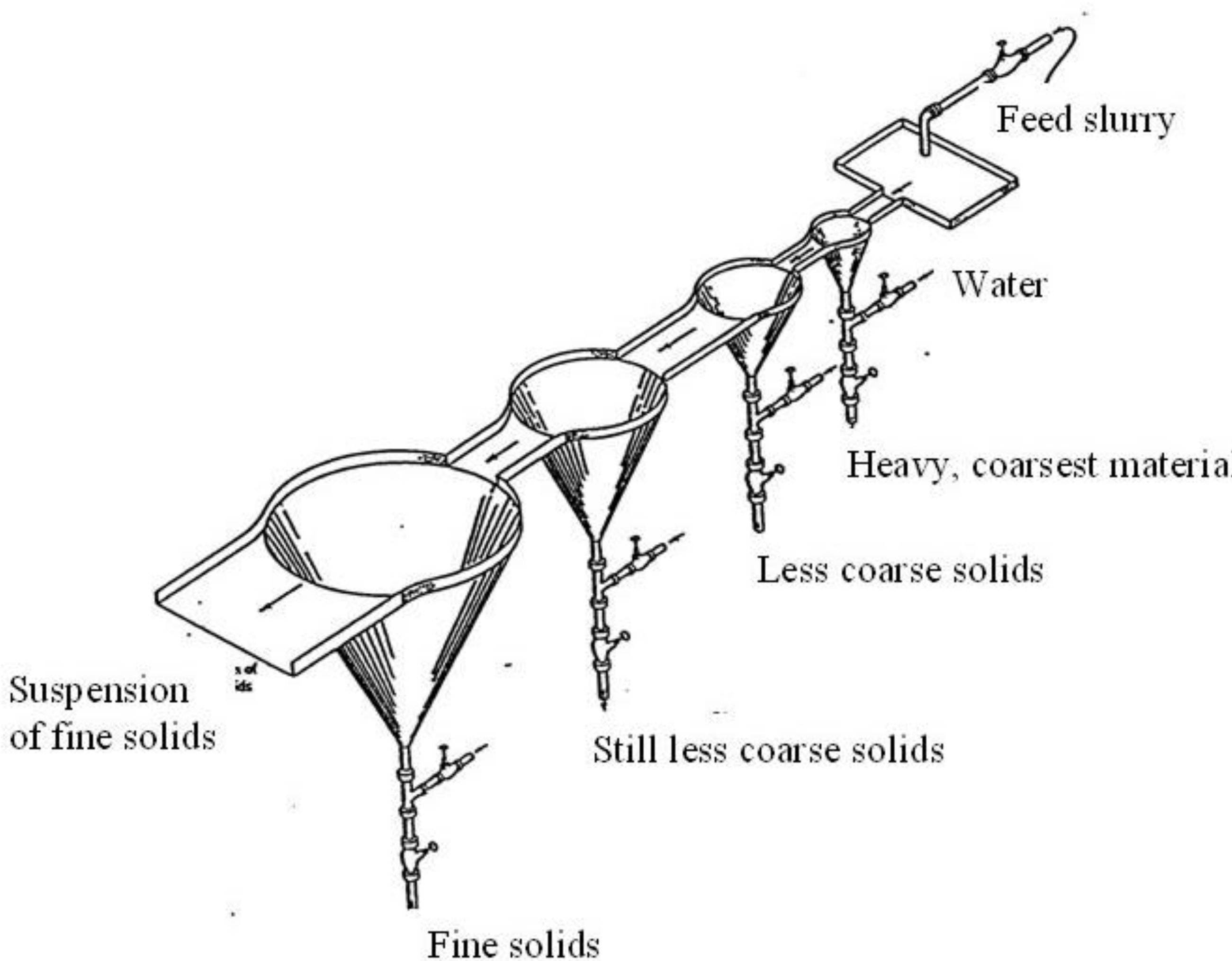


https://www.canadasoilsands.ca/en/explore-topics/tailings-ponds

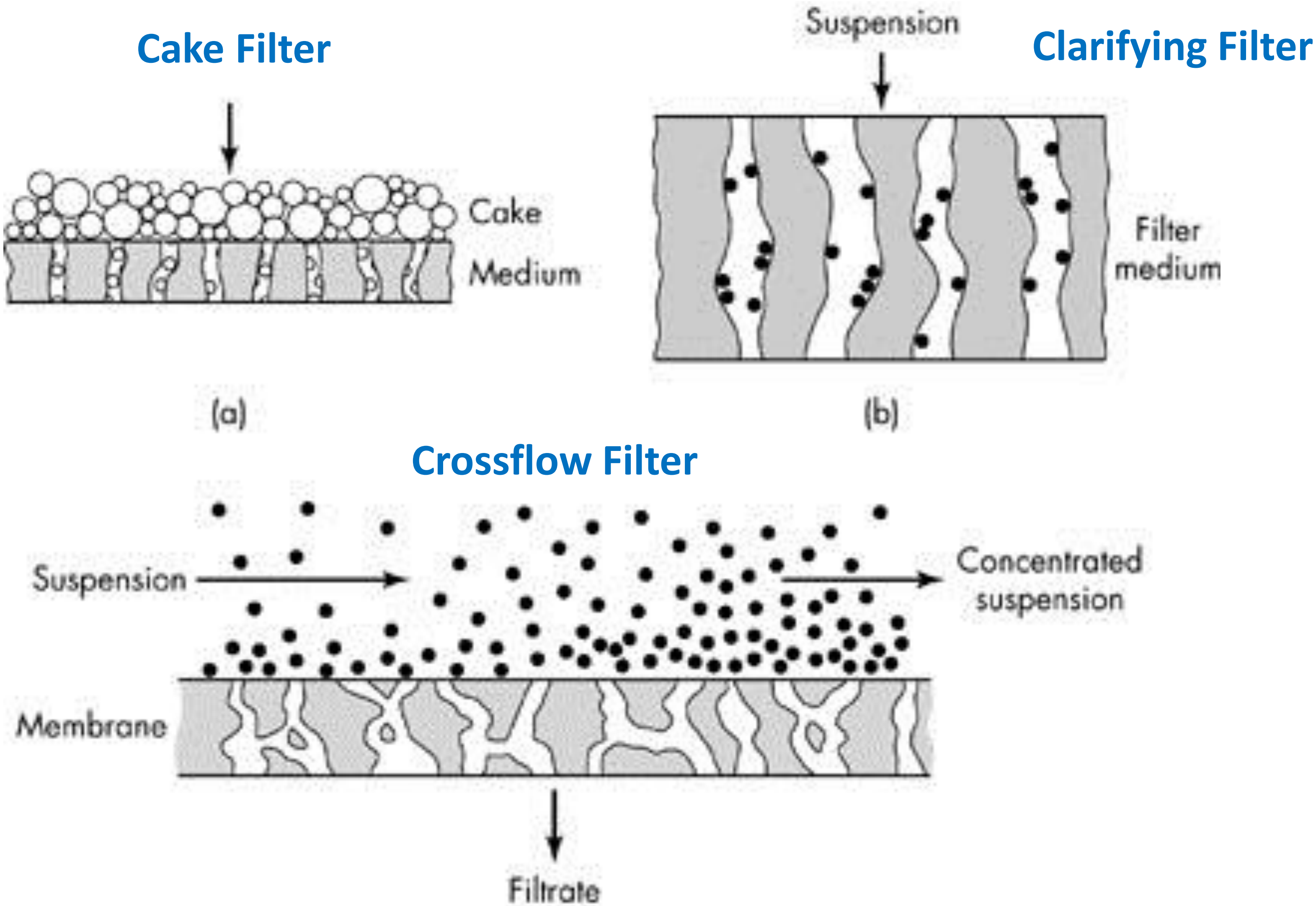
Ideal Continuous Sedimentation Unit



Simple Elutriation



Filtration



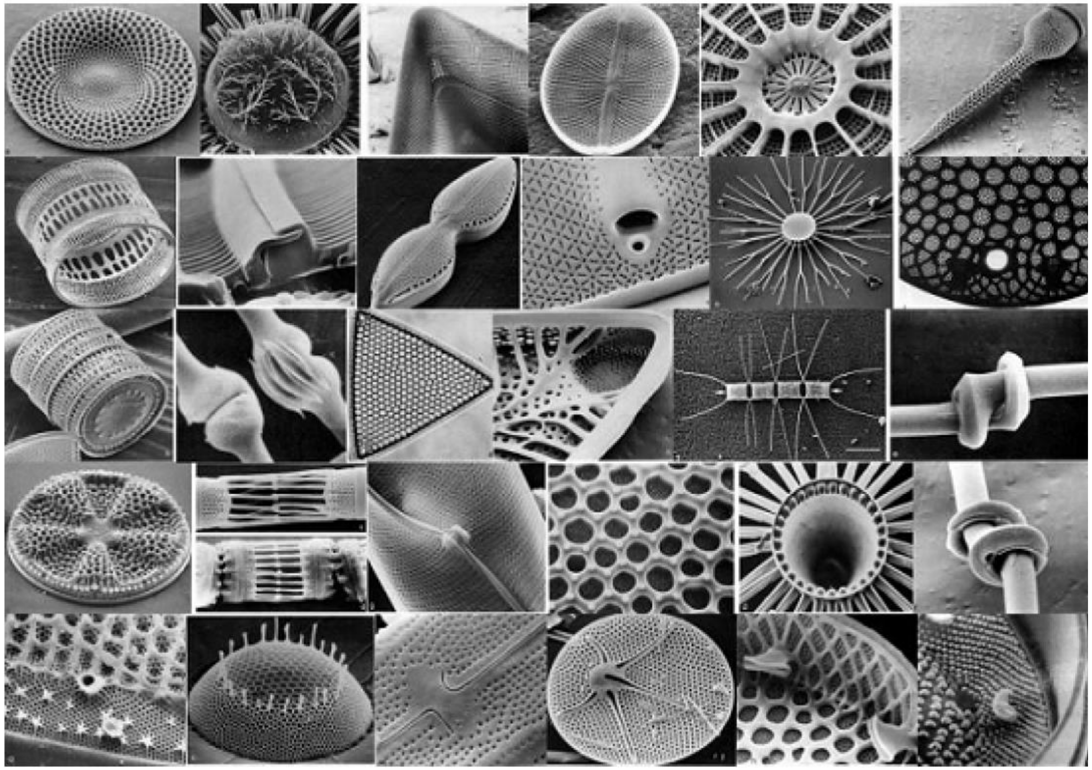
In bioprocessing

TFF

Filter Aids

Diatomaceous Earth

By SprocketRocket
https://commons.wikimedia.org/w/index.php?curid=30156246



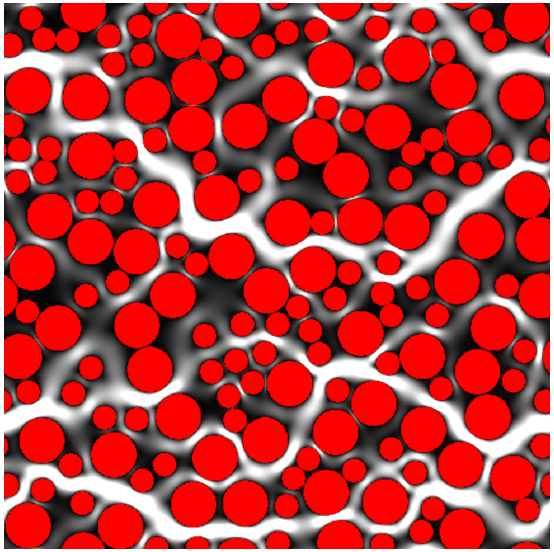
C. Gaddis. Diatom Alchemy. Masters Thesis. 2004

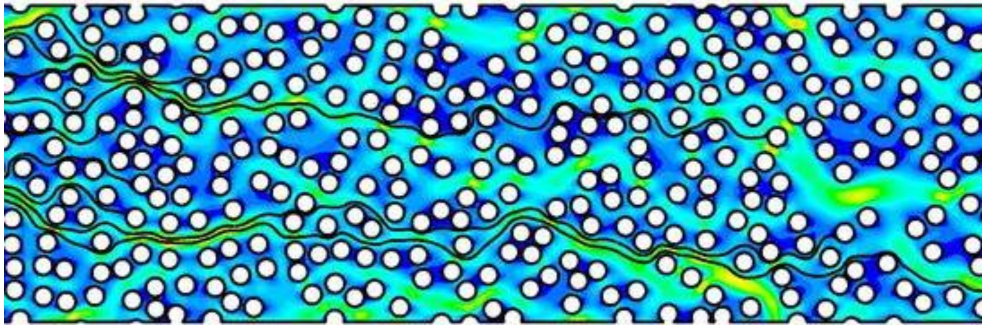
Flow in Porous Media

Oil Reserviors

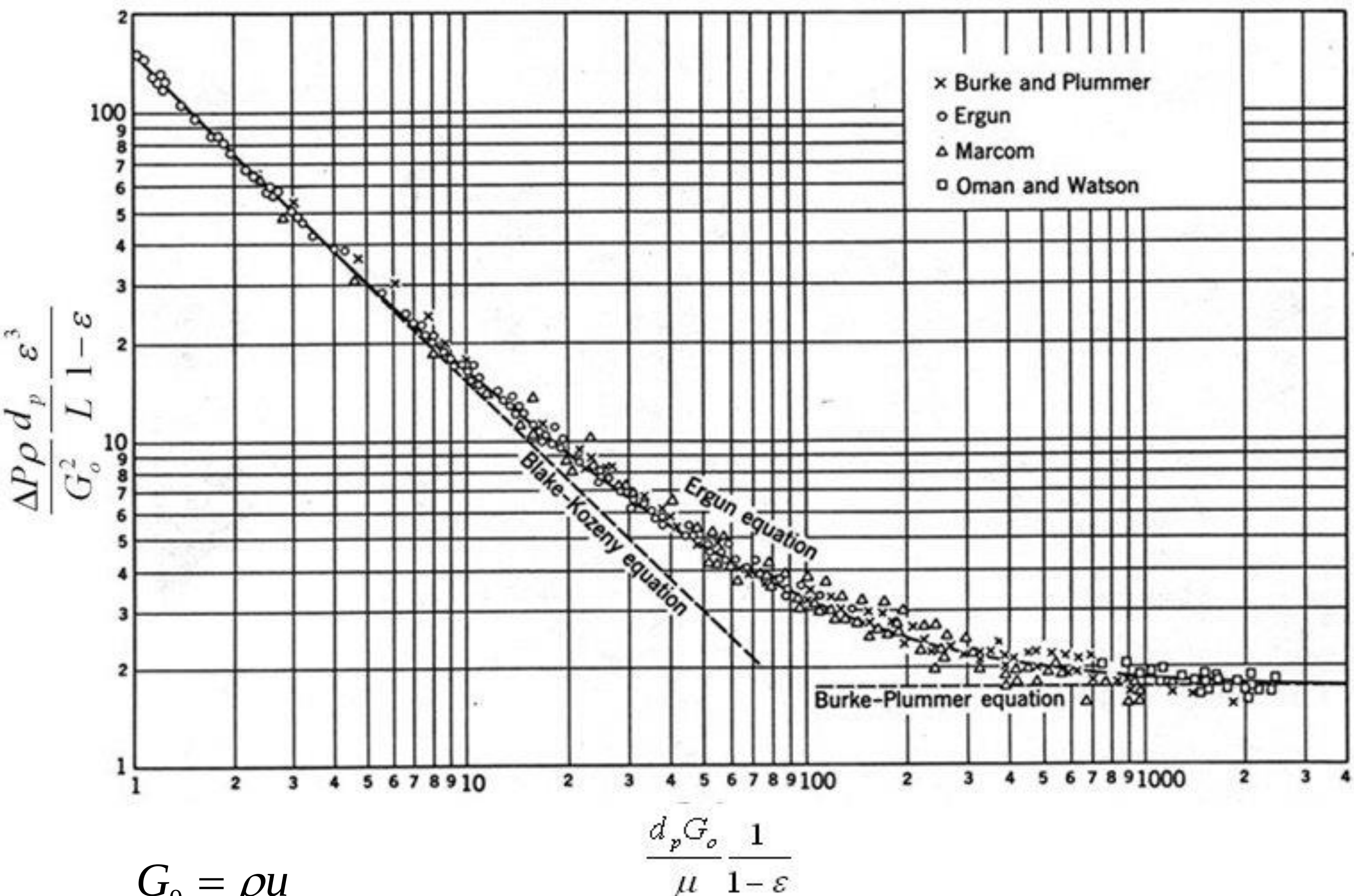
https://www.azom.com/article.aspx?ArticleID=5719

Packed Beds



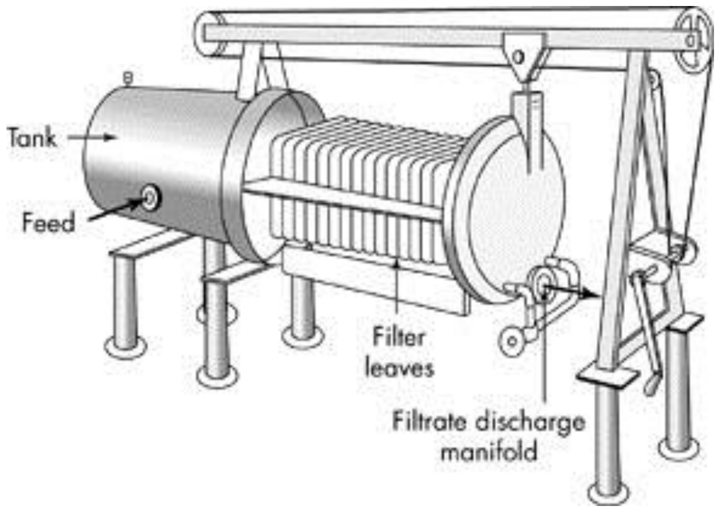


The Ergun Equation

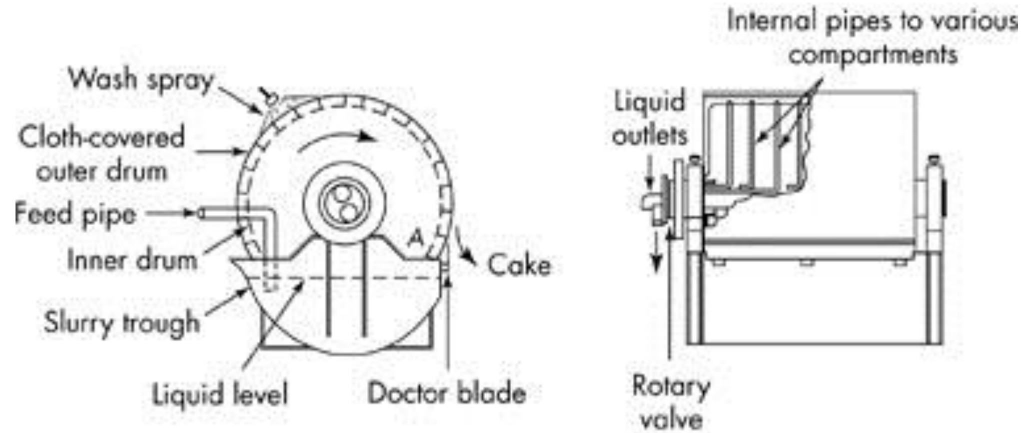


$$G_0 = \rho u$$

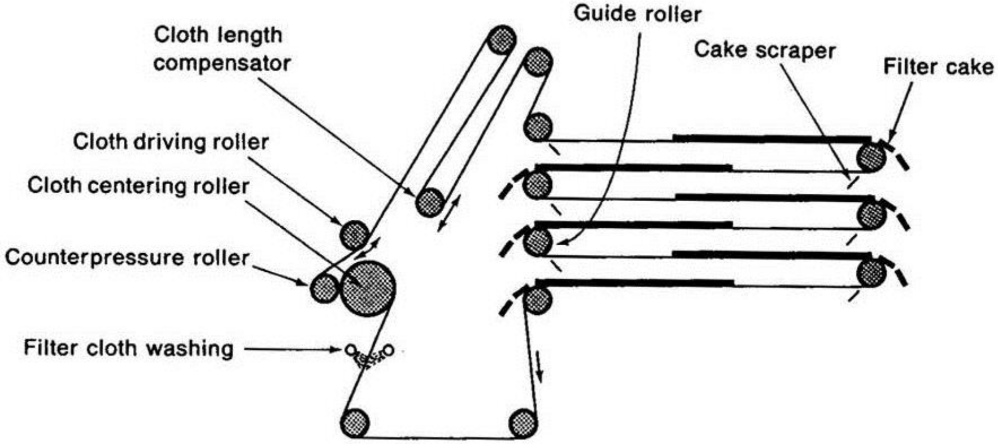
Filtration Units



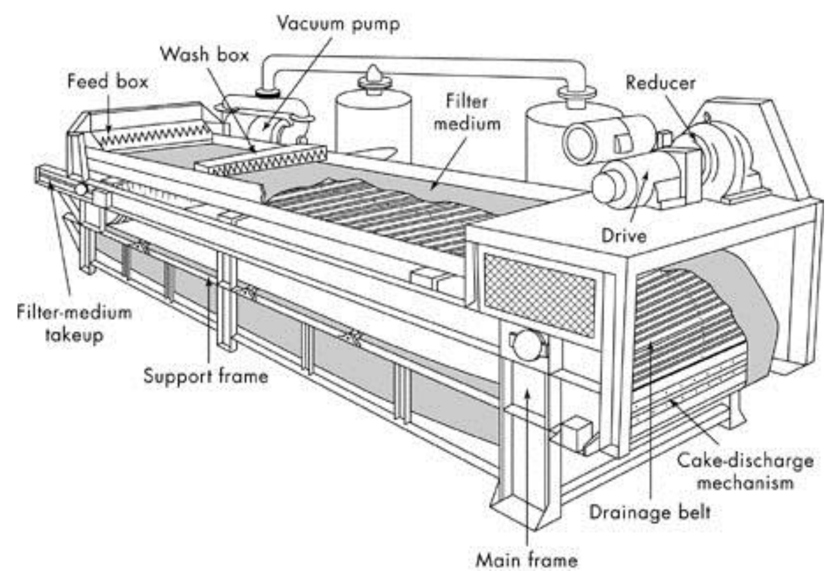
Horizontal-tank pressure leaf filter



Continuous vacuum filter.



Automatic filter with mechanism for cake discharge



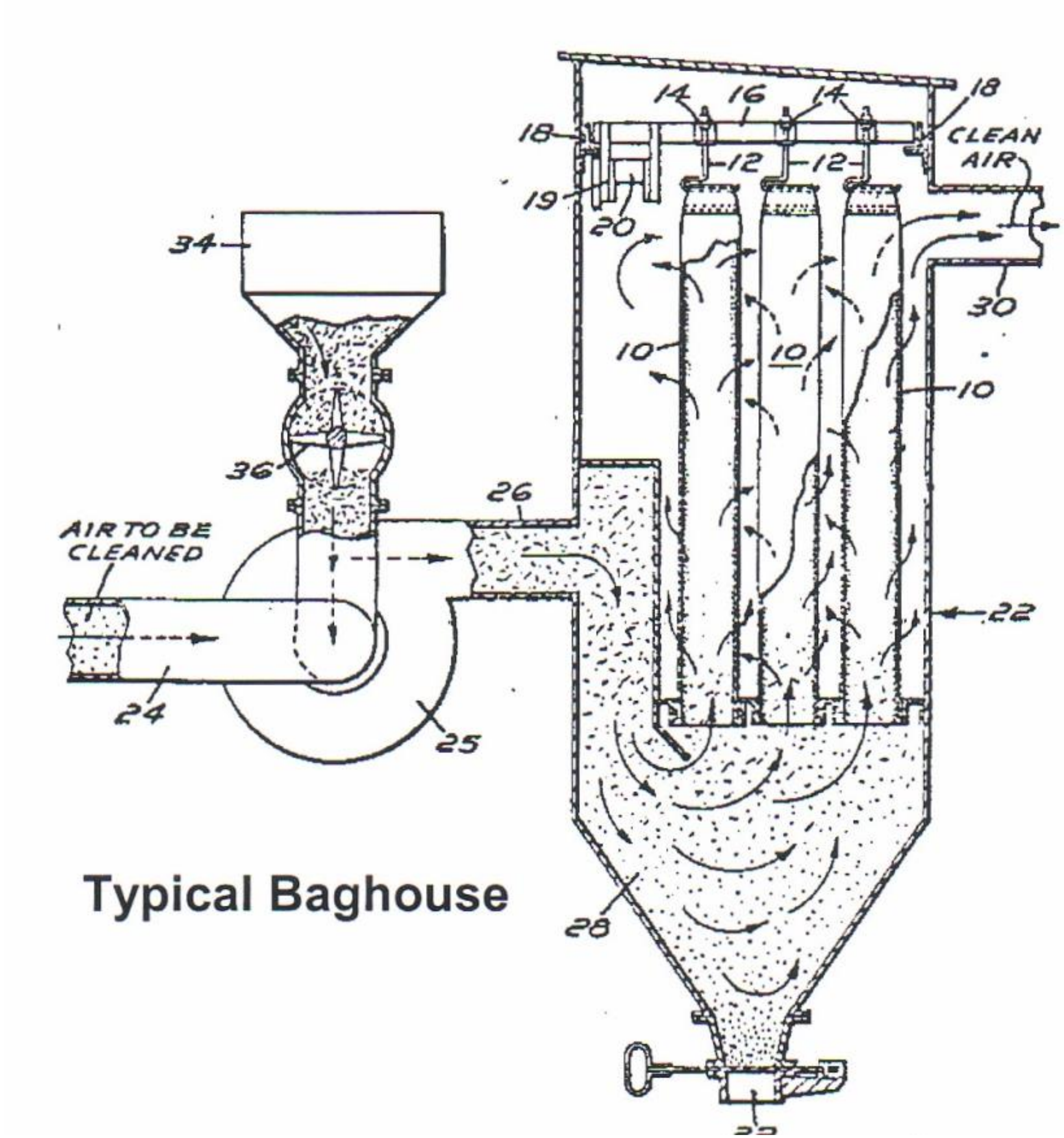
Horizontal belt filter

Continuous Filtration

Back-flushing system

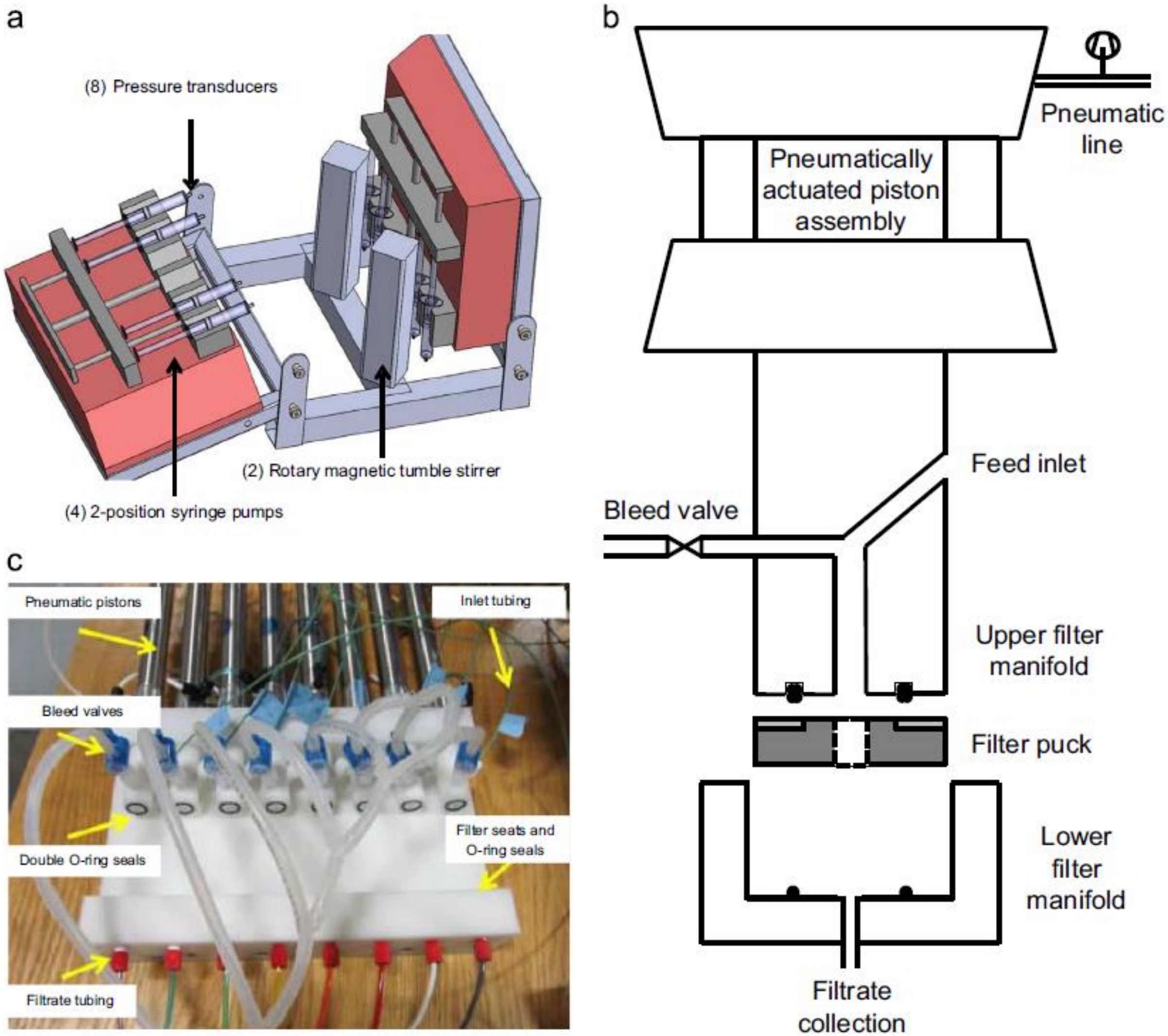
Drum scraping system

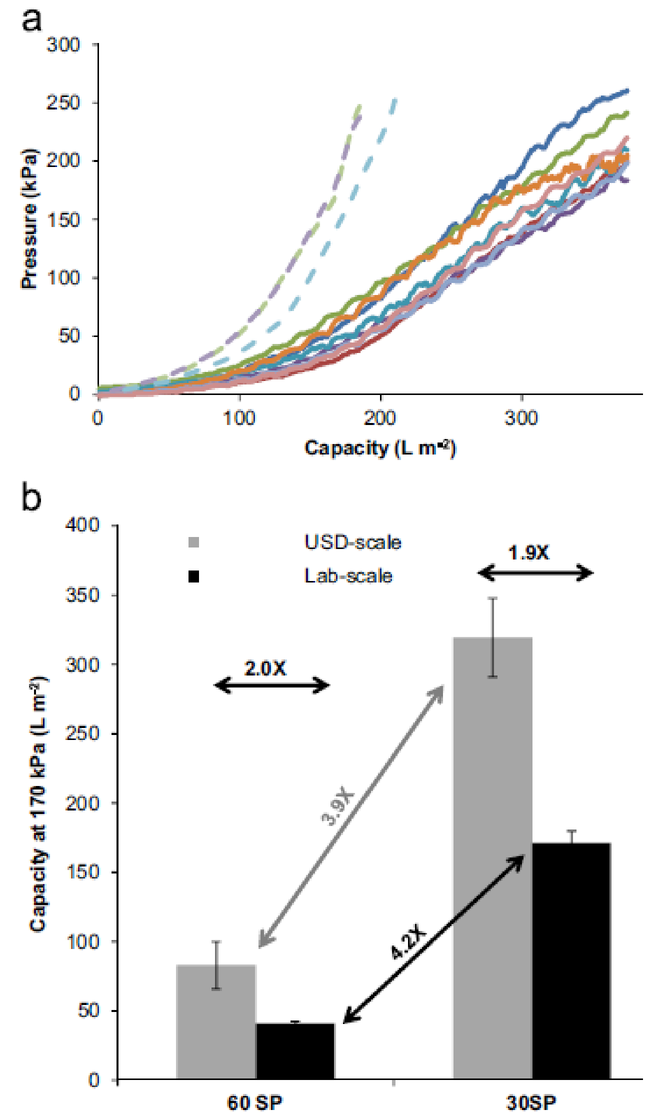
Gas Filtration (Fabric Filtration)



Typical Baghouse

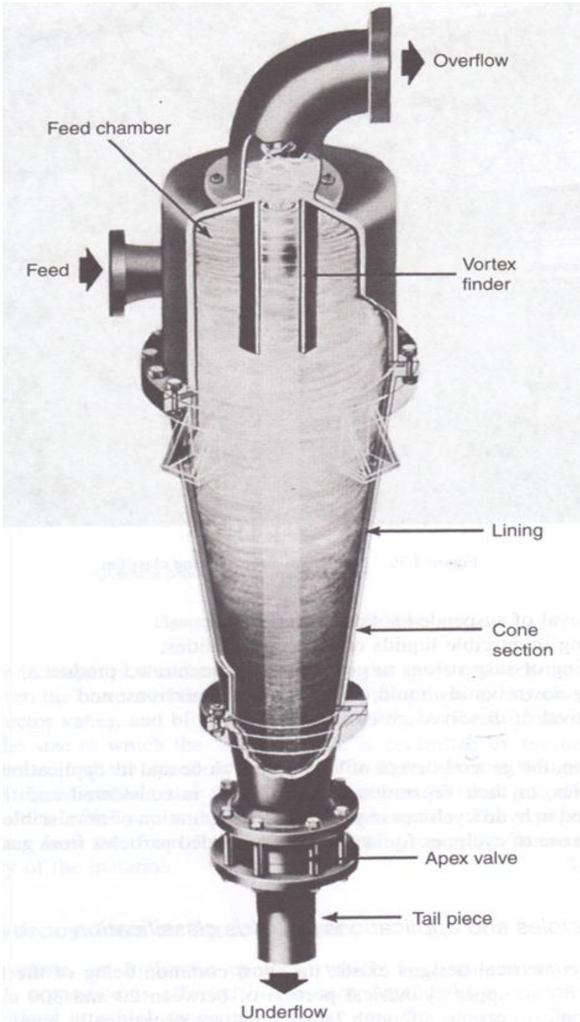
Scaling Considerations



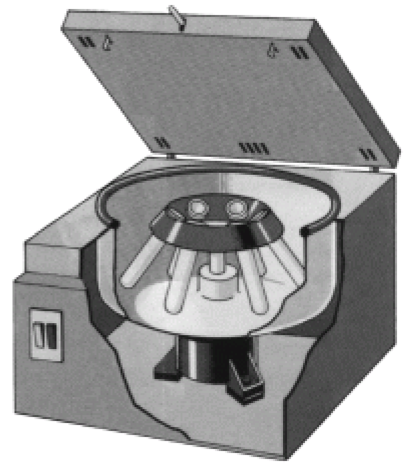


Centrifugation and Centrifugal Separation

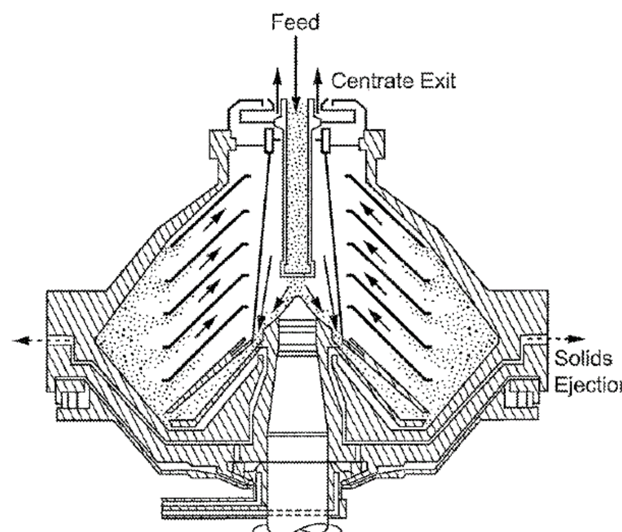
Cyclone or Hydrocyclone



Centrifuge

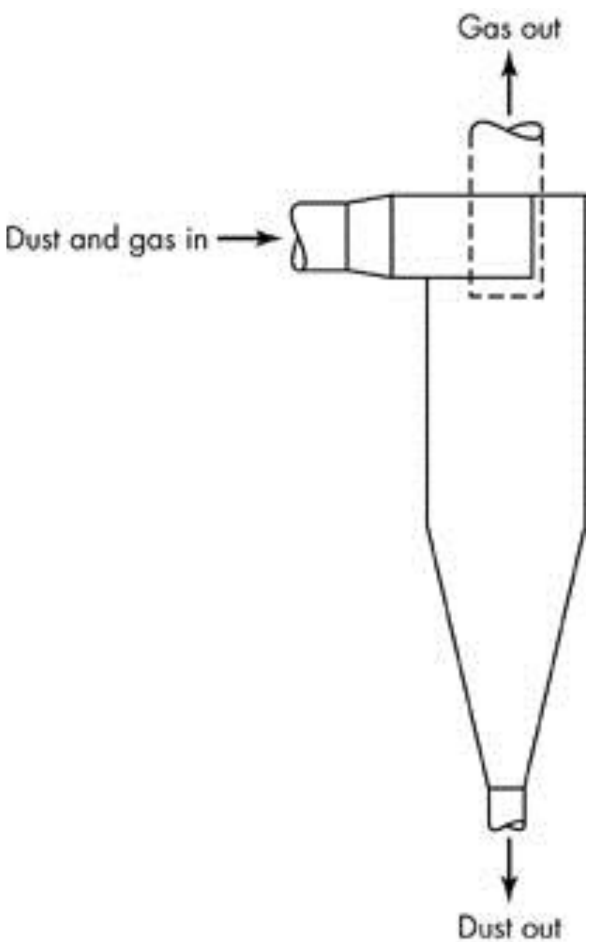


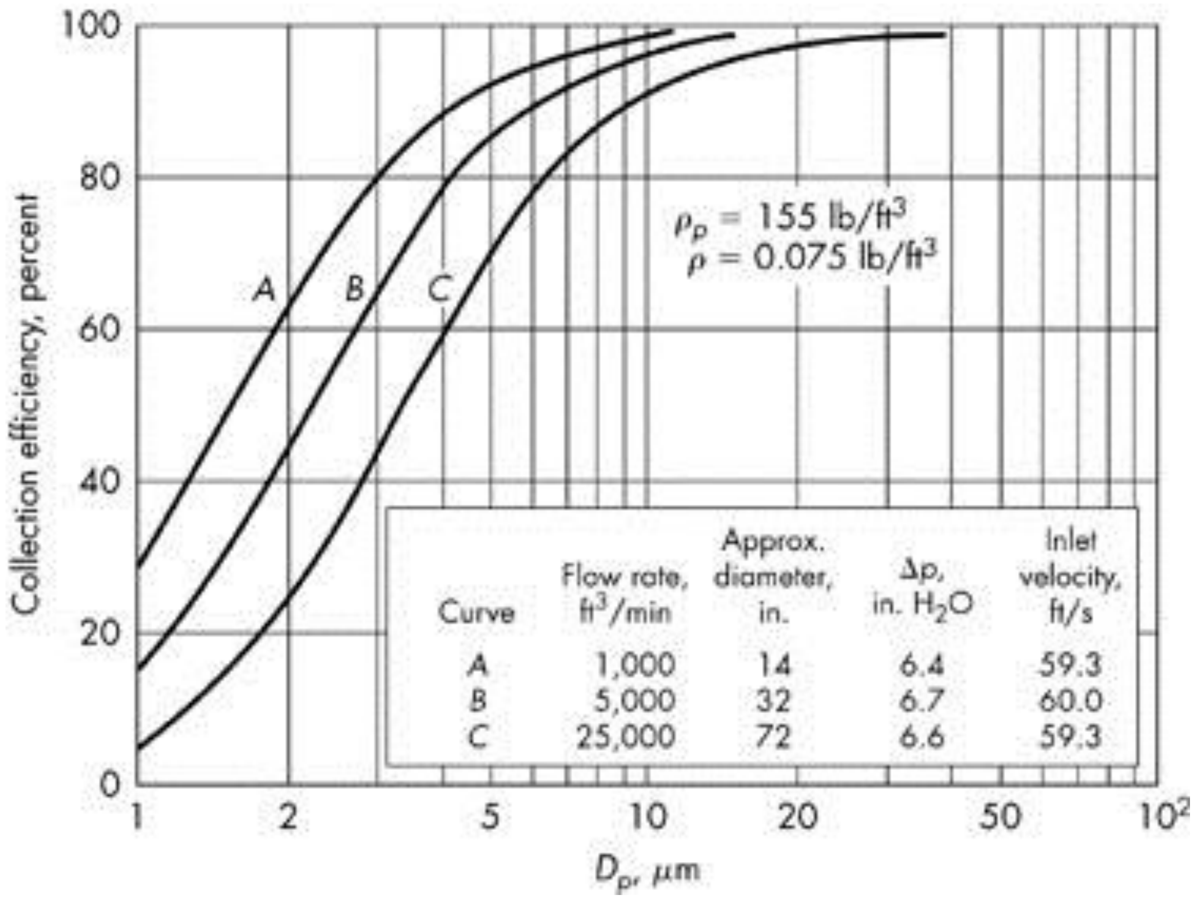
Disk Centrifuge (Continuous)



Dyson vacuum cleaners

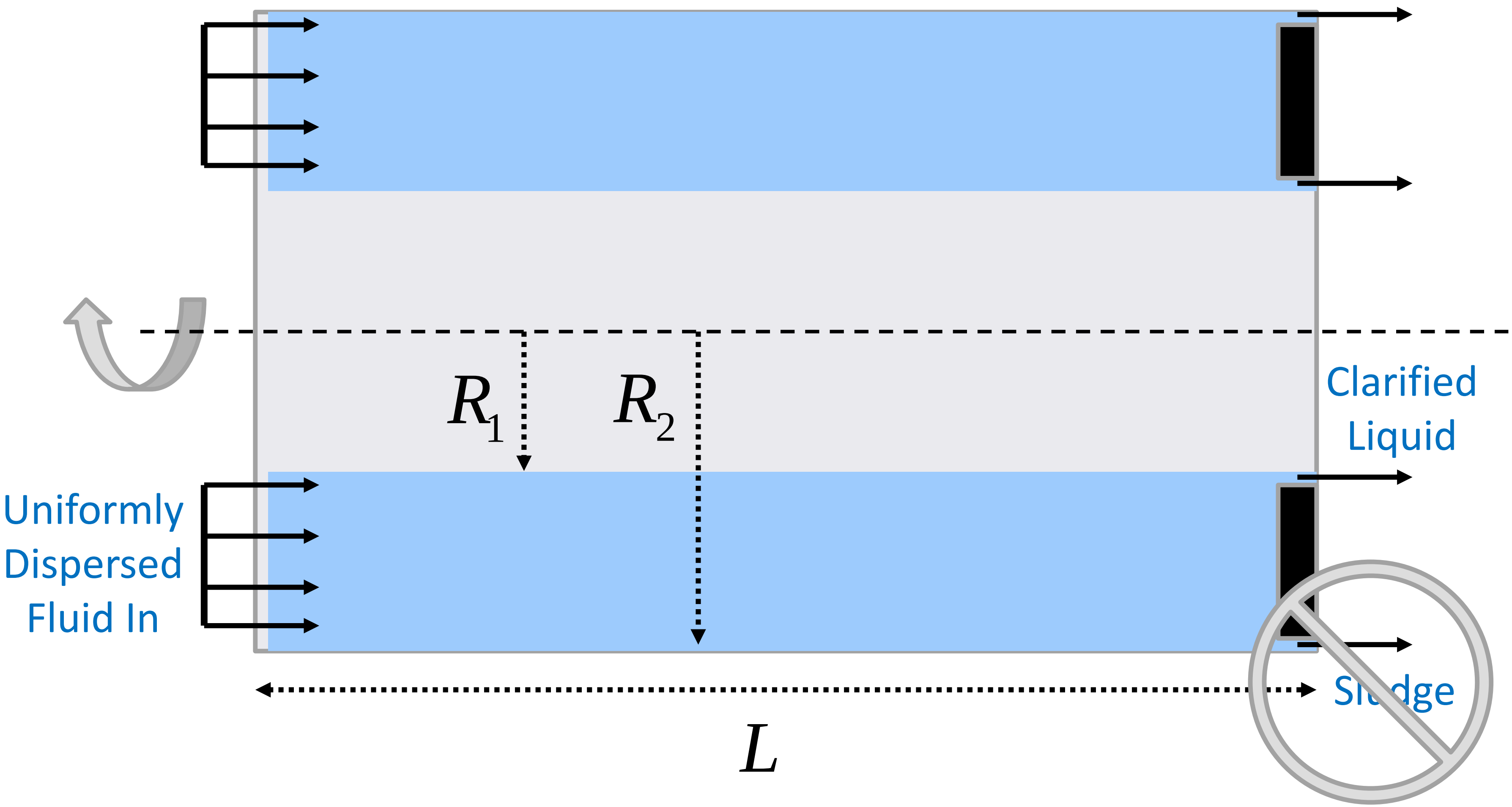
Cyclones (Separation of Solids from Gases)



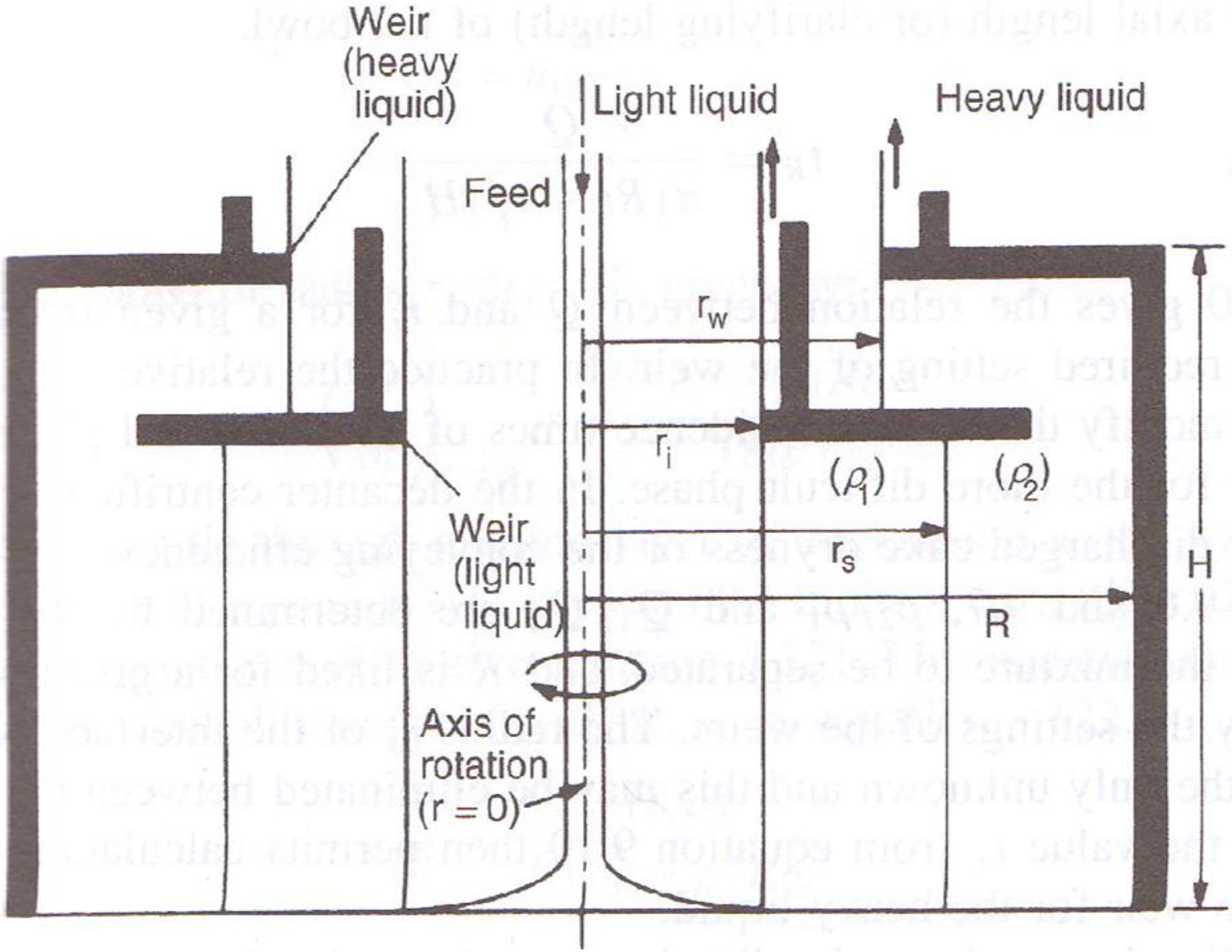


Sand separators

Ideal Continuous Centrifugal Sedimentation

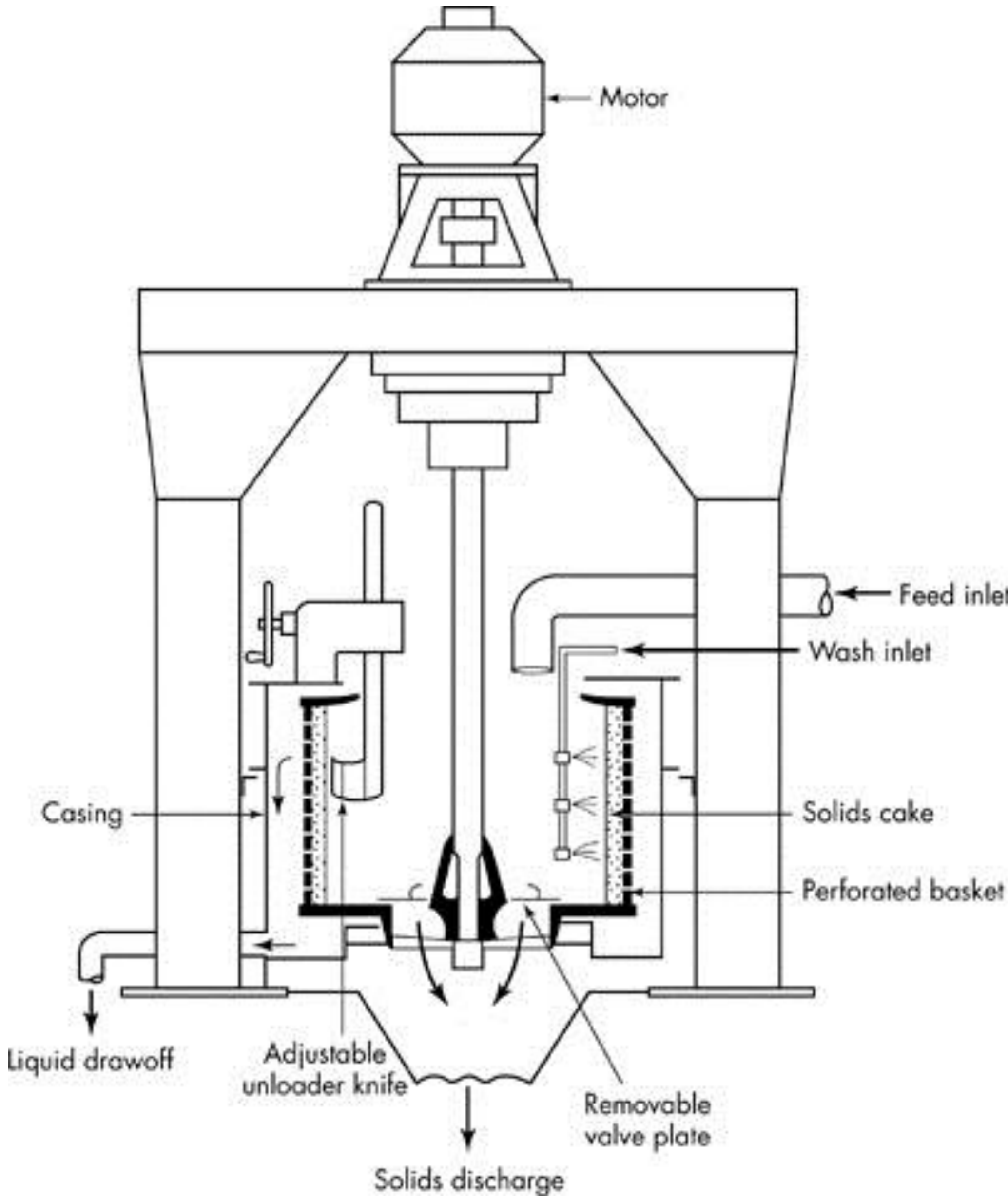


Separation of Immiscible Liquids

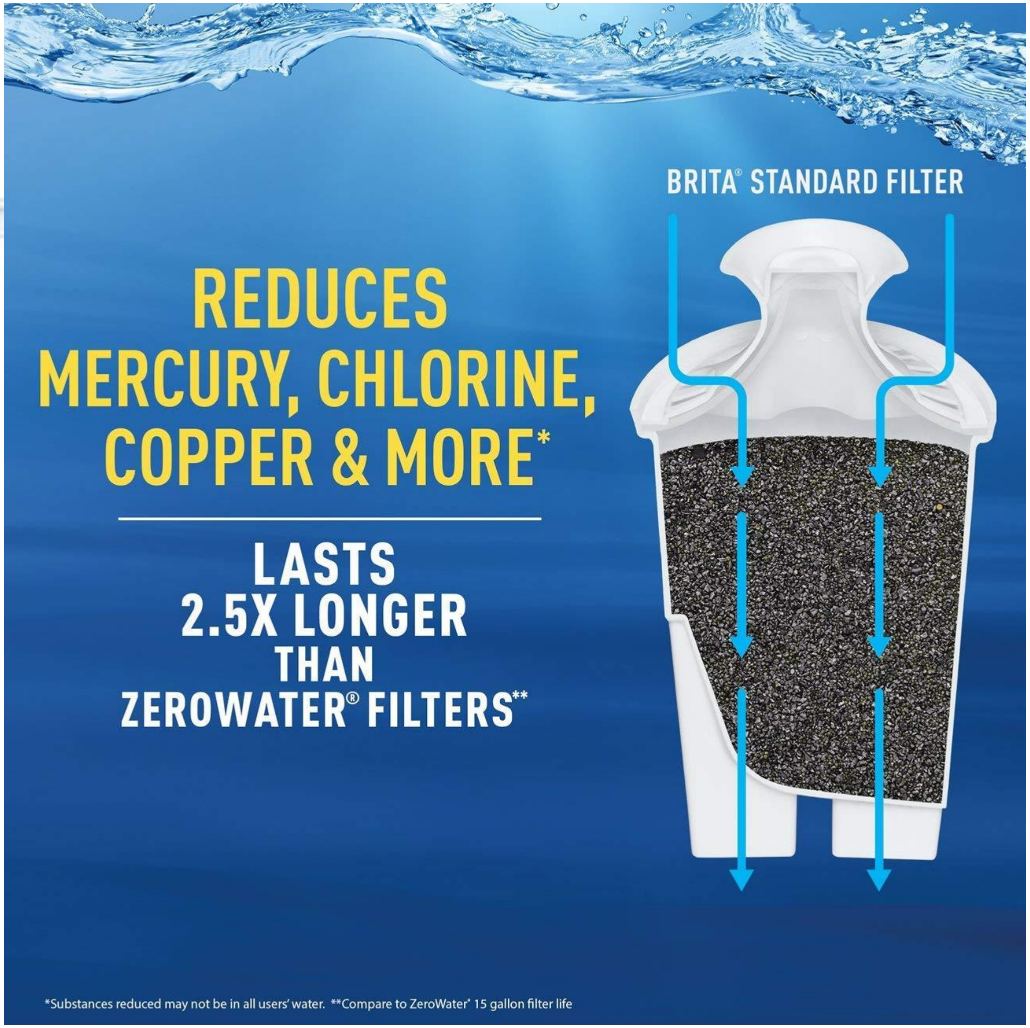


Oil-water separation

Centrifugal Filtration

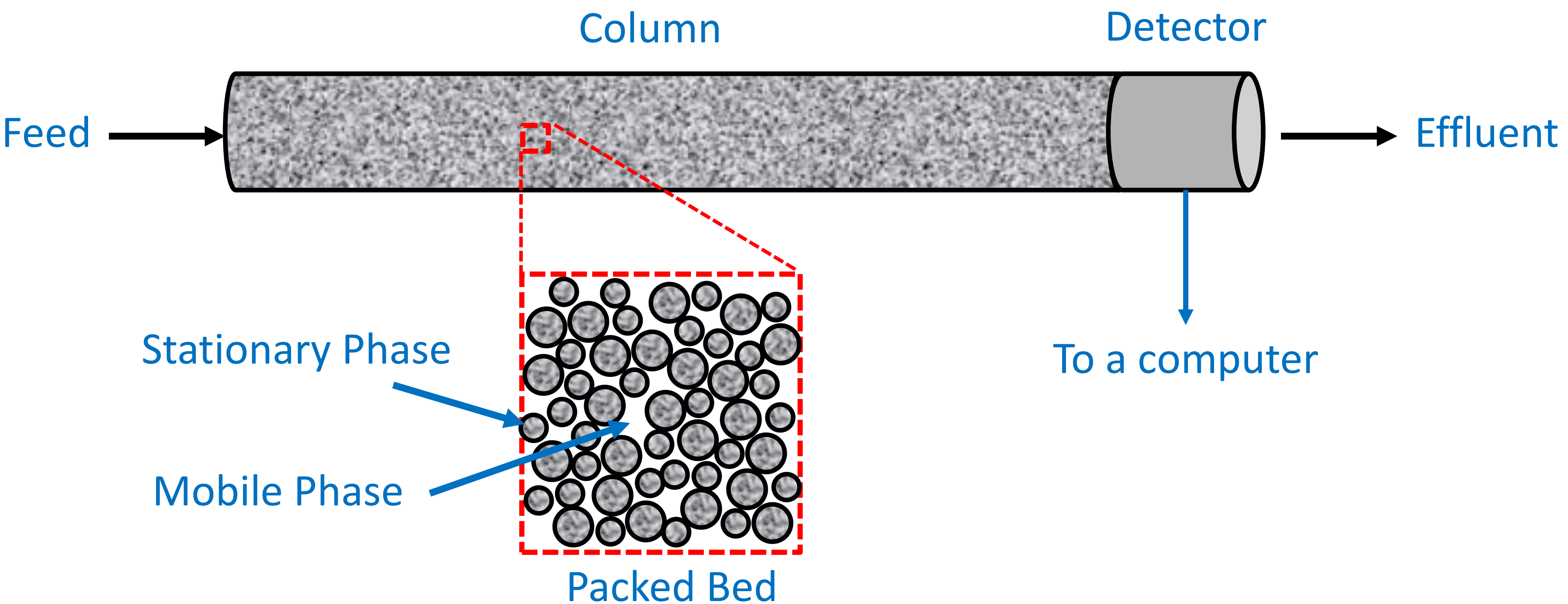


Packed Beds for Filtration



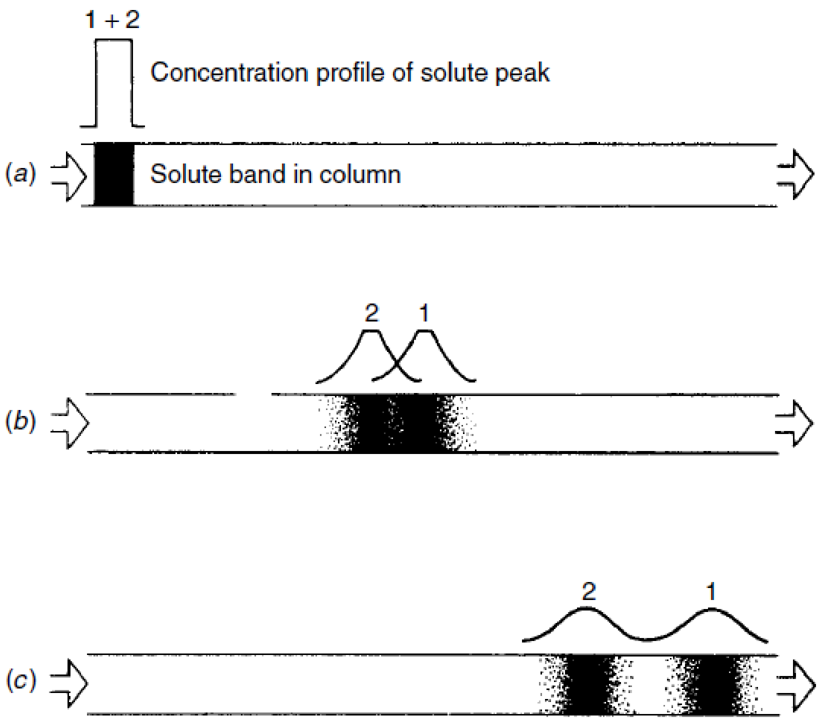
Do it yourself water filter

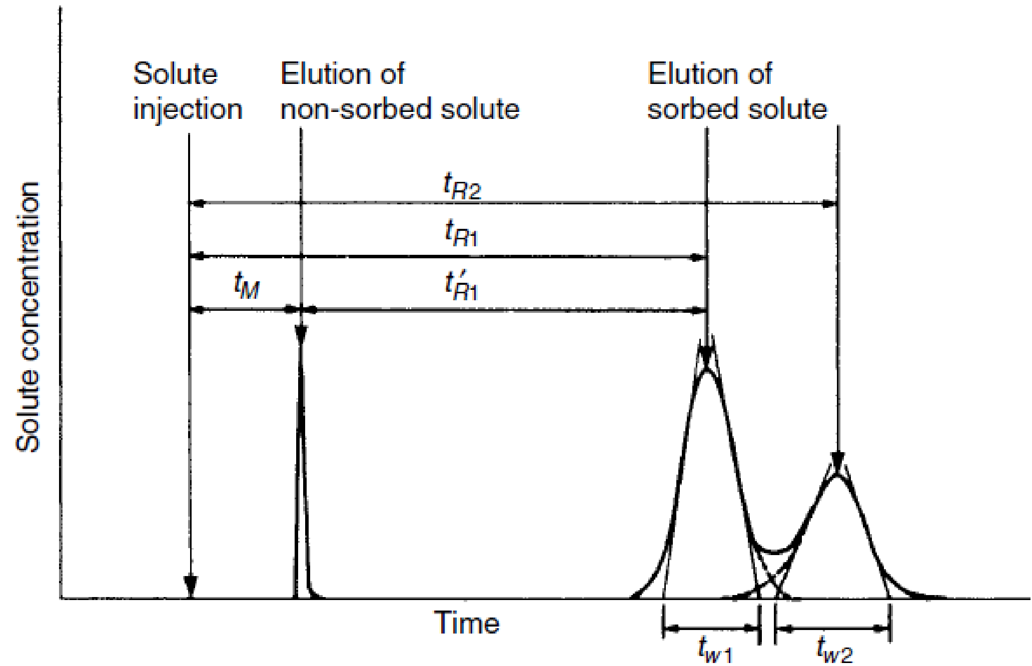
Chromatography



Purifying porphyrin

Elution Chromatography





Separating two components