CHEMICAL ENGINEERING DESIGN & SAFETY

CHE 4253

Prof. Miguel Bagajewicz

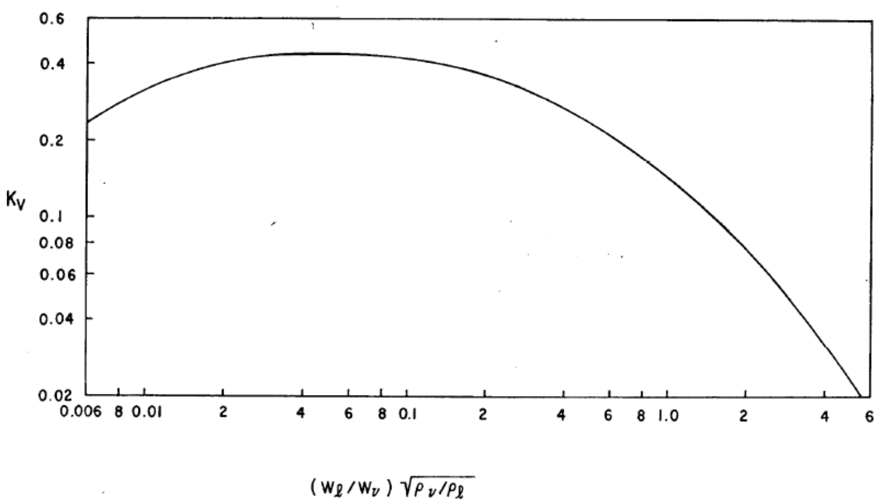
Flash and Tray Design Examples

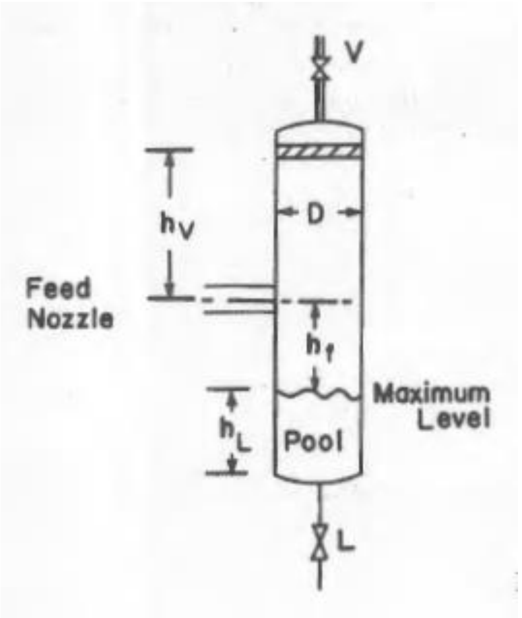
FLASH DRUM DESIGN

D related to vapor velocity.

Permitted velocity

$$v_{perm} = K\sqrt{\frac{(\rho_L - \rho_V)}{\rho_V}}$$





$$K = e^{A + B\ln F_{lv} + C(\ln F_{lv})^2 + d(\ln F_{lv})^3 + E(\ln F_{lv})^4}$$

$$F_{lv} = \frac{W_L}{W_V}\sqrt{\frac{\rho_V}{\rho_L}}$$

$A = -1.877478$

$B = -0.814580$

$C = -0.187074$

$D = -0.014523$

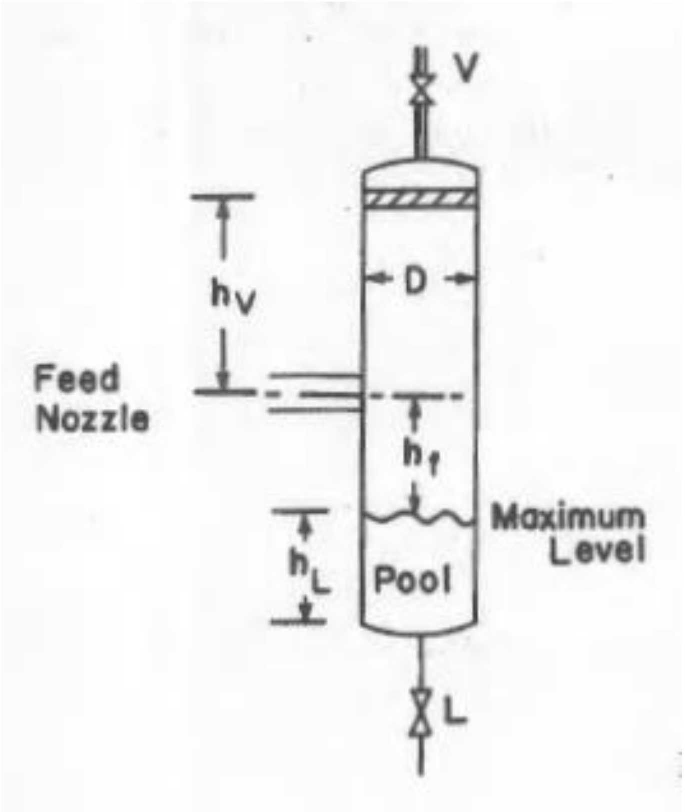
$E = -0.001015$

Where do these come from ?

FLASH DRUM DESIGN

$$h_V = 36'' + \frac{1}{2} diameter\ of\ \ feedline$$

$$h_f = 12'' + \frac{1}{2} diameter\ of\ \ feedline$$



Who came up with this rule and why?
Not known exactly what is the rationale

Residence Time, Failure Analysis,
Other Control issues?)

or ~2 minutes residence time. RESIDENCE TIME PREFERRED WHEN V_{pool} IS NOT AVAILABLE

Finally:

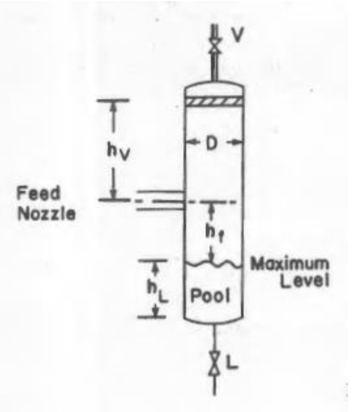
$$H = h_V + h_f + h_L$$

Nozzle size

$$(u_{max})_{nozzle} = 100/\sqrt{\rho_{mix}}\ \text{ft./sec.}$$

$$(u_{min})_{nozzle} = 60\sqrt{\rho_{mix}}\ \text{ft./sec.}$$

FLASH DRUM DESIGN

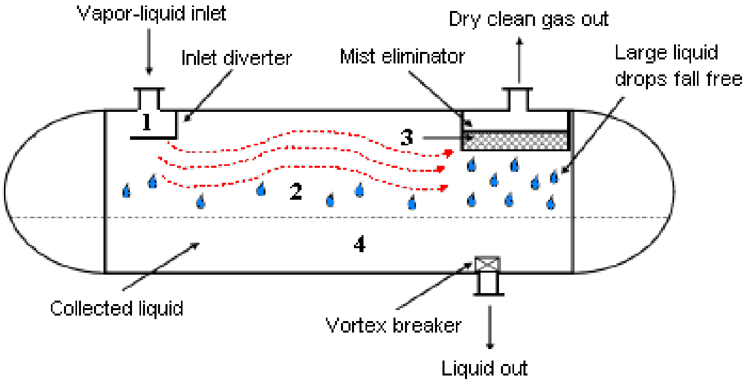


Final considerations

IF $\frac{H}{D} < 3$ increase V_{pool} (Why???)

IF $\frac{H}{D} > 5$ Use horizontal drum (Why???)

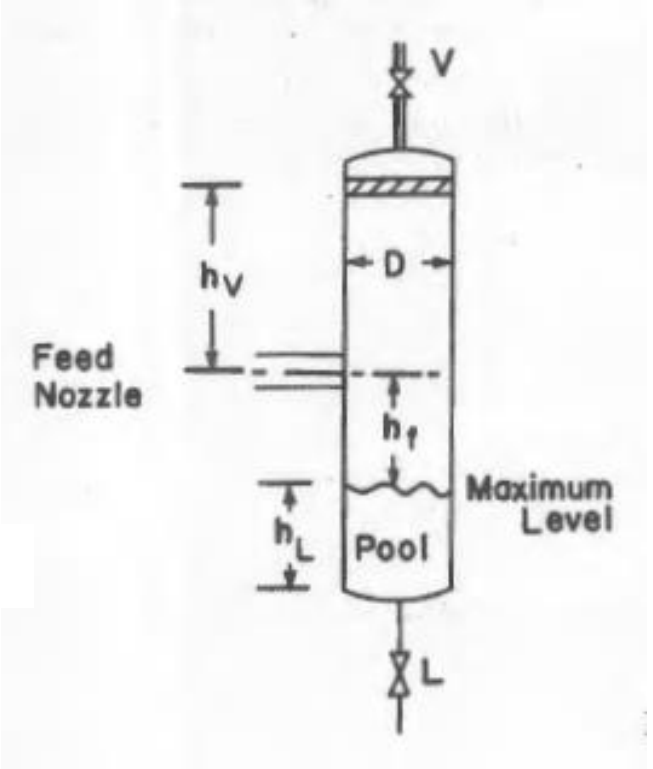
Different design protocol: Why?



FLASH DRUM DESIGN

EXAMPLE

DATA
$\widehat{Q_v} = 0.14157\ m^3/s$
$\widehat{Q_l} = 0.001179\ m^3/s$
$\widehat{\rho_l} = 999.552\ kg/m^3$
$\widehat{\rho_v} = 1.20139\ kg/m^3$
$\hat{t}_s = \mathbf{120}\ s$
$\hat{P} = 30\ psig$



$$F_{lv} = \frac{\hat{W}_l}{\hat{W}_v}\sqrt{\frac{\rho_V}{\rho_L}} = \left(\frac{0.001179*999.552}{0.14157*1.20139}\right)\sqrt{\frac{1.2013}{999.552}}$$ =0.2402

$$K = e^{A+B\ln F_{lv}+C(\ln F_{lv})^2+d(\ln F_{lv})^3+E(\ln F_{lv})^4}$$ =0.2365

$A = -1.877478$

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$E = -0.001015$

$$v_{perm} = K\sqrt{\frac{(\rho_L-\rho_V)}{\rho_V}} = 0.2365\sqrt{\frac{(999.552-1.20139)}{1.20139}}$$ =6.823

FLASH DRUM DESIGN

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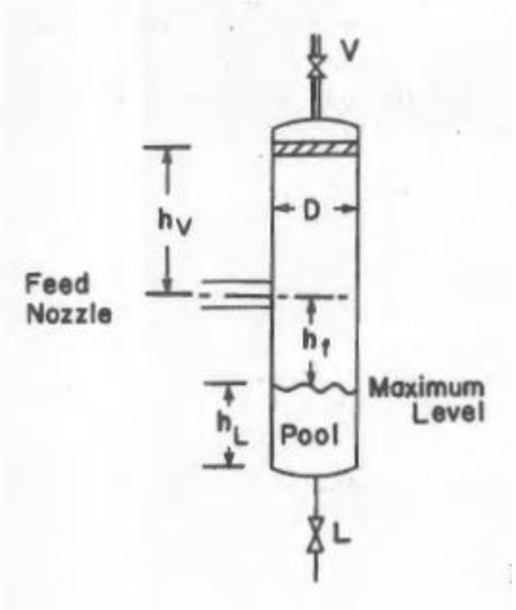

$$v_{perm} = K\sqrt{\frac{(\rho_L - \rho_V)}{\rho_V}}$$ =6.823 ft/sec

$$A = \hat{Q}_v / v_{perm} = 0.14157/(6.823*0.30103)$$ =0.0689 m²

$$D = \sqrt{\frac{4A}{\pi}} = \sqrt{4*0.0689/3.1416}$$ =0.29 m

FLASH DRUM DESIGN

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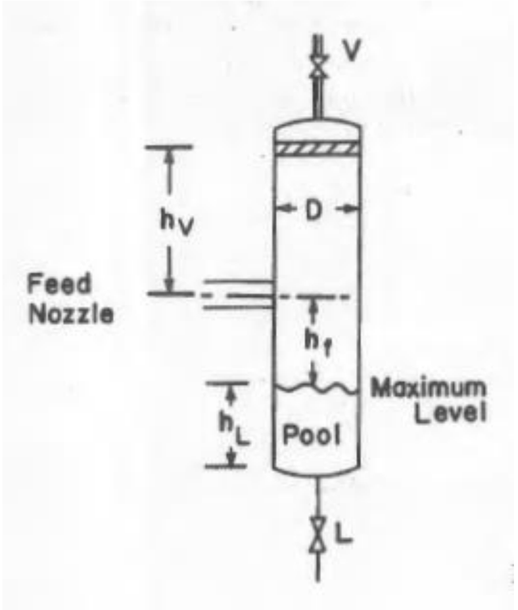

D =0.29 m

$$h_V = 36'' + \frac{1}{2} diameter\ of\ \ feedline$$

$$h_f = 12'' + \frac{1}{2} diameter\ of\ \ feedline$$

$$(u_{max})_{nozzle} = 100/\sqrt{\rho_{mix}},\ \text{ft./sec.}$$

$$(u_{min})_{nozzle} = 60\sqrt{\rho_{mix}},\ \text{ft./sec.}$$

$$\hat{t}_s = V_{pool}/\hat{Q}_L = \left[\frac{\pi D^2}{4} h_L\right] \Big/ \hat{Q}_L \Rightarrow h_L = \hat{Q}_L \hat{t}_s \Big/ \left[\frac{\pi D^2}{4}\right]$$

FLASH DRUM DESIGN

EXAMPLE

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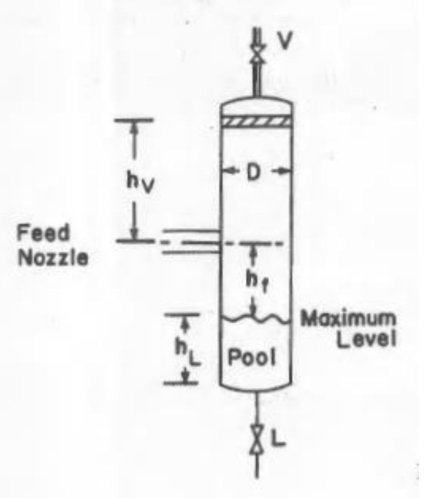

$$v_{\max nozzle} = 100\sqrt{\rho_{mix}} = 100\sqrt{\frac{(0.14157*1.20139+0.001179*999.552)}{(0.14157+0.001179)(35.3147*0.453592)}}$$ =76 ft/s

$$v_{\min nozzle} = 60\sqrt{\rho_{mix}} = 60\sqrt{\frac{(0.14157*1.20139+0.001179*999.552)}{(0.14157+0.001179)(35.3147*0.453592)}}$$ = 46 ft/s

Area of nozzle = $(\widehat{Q_v} + \widehat{Q_l}) / v_{nozzle}$

$=(0.14157+0.001179)*3.3219/[(46+76)/2]=$ 0.0078 m^2

$$D_{nozzle} = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4*0.0078}{\pi}}$$ = 0.1 m

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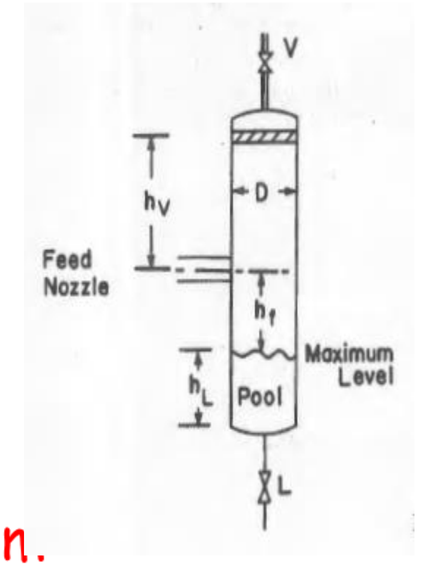
$\widehat{\rho_v} = 1.20139\ kg/m^3$
$\hat{t}_s = 120\ s$
$\hat{P} = 30\ psig$

D =0.29 m D_{nozzle} = 0.1 m

A = 0.0689 m²



$$h_V = 36'' + \frac{1}{2}\,diameter\ of\ \ feedline\ = 0.0254*36 + 0.05$$ =0.9644 m

$$h_f = 12'' + \frac{1}{2}\,diameter\ of\ \ feedline\ = 0.0254*12 + 0.05$$ =0.3548 m

$$h_L = \hat{Q}_L \hat{t}_s / A\quad = 0.001179 * 120 / 0.069$$ =2.05 m

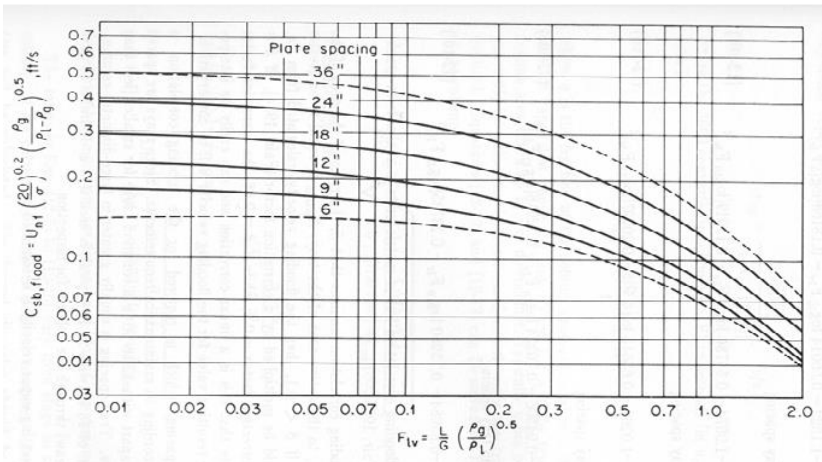
$$H = h_V + h_f + h_L = 0.9644 + 0.3548 + 2.05$$ =3.37 m

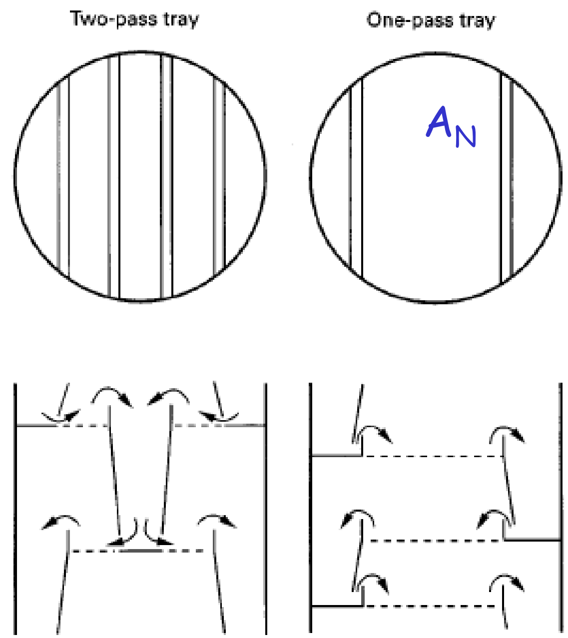
$$H / D = 3.37 / 0.29$$ =11.3 m Use Horizontal Separator

DISTILLATION/ABSORPTION COLUMN TRAY DESIGN

Diameter first. Design for velocity. Flooding velocity given by (are you surprised?)

Fair correlation





$$U_{N,f} = C_{SB}\left(\frac{\rho_L - \rho_V}{\rho_V}\right)^{0.5}\left(\frac{\sigma_L}{20}\right)^{0.2}$$

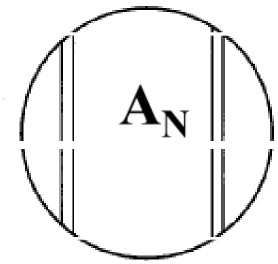
$$F_{lV} = (L/V)(\rho_V/\rho_L)^{0.5};$$

$$\log 10(C_{SB}) = -1.1977 - 0.53143\log 10(F_{LV}) - 0.1876\left[\log 10(F_{LV})\right]^2$$

Use ~80% of flooding velocity. Diameter is a function of the NET area A_N

DISTILLATION/ABSORPTION COLUMN TRAY DESIGN

One-pass tray



$$A_N = \widehat{Q_v} / (0.8\ U_{n,f})$$

Heuristics: $A_{dc} = 0.1\ A$

But $A = A_N + 2\ A_{dc}$

Then: $A = A_N + 0.2\ A$ ➡ $A = A_N / 1.2$

➡ $$D = \sqrt{\frac{4\ A}{\pi}}$$

DISTILLATION DESIGN

EXAMPLE

DATA

$\widehat{Q_v} = 1.42\ m^3/s$
$\widehat{Q_l} = 0.012\ m^3/s$
$\widehat{\rho_l} = 1100\ kg/m^3$
$\widehat{\rho_v} = 1.043\ kg/m^3$
$\hat{\sigma} = 15\ mN/m$

$$F_{LV} = (L/V)(\rho_V/\rho_L)^{0.5} = 0.027$$

$$U_{N,f} = C_{SB}\left(\frac{\rho_L - \rho_V}{\rho_V}\right)^{0.5}\left(\frac{\sigma_L}{20}\right)^{0.2}$$

$$\log 10(C_{SB}) = -0.94506 - 0.70234 \log 10(F_{LV}) - 0.22618[\log 10(F_{LV})]^2 = -0.3998$$

$$C_{SB} = 0.398 \Rightarrow U_{n,f} = 0.398\sqrt{\frac{(1100-1.043)}{1.043}}\left(\frac{15}{20}\right)^{0.2} = 10.84$$

$U = 0.8\ U_{n,f} = 0.8 * \mathbf{10.84} = 8.67$

DISTILLATION/ABSORPTION COLUMN TRAY DESIGN

DATA

$\widehat{Q_v} = \mathbf{1.42}\ m^3/s$

$\widehat{Q_l} = 0.012\ m^3/s$

$\widehat{\rho_l} = \mathbf{1100}\ kg/m^3$

$\widehat{\rho_v} = \mathbf{1.043}\ kg/m^3$

$\hat{\sigma} = 15\ mN/m$

$$A_N = \widehat{Q_v} / (0.8\ U_{n,f}) = 1.4157 / (8.67*0.30103) = \mathbf{0.54}\ m^2$$

$$A = A_N/0.8 = 0.54/0.8 = \mathbf{0.68\ m^2}$$

$$D = \sqrt{\frac{4\ A}{\pi}} = \mathbf{0.93\ m}$$