Mixing & Segregation

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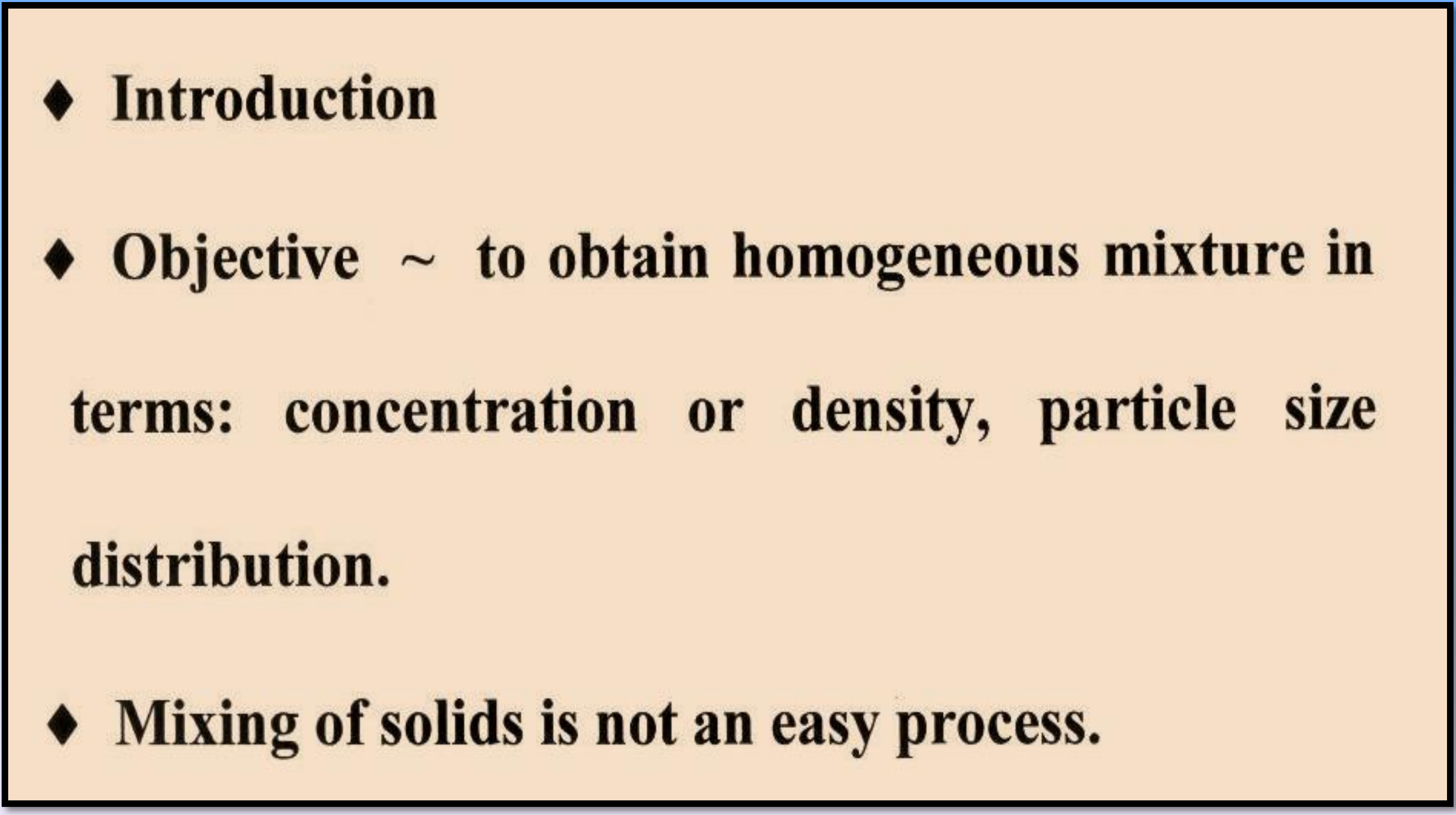
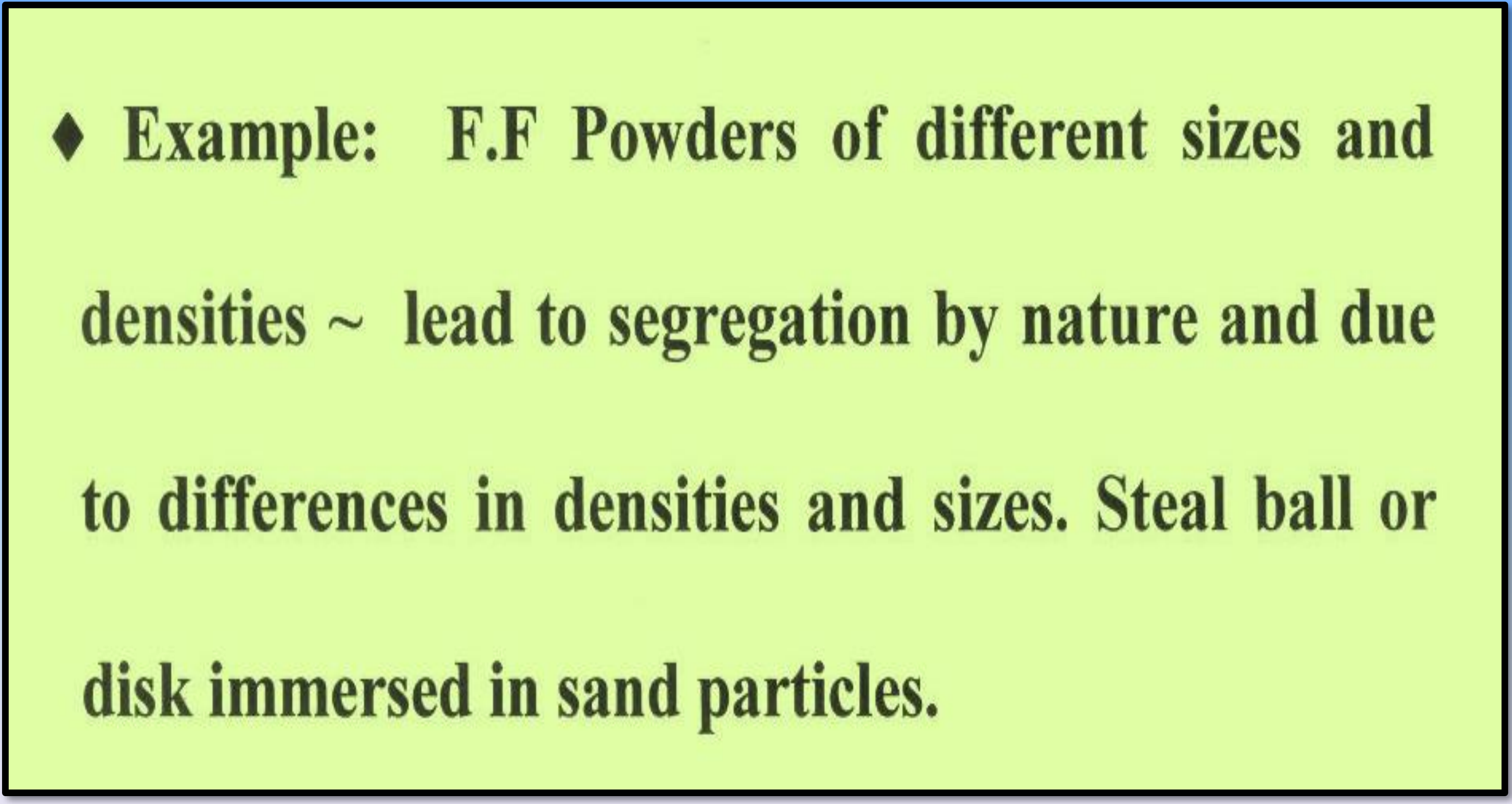


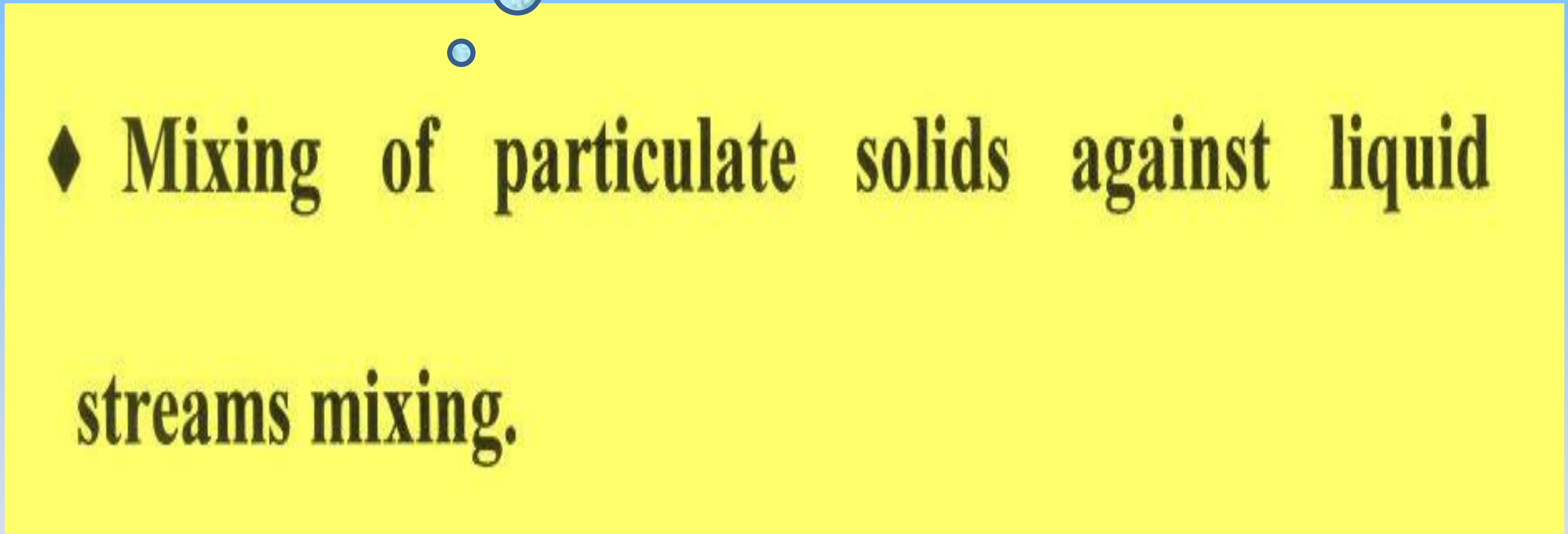
- Introduction
- Objective ~ to obtain homogeneous mixture in terms: concentration or density, particle size distribution.
- Mixing of solids is not an easy process.

Example



- **Example:** F.F Powders of different sizes and densities ~ lead to segregation by nature and due to differences in densities and sizes. Steal ball or disk immersed in sand particles.

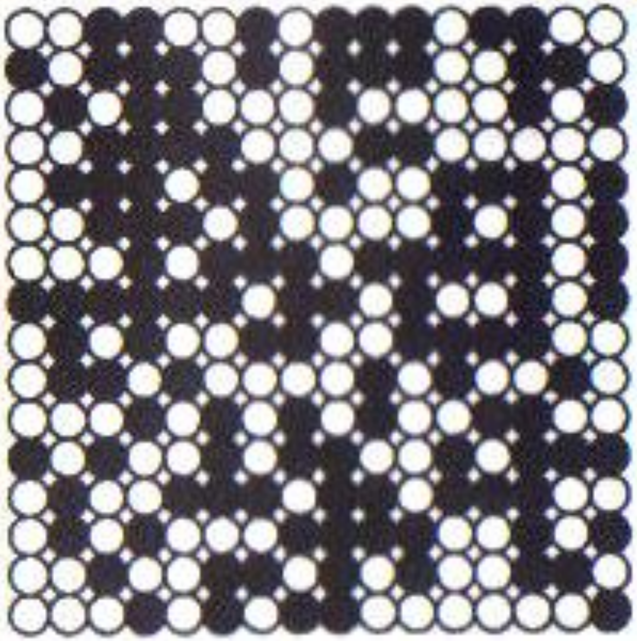
Exercise



- Mixing of particulate solids against liquid streams mixing.

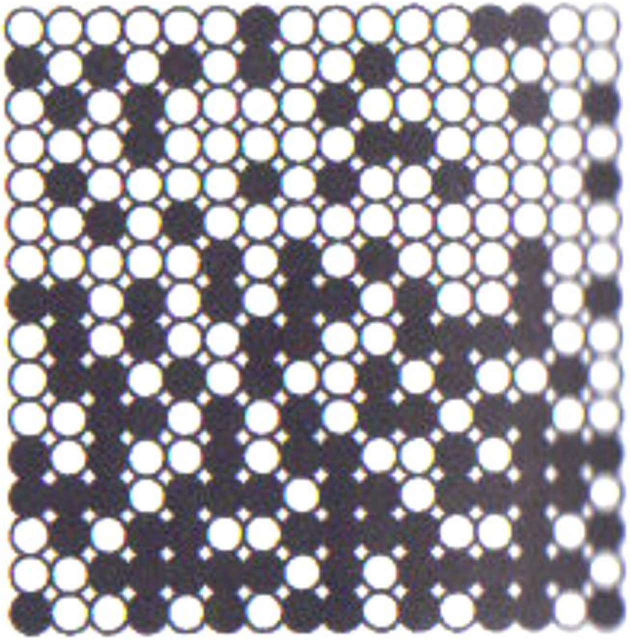
Types of mixture

Perfect mixture



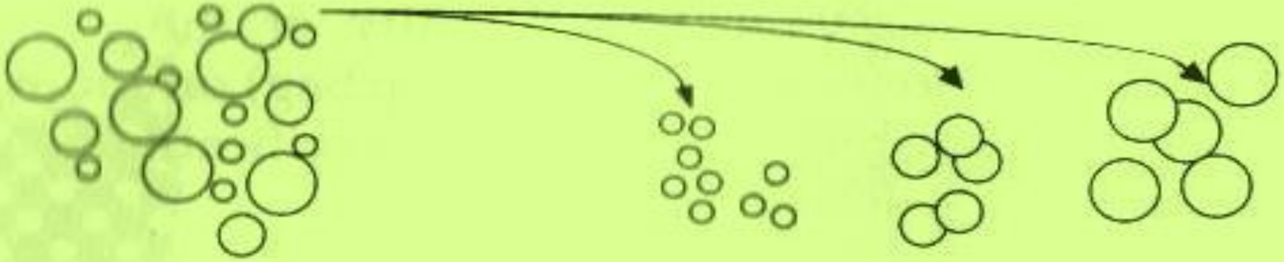
Random mixture

Types of mixture



Segregating mixture

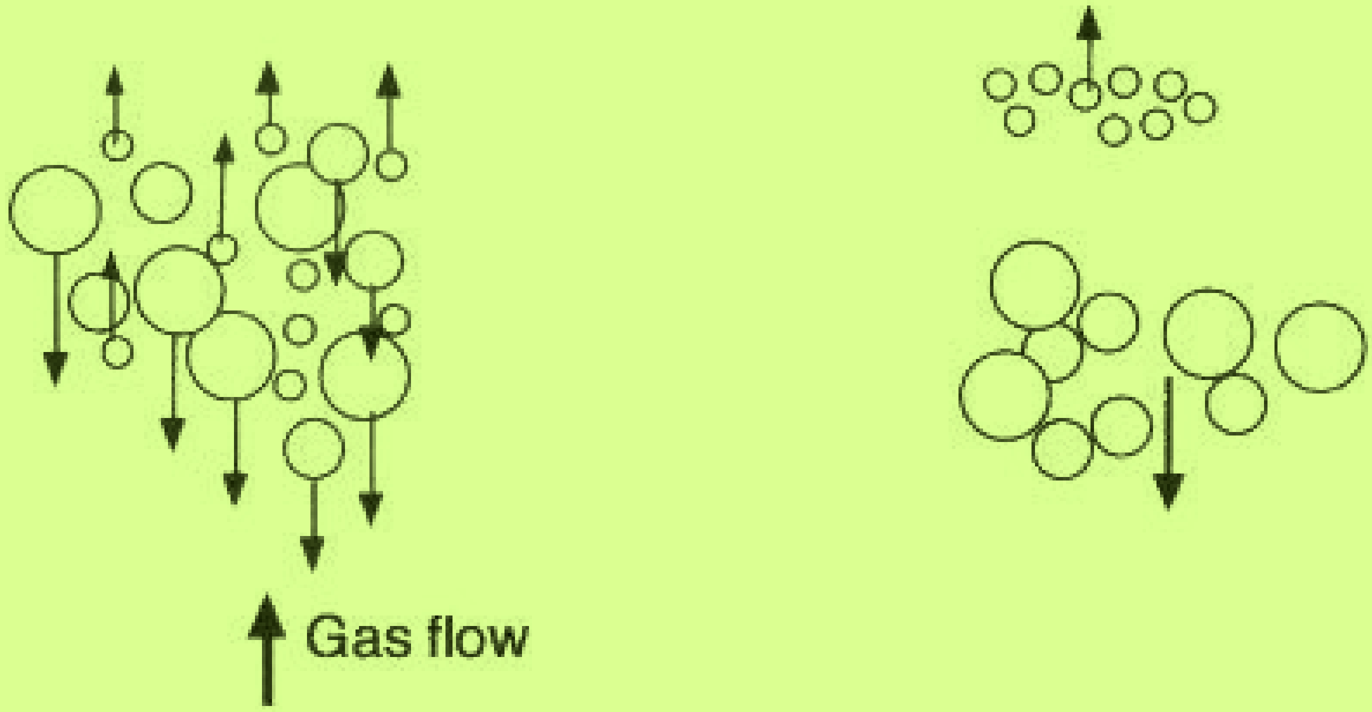
Mechanism of Segregation



Trajectory segregation

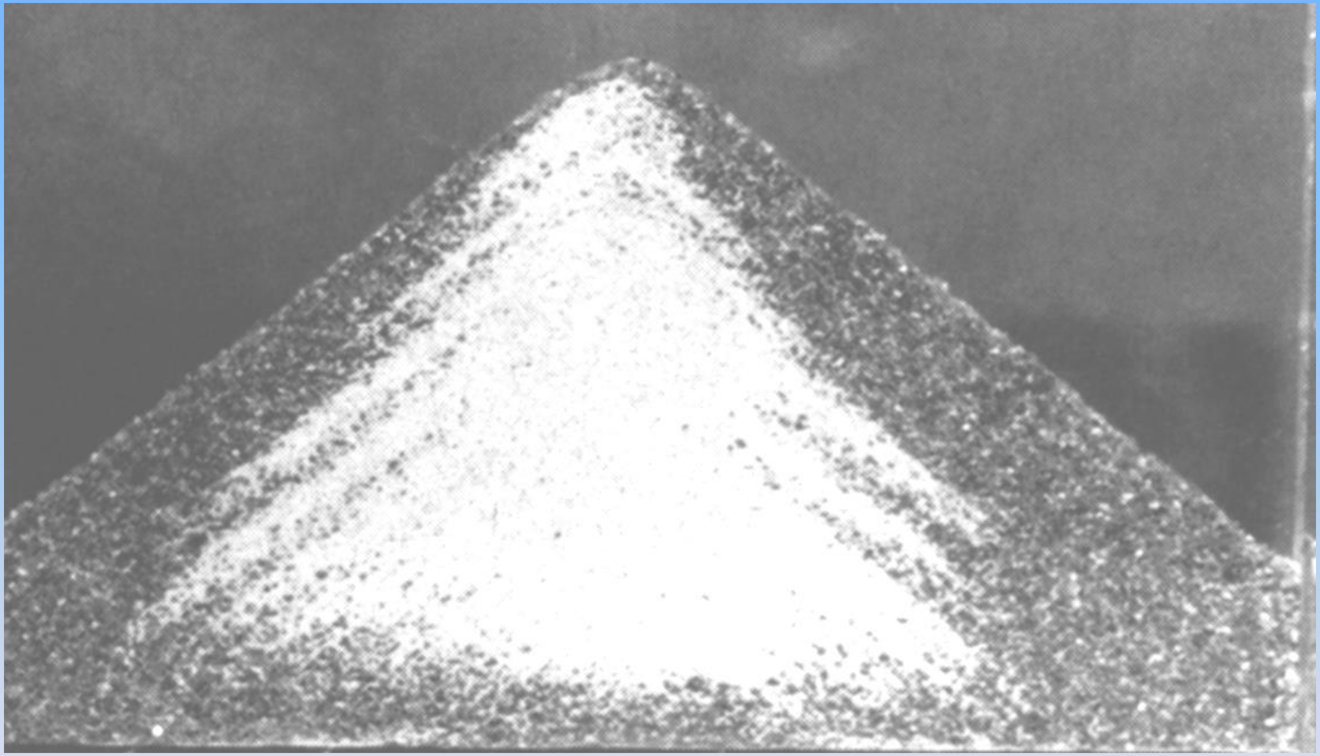
Segregation by percolation

Mechanism of Segregation



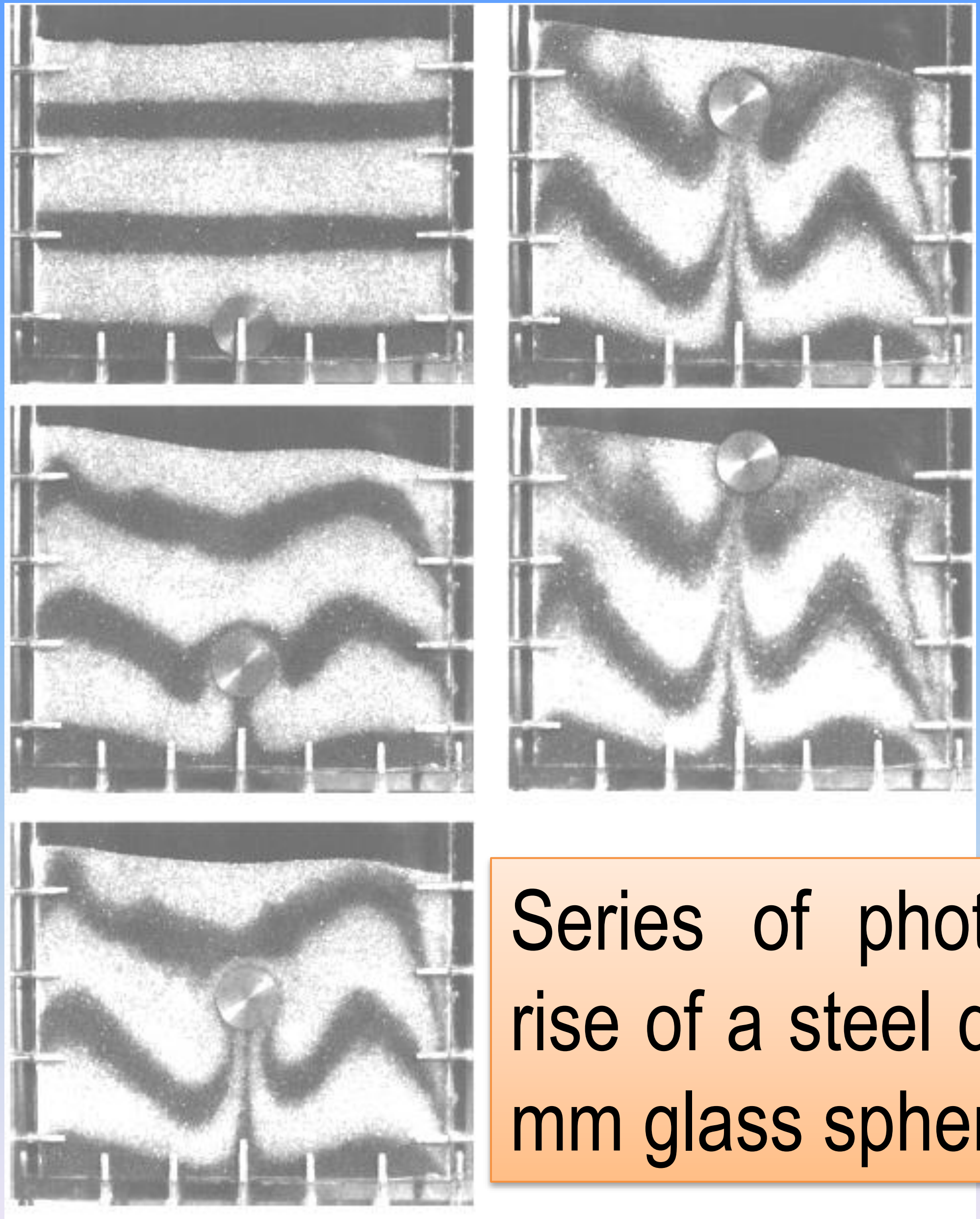
Segregation by elutriation

Segregation pattern formed by pouring a free-flowing mixture of two sizes of particles into a heap



Mechanism of Segregation

Rise of coarse particles on Vibration



Series of photographs showing the rise of a steel disc through a bed of 2 mm glass spheres due to vibration.

Discussion

Suggest appropriate techniques for reduction of segregation

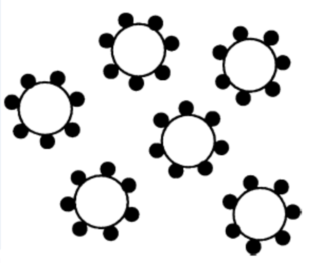
Reduction of Segregation

Make the size of components as similar as possible

Segregation is not serious problem when sizes <30 μm

The mobility of F.F. Particles can be reduced by the addition of liquid

Using ordered or interactive mixtures (small particles <5μm) adhered to the surface of a carrier particle in a control manner



Note

If it is not possible to alter the size of the components of the mixture or to add liquid, then in order to avoid serious segregation, care should be taken to avoid ***situations*** which are likely to promote segregation. In particular pouring operations and the formation of a moving sloping powder surface should be avoided.

Mechanisms of Mixing

In the mixing of solid particles, the following ***three mechanisms*** may be involved:

(a) ***Convective mixing***, in which groups of particles are moved from one position to another.

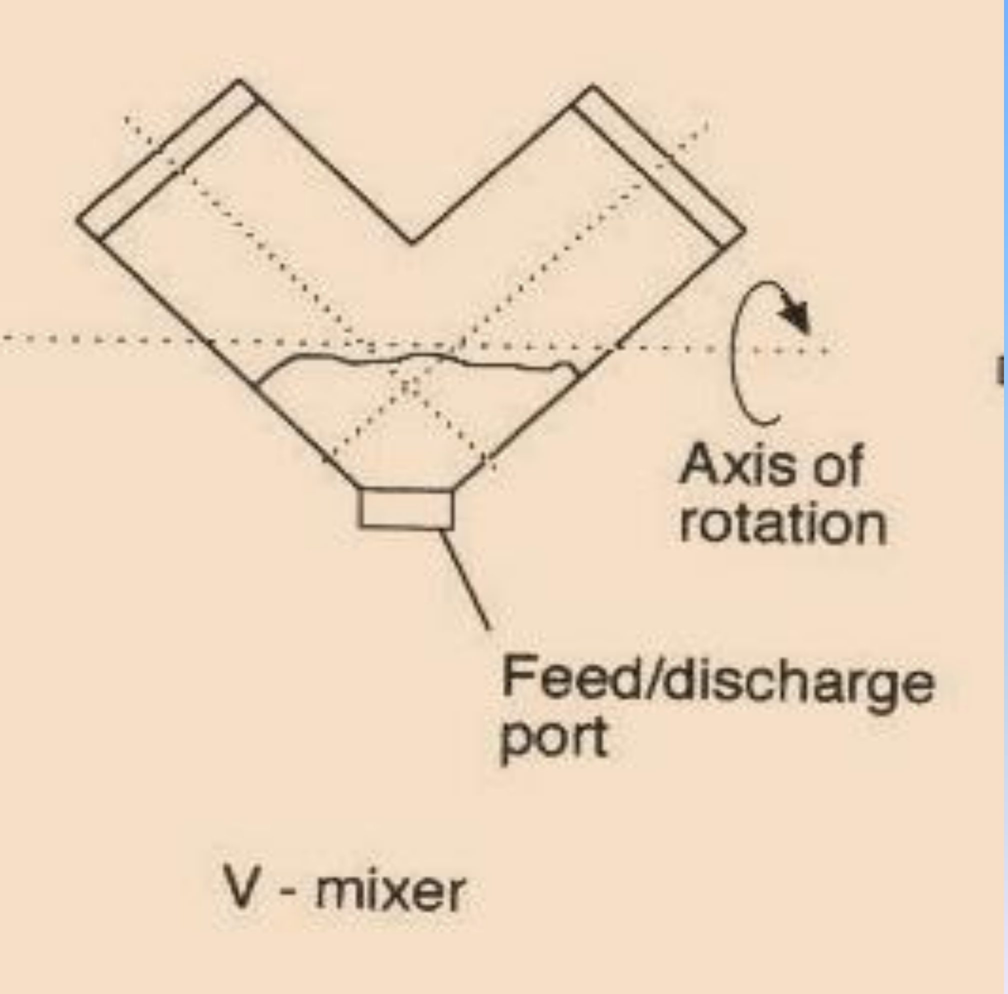
(b) ***Diffusion mixing***. This one takes place when particles roll down a sloping surface.

(c) ***Shear mixing.*** In this type, shear stresses give rise to slip zones and mixing takes place by interchange of particles between layers within the zone.

- These mechanisms operate to varying extents in different kinds of mixers and with different kinds of particles.

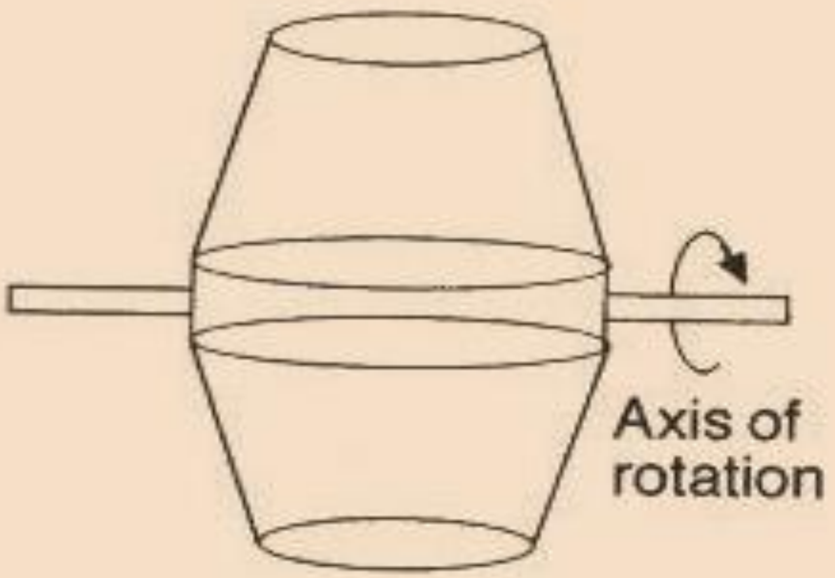
Type of mixers

1.Tumbling mixers
‘V-mixer’



Dominant mechanism is diffusive mixing

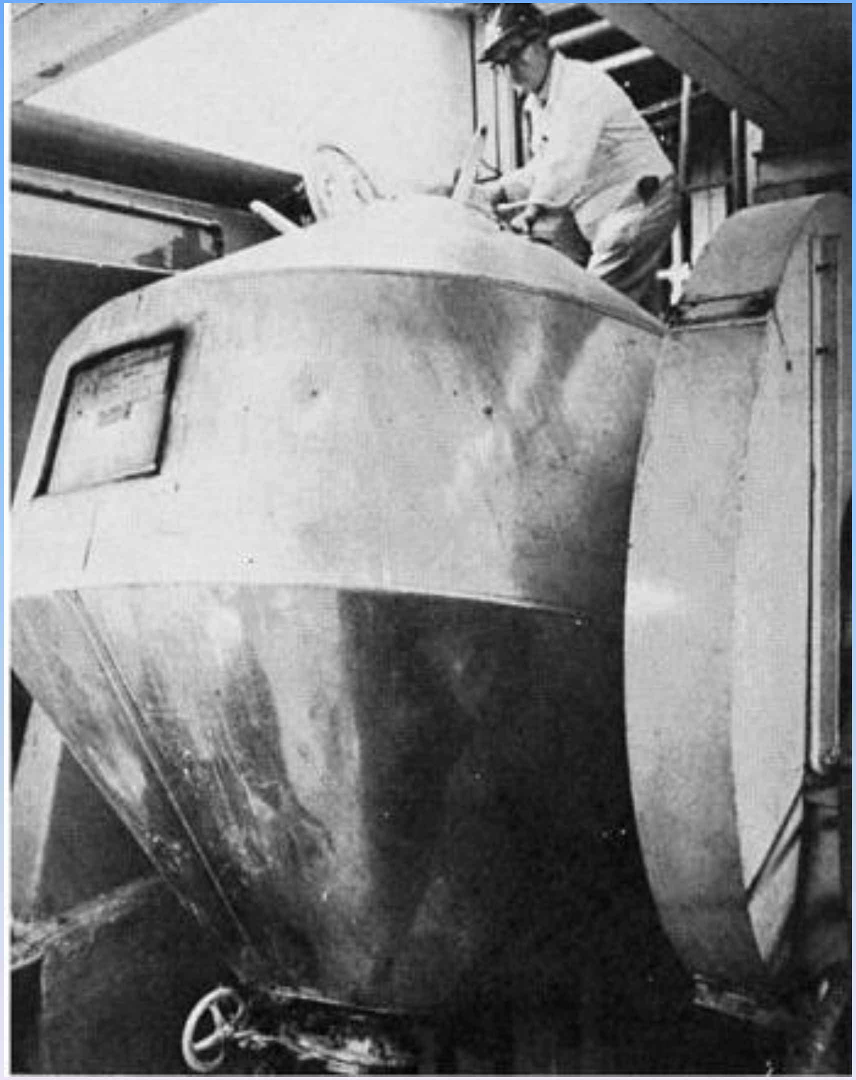
1.Tumbling mixer
‘Double cone’



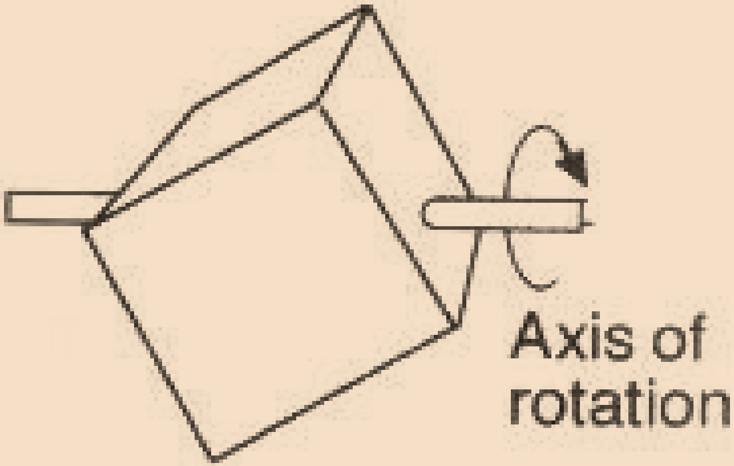
Double cone

Dominant mechanism is diffusive mixing

Oblicone blender



1.Tumbling mixer
‘cube mixer’

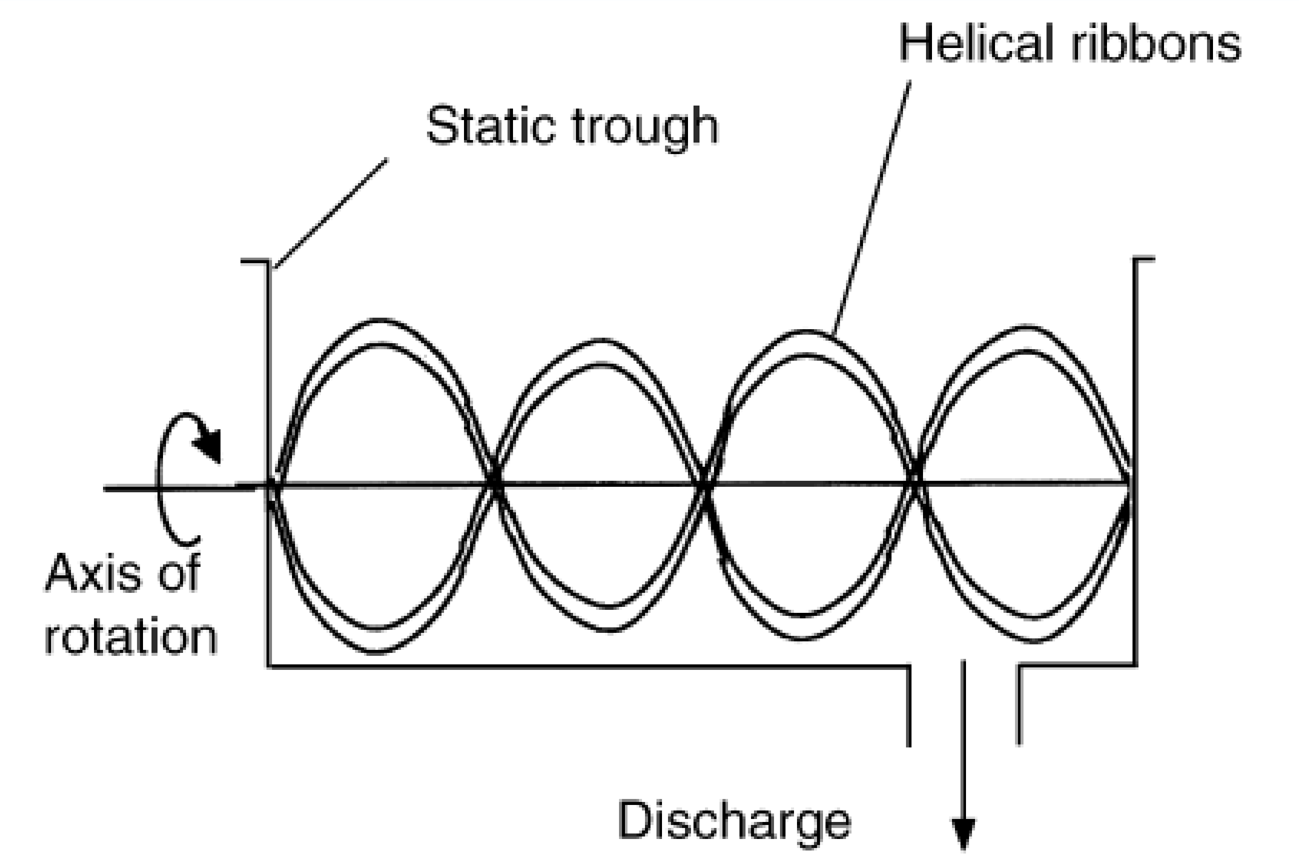


Rotating cube

Dominant mechanism is diffusive mixing

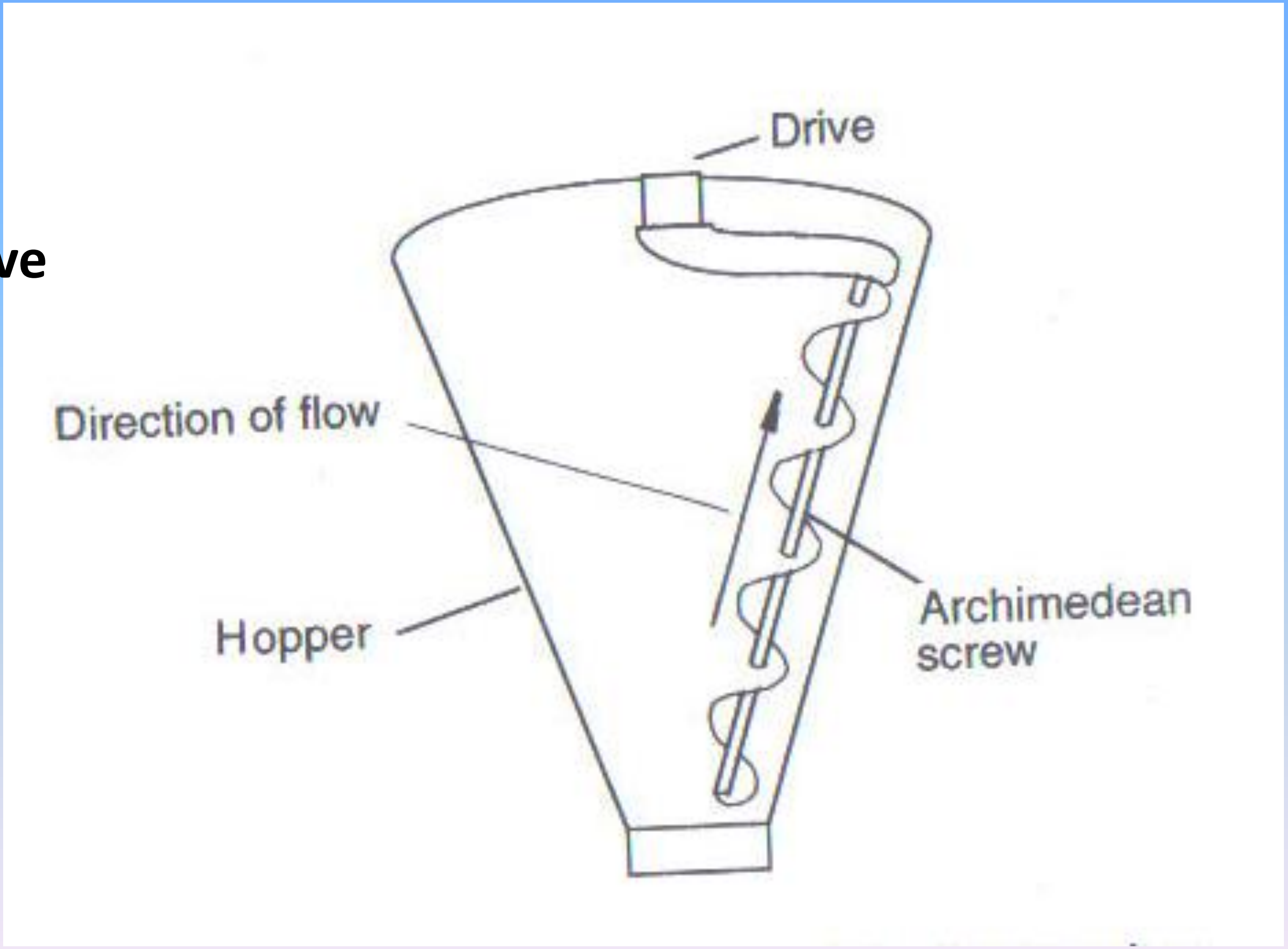
2.Convective mixers
‘Ribbon blender’

Convective mixer



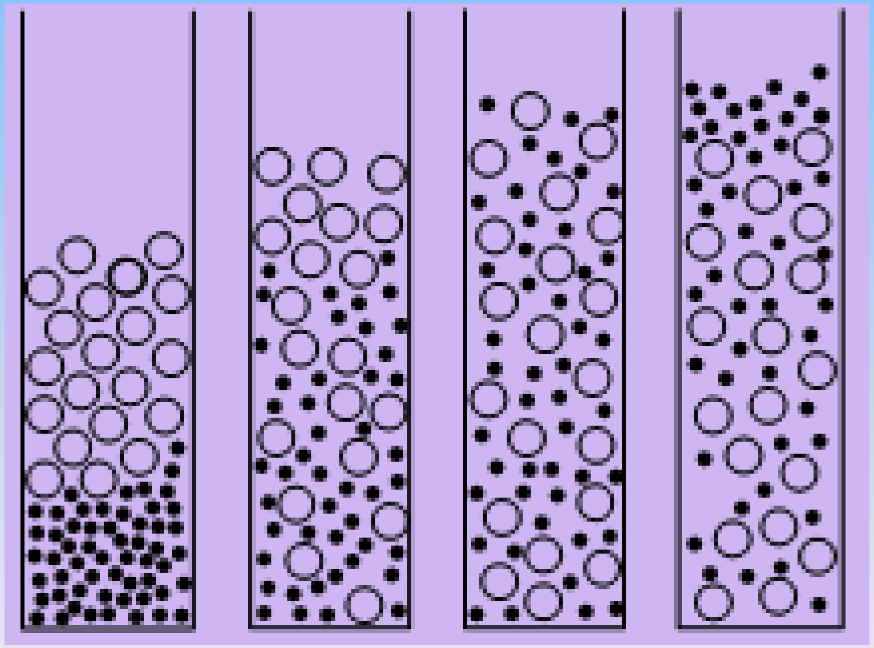
2.Convective mixers 'Nautamixer'

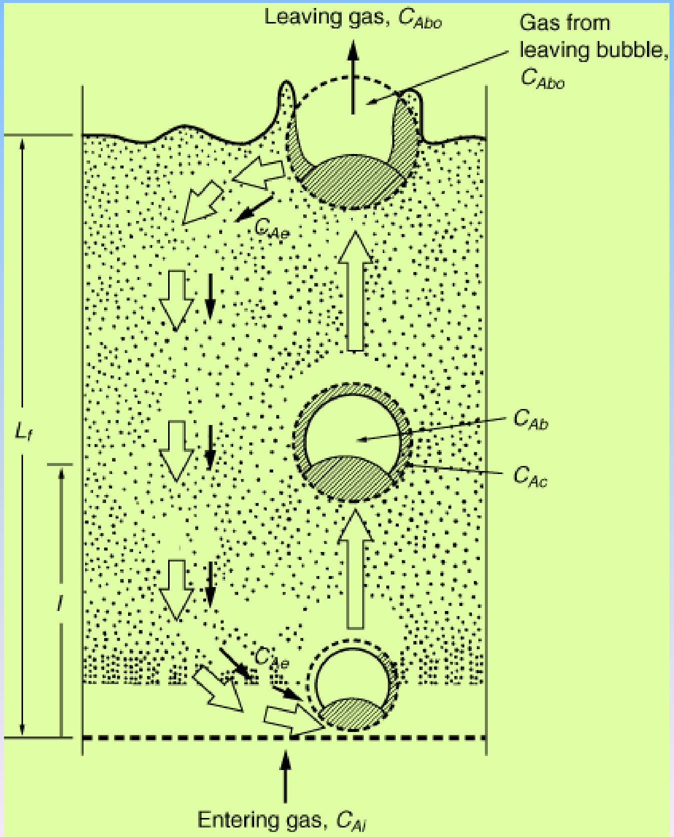
Convective mixer



Type of mixers

3. Fluidized bed mixer : convective mixing with circulating pattern of solids around bubbles.





Type of mixers

- High shear mixers

The degree of mixing

- For solid particles, the **statistical variation in composition** among samples withdrawn at any time from a mix is commonly used as a measure of the degree of mixing.
- The standard deviation **s** (the square root of the mean of the squares of the individual deviations) or the variance s^2 is generally used.
- It should be noted that particulate material cannot attain the perfect mixing.

- The best that can be obtained is **a degree of randomness** in which two similar particles may well be side by side.
- For a ***completely* random mix** of uniform particles, it is suggested that:

$$s_r^2 = p(1 - p)/n \qquad (1.33)$$

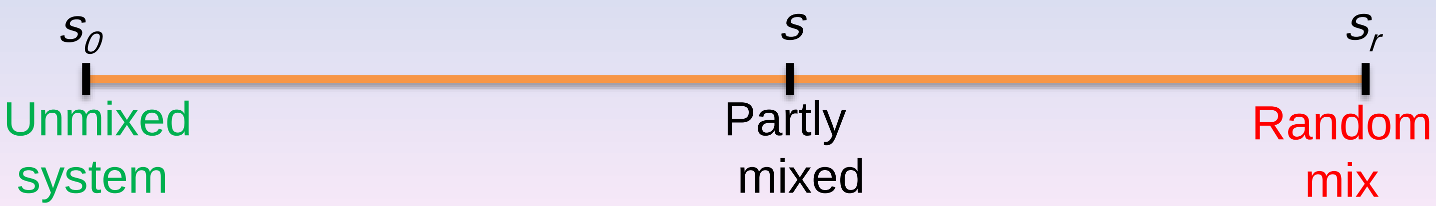
Where s_r^2 *is the variance for the mixture,* p *is the overall proportion of particles of one* colour, and n *is the number of particles in each sample.*

- For ***completely unmixed system***, indicated by the suffix 0, it may be shown that:

$$s_0^2 = p(1 - p) \qquad (1.34)$$

which is independent of the number of particles in the sample.

- When a material is **partly mixed**, then **the degree of mixing** may be represented by some term ***b****, and several methods have been suggested for expressing* ***b*** *in terms of measurable* quantities.



- ***b*** *may be defined as being equal to* s_r/s, *or* $(s_0 - s)/(s_0 - s_r)$
- ***Note:***

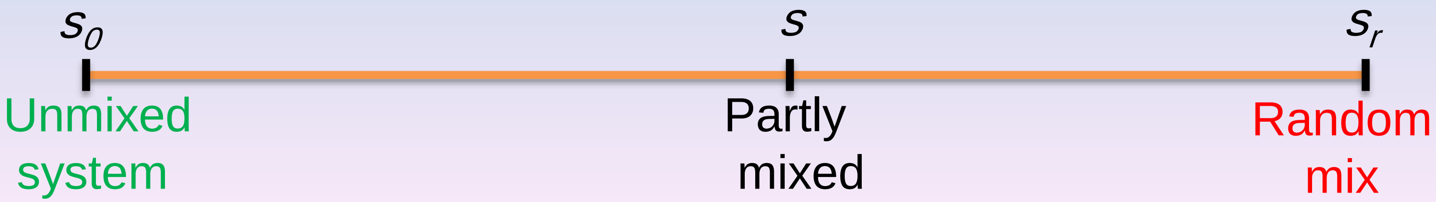
  $b = 0$ *for unmixed mixture*

  $b = 1$ *for a completely randomized material, where* $s = s_r$

- If s^2 is instead of s, then b could be written as:

$$\boldsymbol{b = (s_0^2 - s^2)/(s_0^2 - s_r^2)} \quad \textbf{or}$$

$$\boldsymbol{1\text{-}b = (s^2 - s_r^2)/(s_0^2 - s_r^2)} \qquad (1.35)$$



s_0 s s_r

Unmixed system

Partly mixed

Random mix

Discussion and useful Expressions

- When mixing continues over a long period demixing or segregation can occur, particularly if the materials are of different sizes or density.
- If the average number fraction of one type of particle is μ, consider N samples taken from the mixture.
- The measured number fraction of one type of particle in each of these N samples x_i (i = 1,2, ...,N) will differ from μ and from the measured values for the other samples.

- The mean, $\overline{X}$ of the x_i's will not be equal to μ unless a very large number of samples is taken.
- The standard deviation around is $\overline{X}$:

$$S = \left\{ \frac{\sum_{i=1}^{N} (x_i - \overline{x})^2}{N-1} \right\}^{\frac{1}{2}}$$

- Even when mixing is complete (ie random) the composition of successive samples will not be the same, unless the samples are very large. Otherwise, the standard deviation about μ, the true mean is

$$\sigma_e = \left\{ \frac{\mu(1-\mu)}{n} \right\}^{\frac{1}{2}}$$

'randomly mixed'

As given before

where n is the number of particles in each sample.

- The **Mixing Index**, *I*, is defined by

$$I = \frac{\sigma_e}{S} = \left\{ \frac{(N-1)\mu(1-\mu)}{n\sum_{i=1}^{N}(x_i-\overline{x})^2} \right\}^{\frac{1}{2}}$$

i.e the predicted standard deviation divided by the actual measured standard deviation.

- ***Note:*** S_e is always greater than *S*.

Mixing rate and mixing time

- **First Order Mixing Approximation**

$$\frac{dI}{dt} = k(1 - I)$$

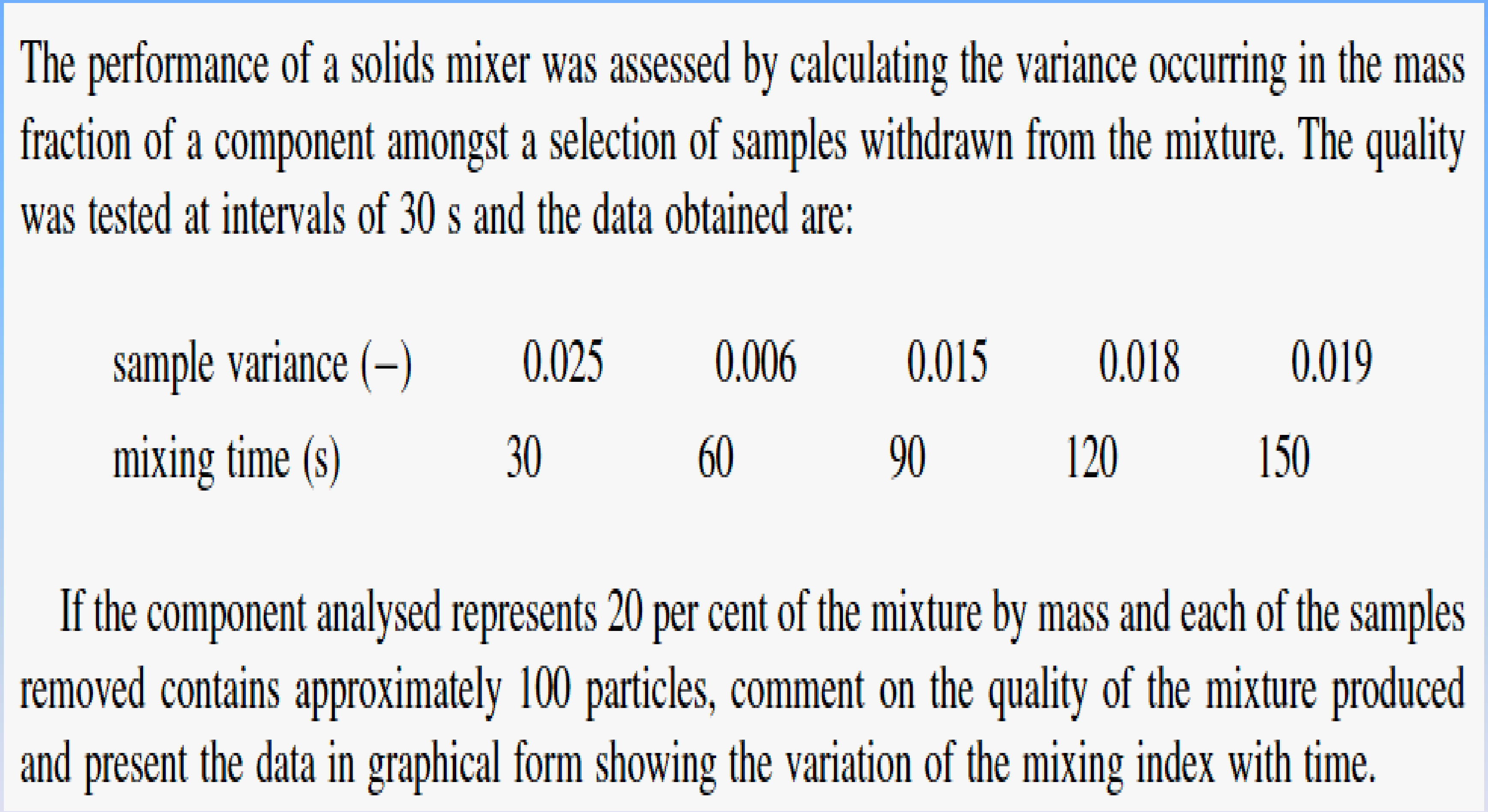
where k is a constant characteristic of the system and the mixing unit used.

- This integrates to

$$t_{12} = \frac{1}{k}\int_{I_1}^{I_2} \frac{dI}{1 - I} = \frac{1}{k} ln\left(\frac{1 - I_1}{1 - I_2}\right)$$

- if the sample is unmixed I_0 is approximately equal to $\frac{1}{\sqrt{n}}$

Example

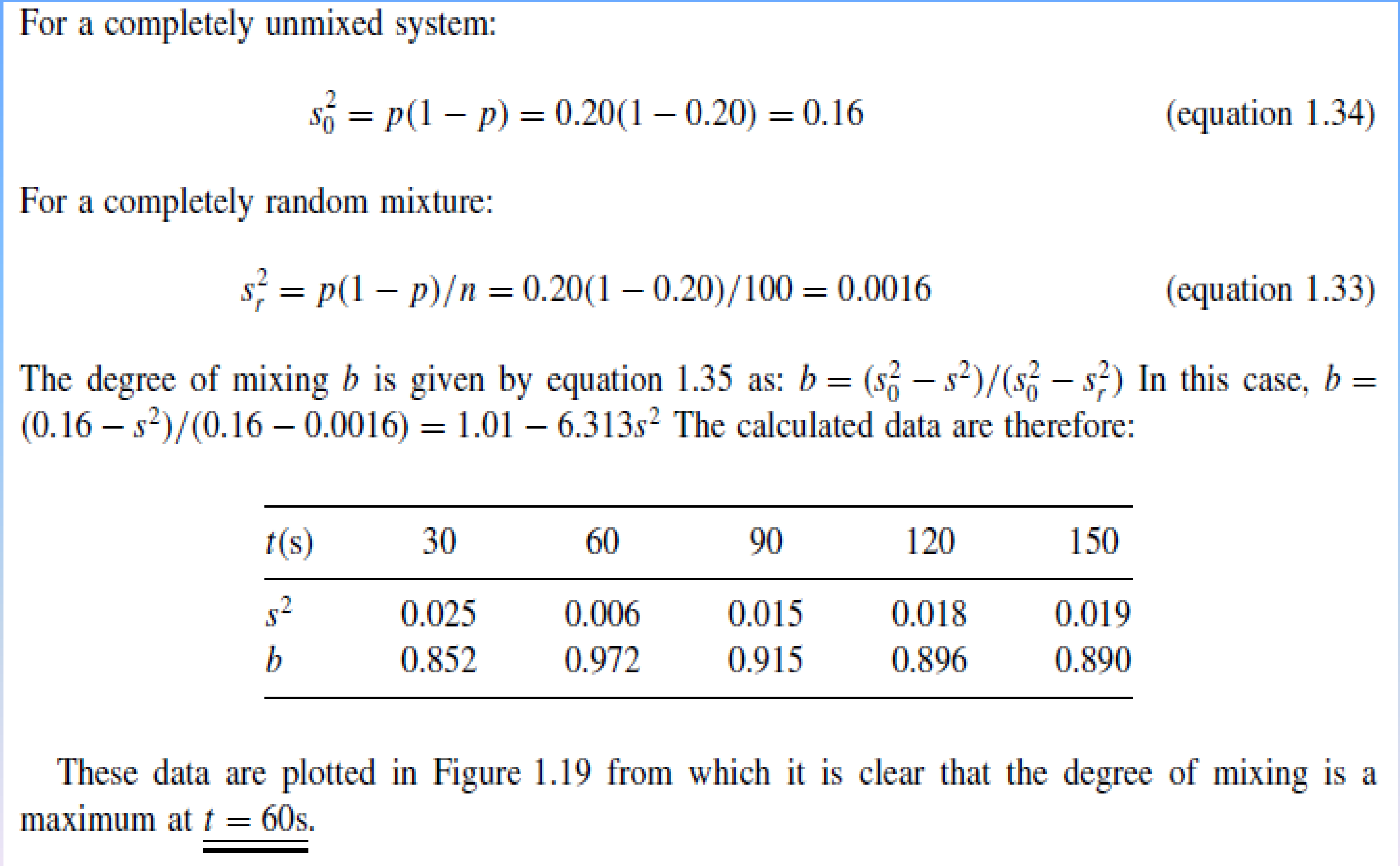


The performance of a solids mixer was assessed by calculating the variance occurring in the mass fraction of a component amongst a selection of samples withdrawn from the mixture. The quality was tested at intervals of 30 s and the data obtained are:

sample variance (–)	0.025	0.006	0.015	0.018	0.019
mixing time (s)	30	60	90	120	150

If the component analysed represents 20 per cent of the mixture by mass and each of the samples removed contains approximately 100 particles, comment on the quality of the mixture produced and present the data in graphical form showing the variation of the mixing index with time.

Solution



For a completely unmixed system:

$$s_0^2 = p(1 - p) = 0.20(1 - 0.20) = 0.16 \qquad \text{(equation 1.34)}$$

For a completely random mixture:

$$s_r^2 = p(1 - p)/n = 0.20(1 - 0.20)/100 = 0.0016 \qquad \text{(equation 1.33)}$$

The degree of mixing b is given by equation 1.35 as: $b = (s_0^2 - s^2)/(s_0^2 - s_r^2)$ In this case, $b = (0.16 - s^2)/(0.16 - 0.0016) = 1.01 - 6.313s^2$ The calculated data are therefore:

t(s)	30	60	90	120	150
s^2	0.025	0.006	0.015	0.018	0.019
b	0.852	0.972	0.915	0.896	0.890

These data are plotted in Figure 1.19 from which it is clear that the degree of mixing is a maximum at $\underline{\underline{t = 60\text{s}}}$.

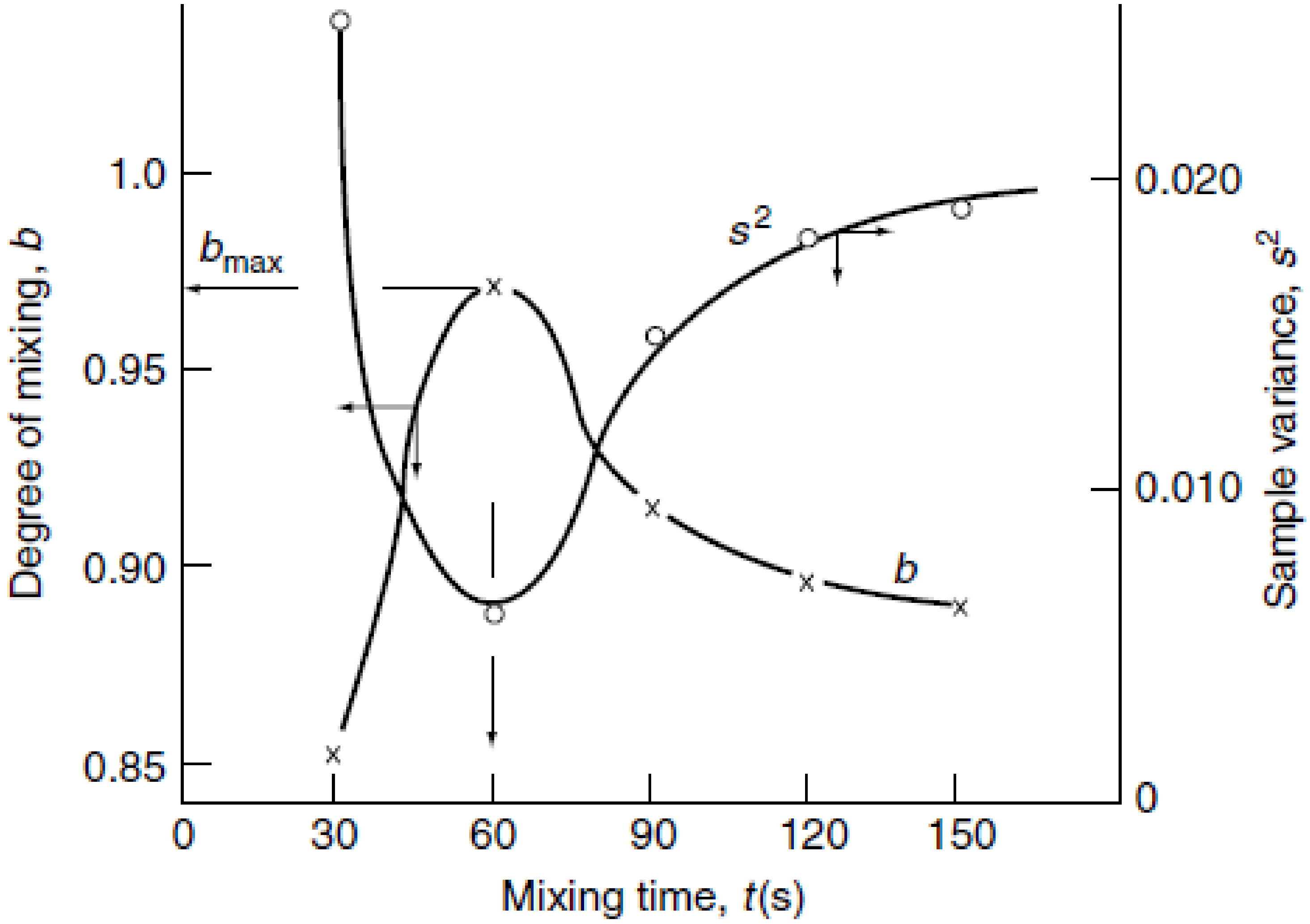


Figure 1.19. Example 1.3. Degree of mixing as a function of mixing time