Chemické inženýrství A/B

Sušení

Drying

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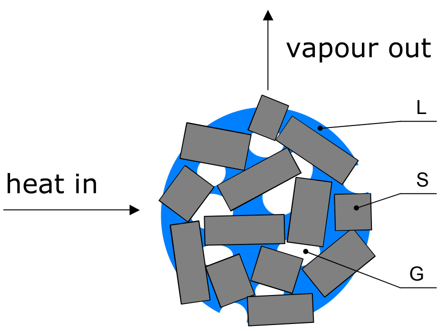
Evropský sociální fond
Praha & EU: Investujeme do vaší budoucnosti

Drying

Filtration/Centrifugation - mechanical separation of liquid from solids

Drying - separation by L-V phase transition



Composition - solid material:

A … liquid; B … solid

dry basis: $x_A = m_A / m_B$

wet basis: $w_A = m_A / (m_A + m_B)$

Composition - gas phase:

partial pressure $p_A = y_A P$

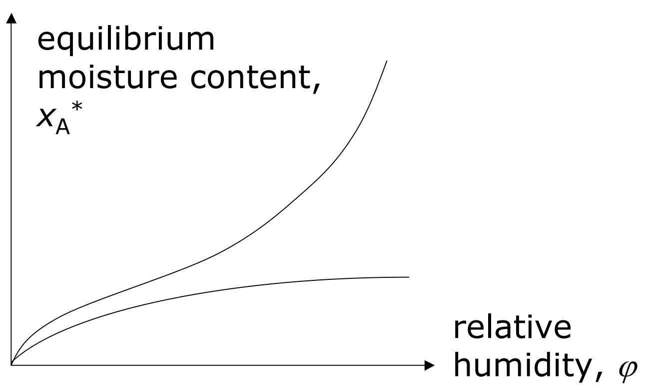
relative saturation $\varphi = p_A / p_A^*$

saturated vapour pressure $p_A^* = p_A^*(T)$

(e.g. from Antoine equation)

Moisture equilibrium:

- free moisture content $x_A = x_{A,tot} - x_A^*$



Classification of drying processes

Means of heat supply:

- direct heat transfer (hot gas)
- indirect heat transfer (heat exchange surface, microwave, or radiative)

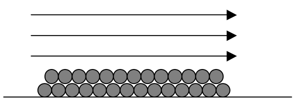
Means of vapour removal:

- cross-flow of carrier gas
- through-flow of carrier gas
- suction

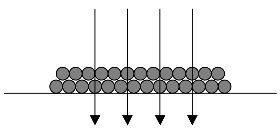
Means of solids motion:

- static vs. agitated (mechanically, fluidisation)

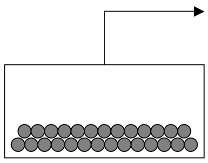
Vapour removal



cross-flow

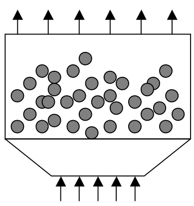


through-flow

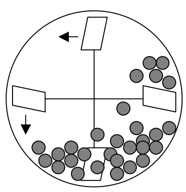


suction

Solid phase motion

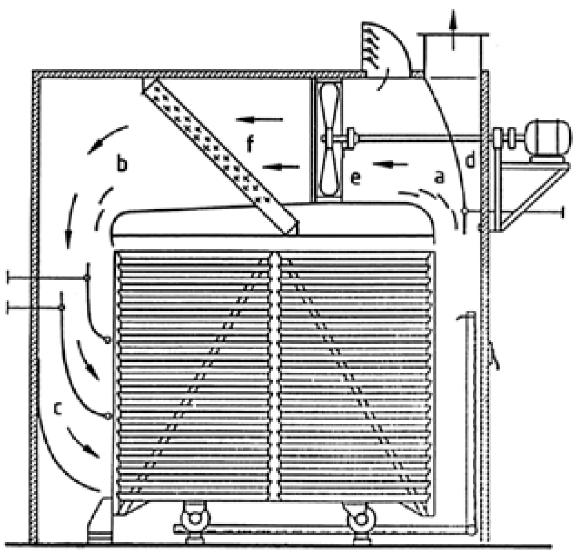


fluidized bed

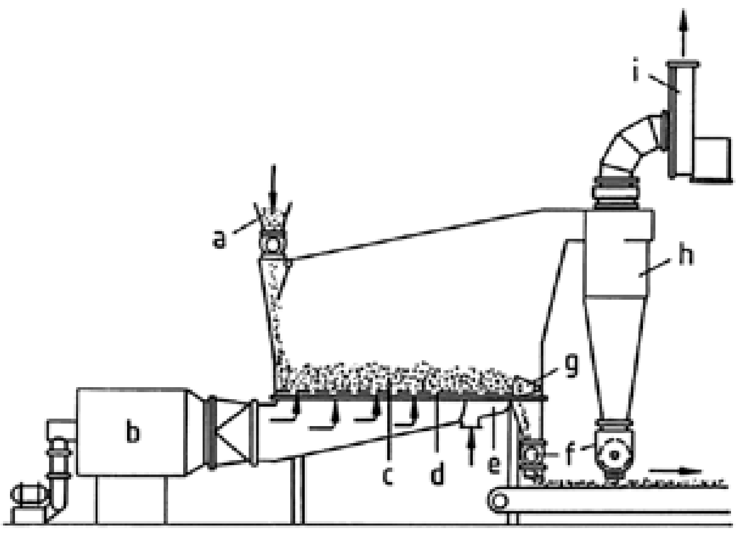


tumble drum or agitated vessel

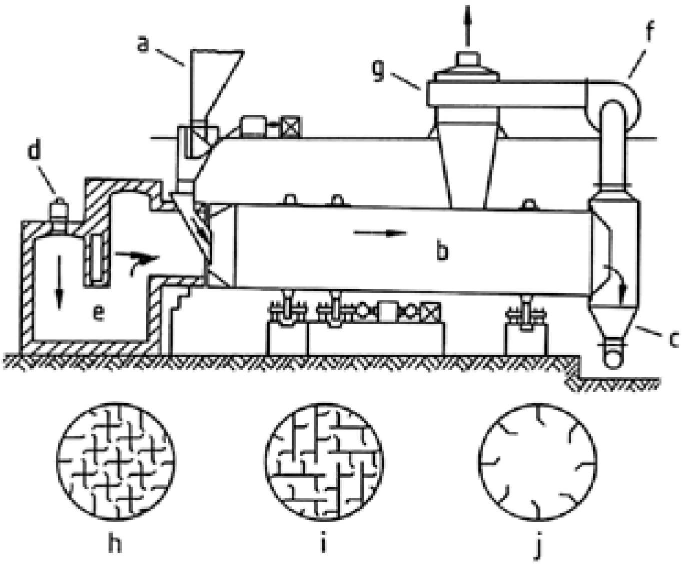
Drying equipment: tray dryer



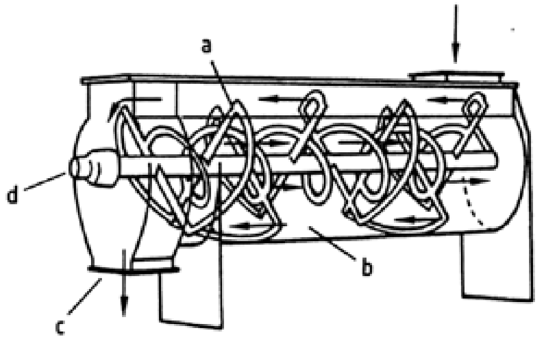
Drying equipment: fluid-bed dryer



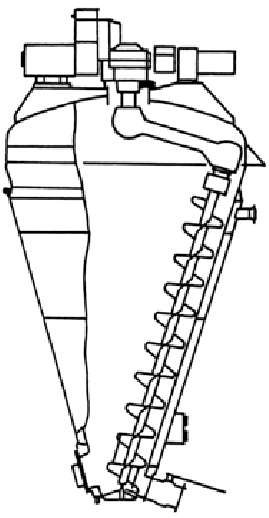
Drying equipment: rotary drum dryer



Drying equipment: contact dryers



Horizontal agitated vessel



Cone mixer

Heat-transfer rate:

$Q = h_q A \Delta T$ or $Q = h_q aV \Delta T$

ΔT … mean temperature difference, $\Delta T \sim (T_h - T_v)$

(not necessarily ΔT_{LM})

<u>Heat-transfer coefficients:</u>

-from gas to a single particle (or droplet)

$$Nu = 2.0 + 0.60\, Re_p^{1/2}\, Pr^{1/3}$$

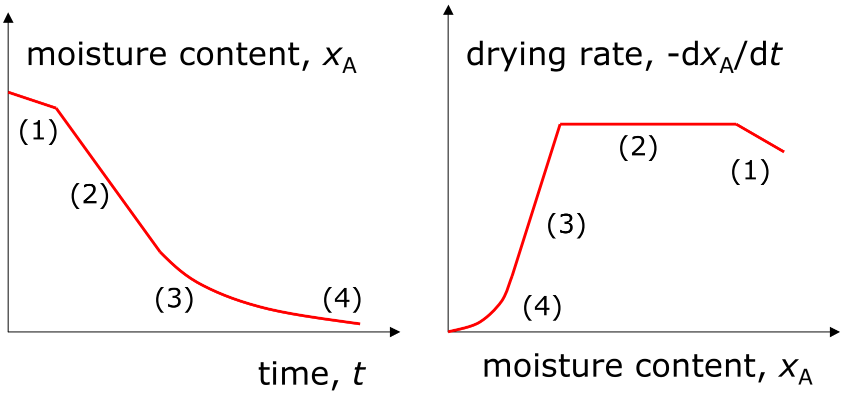
-from fluid to a flat surface (laminar flow and Pr>0.7)

$$Nu = 0.664\, Re^{1/2}\, Pr^{1/3}$$

($Nu = h_q L/\lambda$ $Re = uL\rho/\mu$ $Pr = c_p\mu/\lambda$)

-otherwise correlations for each geometric arrangement

Drying curves and drying rates:



1) warming-up period
2) constant-rate period
3) 1st falling-rate period
4) 2nd falling-rate period

Calculation of drying time:

-Constant drying conditions

Drying rate $R = - (1/A)\ dm_A/dt = - (m_B/A)\ dx_A/dt$

Drying time $t_T = (m_B/A) \int_{x1}^{x2} dx_A/R$

Constant period: $R = R_c \Rightarrow t_c = m_B\ (x_1 - x_2) / (AR_c)$

Falling rate period: $R = a\ x_A + b \qquad a=(R_c-R')/(x_c-x')$

$\Rightarrow t_f = m_B /(aA) \ln(R_1/R_2)$

If single falling-rate period and x'=0, then total time:

$t_T = m_B/(AR_c)[(x_{initial}-x_c)+x_c \ln(x_c/x_{final})]$