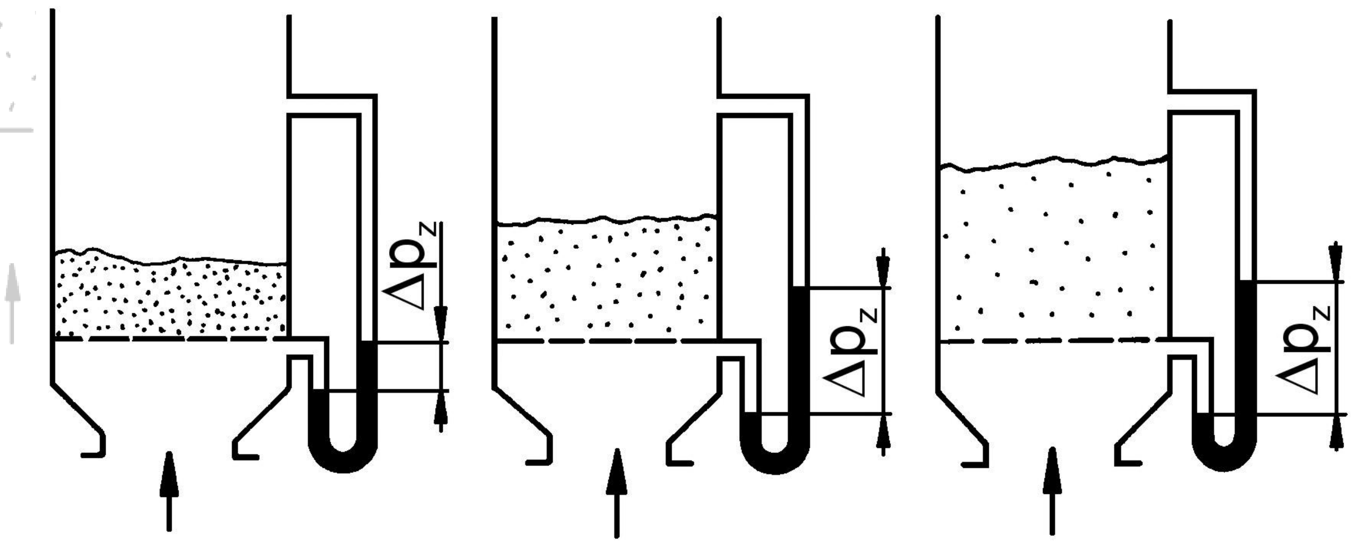
FLOW IN FLUIDIZED BED

Birth of fluidized bed

In a packed bed of small particles, when a fluid enters at sufficient velocity from the bottom and passes up through the particles, the particles are pushed upward and the bed expands and becomes fluidized.

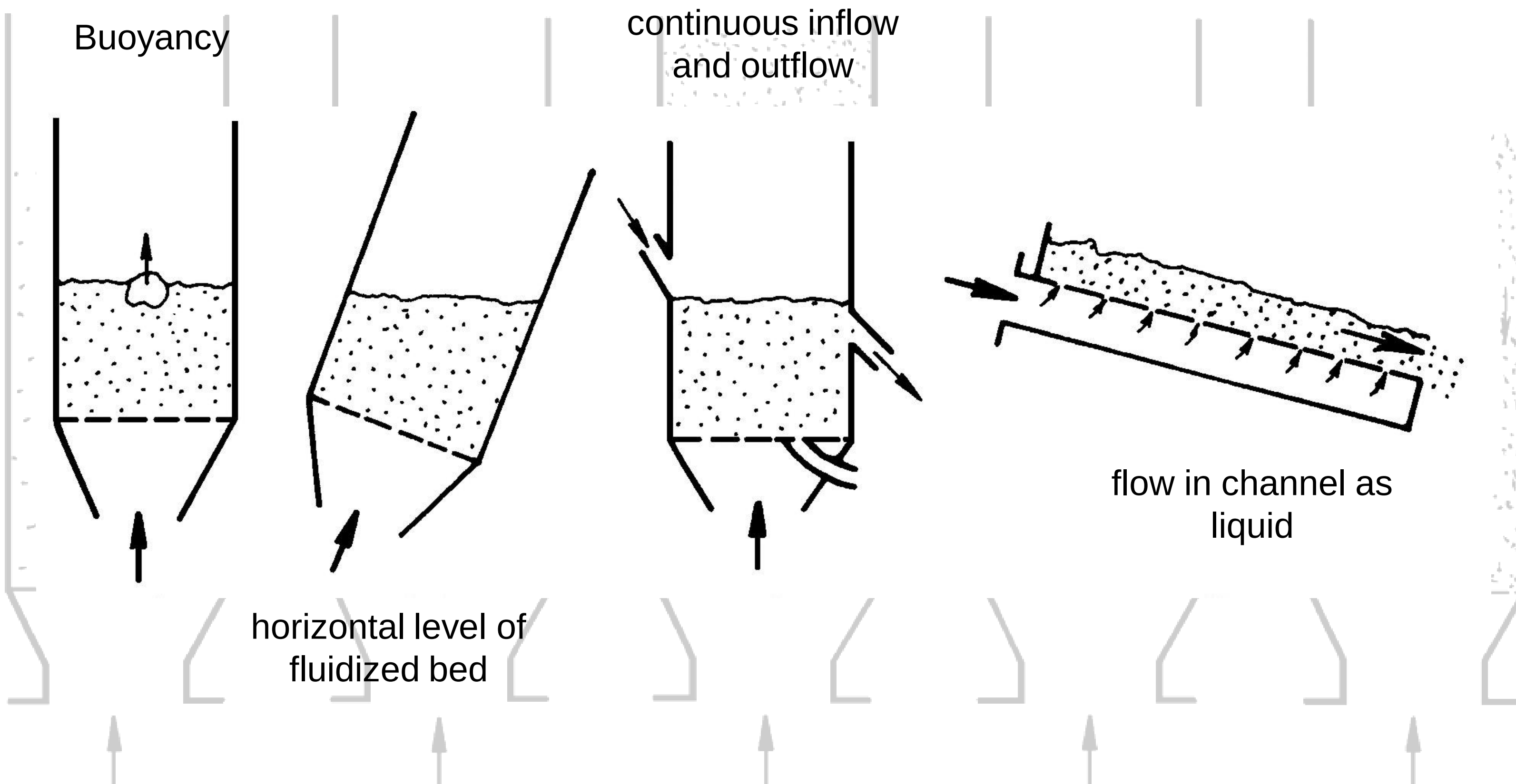
Emergence of fluidized bed:

- flow through porous (packed) bed (a)
- minimum fluidization velocity (b)
- drift velocity of particles (c) $C_D Re^2 = \frac{4}{3}\frac{D^3(\rho_s - \rho)\rho g}{\mu^2}$

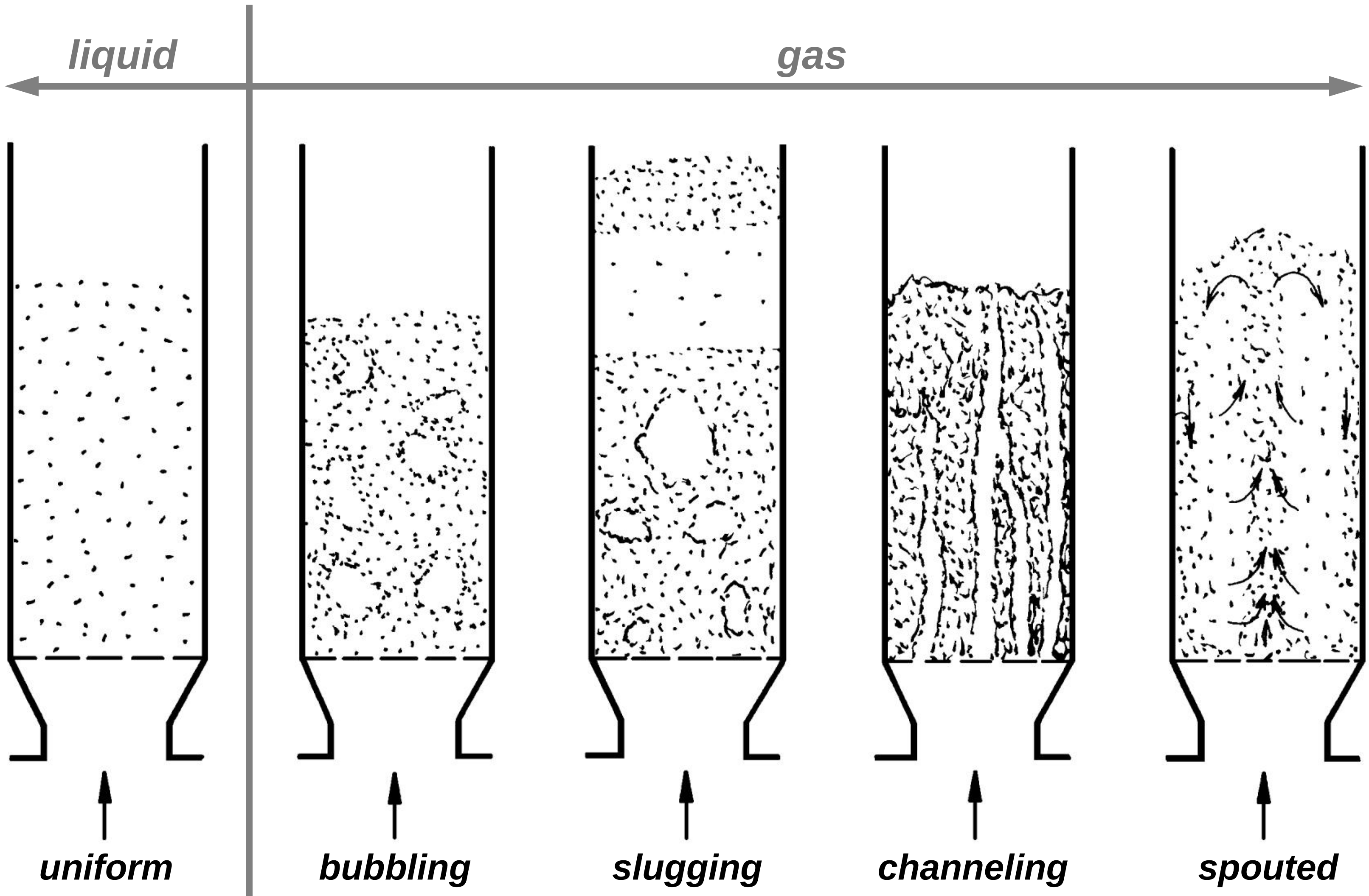


a) b) c)

Behavior of fluidized bed



Types of fluidization



uniform (particulate)
typical for liquids

bubbling
typical for gasses, size of bubbles increases upward

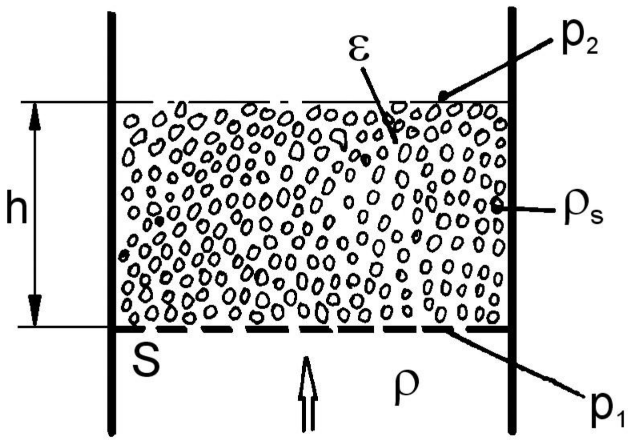
slugging
high slender beds

channeling
fine sticking particles, undesirable, prevention by pulsation, by increase of velocity and mixing

spouted
in cone apparatuses, good mixing

Basic parameters of fluidization

Minimum fluidization velocity



Force balance:

$$p_1 S = p_2 S + S\,h(1-\varepsilon)\rho_s g + S\,h\varepsilon\rho\,g$$

$$p_1 - p_2 = hg\left[(1-\varepsilon)\rho_s + \varepsilon\rho\right]$$

$$\Rightarrow \rho\,e_z = gh(\rho_s - \rho)(1-\varepsilon)$$

Bernoulli equation: $p_1 - p_2 = \rho\,g\,h + \rho\,e_z$

$$e_z = \lambda' \frac{1-\varepsilon}{\varepsilon^3}\frac{h}{D_p}u_o^2$$

$$\frac{1{,}75}{\varepsilon^3}Re_p^2 + \frac{150(1-\varepsilon)}{\varepsilon^3}Re_p = Ar \quad \Leftarrow$$

Ergun`s equation

$$\lambda' = \frac{150}{Re} + 1{,}75 = \frac{150(1-\varepsilon)\mu}{u_o D_p \rho} + 1{,}75$$

$$Re_p = \frac{u_o D_p \rho}{\mu} \qquad Ar = \frac{D_p^3(\rho_s - \rho)\rho g}{\mu^2}$$

Expansion (height and porosity) of fluidized bed

Mass balance of solid phase:

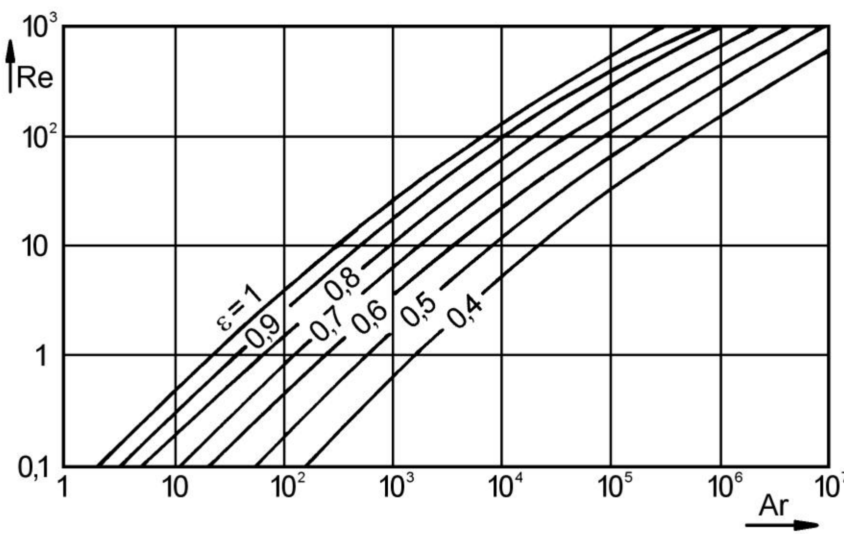
$$h_p S(1-\varepsilon_p) = hS(1-\varepsilon)$$

Goroško, Rozenbaum a Todes (for $\varepsilon = 0.4 \div 1$):

$$Re = \frac{u_o D_p \rho}{\mu}$$

$$Ar = \frac{D_p^3(\rho_s - \rho)\rho g}{\mu^2}$$

$$Re = \frac{Ar\varepsilon^{4,75}}{18 + 0{,}6\sqrt{Ar\varepsilon^{4,75}}}$$

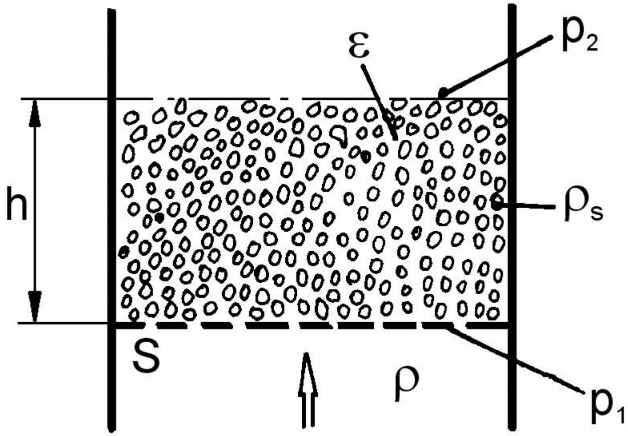


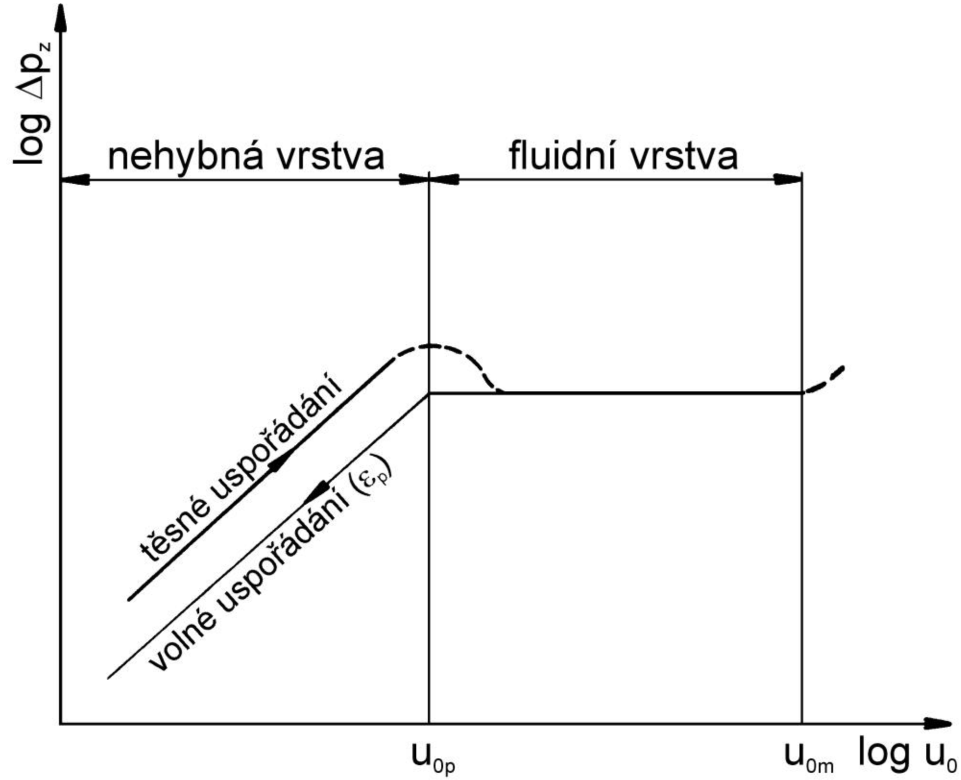
- ***$\varepsilon = \varepsilon_p \Rightarrow$ minimum fluidiz. velocity***
- ***$\varepsilon \rightarrow 1 \Rightarrow$ free settling velocity***

Void fraction ε_p at minimum fluidization condition

Type of Particle	***Particle size D_p [mm]***					
	0,02	***0,05***	***0,07***	***0,1***	***0,2***	***0,3***
Sharp sand, $\sigma = 0{,}67$	–	0,60	0,59	0,58	0,54	0,50
Round sand, $\sigma = 0{,}86$	–	0,56	0,52	0,48	0,44	0,42
Anthracite and glass coal	0,72	0,67	0,64	0,62	0,57	0,56
ABsorption carbon	0,74	0,72	0,71	0,69	–	–
Fischer-Tropsch catalyst, $\sigma = 0{,}58$	–	–	–	0,58	0,56	0,5

Pressure drop of fluidized bed



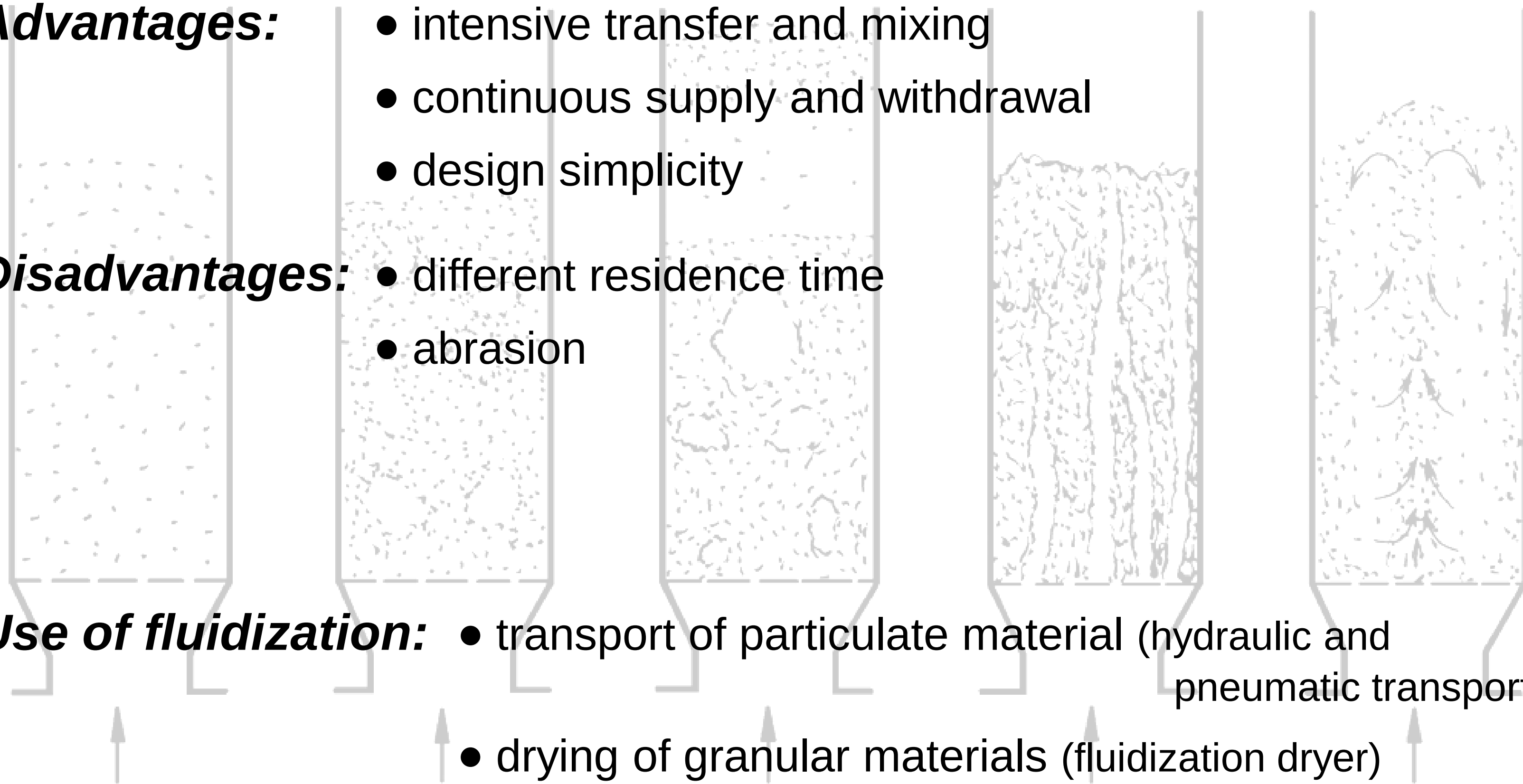


Force balance:

$$p_1 S = p_2 S + S\,h(1-\varepsilon)\rho_s g + S\,h\varepsilon\rho\,g$$

$$p_1 - p_2 = hg(1-\varepsilon)\rho_s = \frac{m_s g}{S}$$

Industrial application of fluidization



Advantages:

- intensive transfer and mixing
- continuous supply and withdrawal
- design simplicity

Disadvantages:

- different residence time
- abrasion

Use of fluidization:

- transport of particulate material (hydraulic and pneumatic transport)
- drying of granular materials (fluidization dryer)
- chemical reactors (fluidized bed combustion, catalytic agent and catalytic reaction)

EXAMPLE: Fluidization dryer – flow in fluidized bed

Corns with mean diameter D_p = 0.2 mm (particle density is 1550 kg·m^{-3}) is dried in fluidization dried by flow of air with temperature T = 140 °C (air density is 0.84 kg·m^{-3} and kinematic viscosity is 27.9·10^{-6} m^2·s^{-1}) . Determine how much of materials take hold of dryer with diameter 2 m and its pressure drop. Maximal height of fluidized bed is 1 m. Working drying air velocity select as geometrical average of minimum fluidization velocity and drift velocity of particles