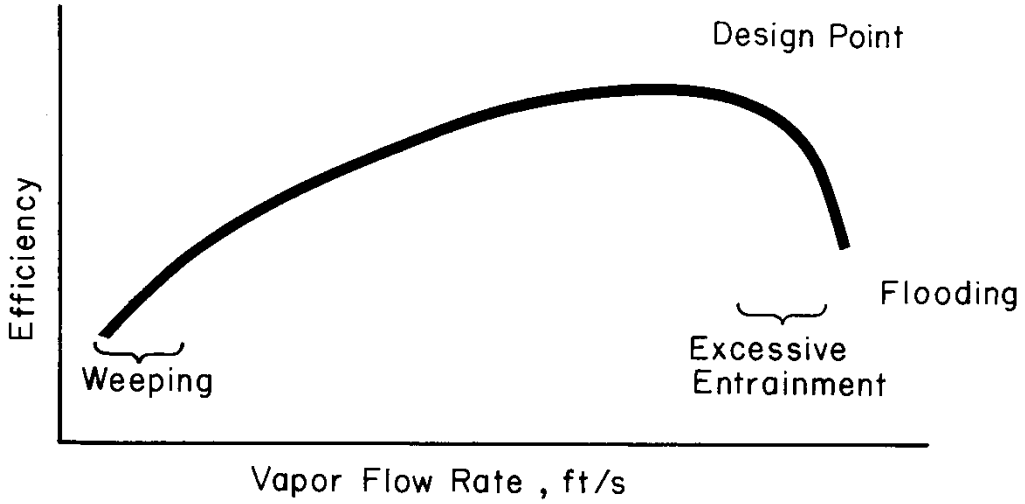
Distillation Design 3: Review

- Tray operation
  - Entrainment
  - Flooding
  - Turn down ratio
  - Tray efficiency
  - Weeping
  - Weir
  - Downcomer
  - Downcomer flooding (less common than entrainment flooding)
  - Valve, sieve and bubble cap trays
- Column diameter



Diameter Calculation

$$Dia = \sqrt{\frac{4VRT}{\pi\eta(3600)p(fraction)u_{flood}}}\ , \text{ft}$$ Eq. 10-16

V in lbmol/h
T in K
R in $\frac{atm\ ft^3}{K\ lbmol}$
p in atm
u in ft/s
η is fraction of tray that is active (unitless)
(fraction) is the fraction of flooding (unitless)

$$u_{flood} = C_{sb,f}\left(\frac{\sigma}{20}\right)^{0.2}\sqrt{\frac{\rho_L - \rho_v}{\rho_v}}\ ,\text{ft/s}$$ Eq. 10-8

Diameter Calculation

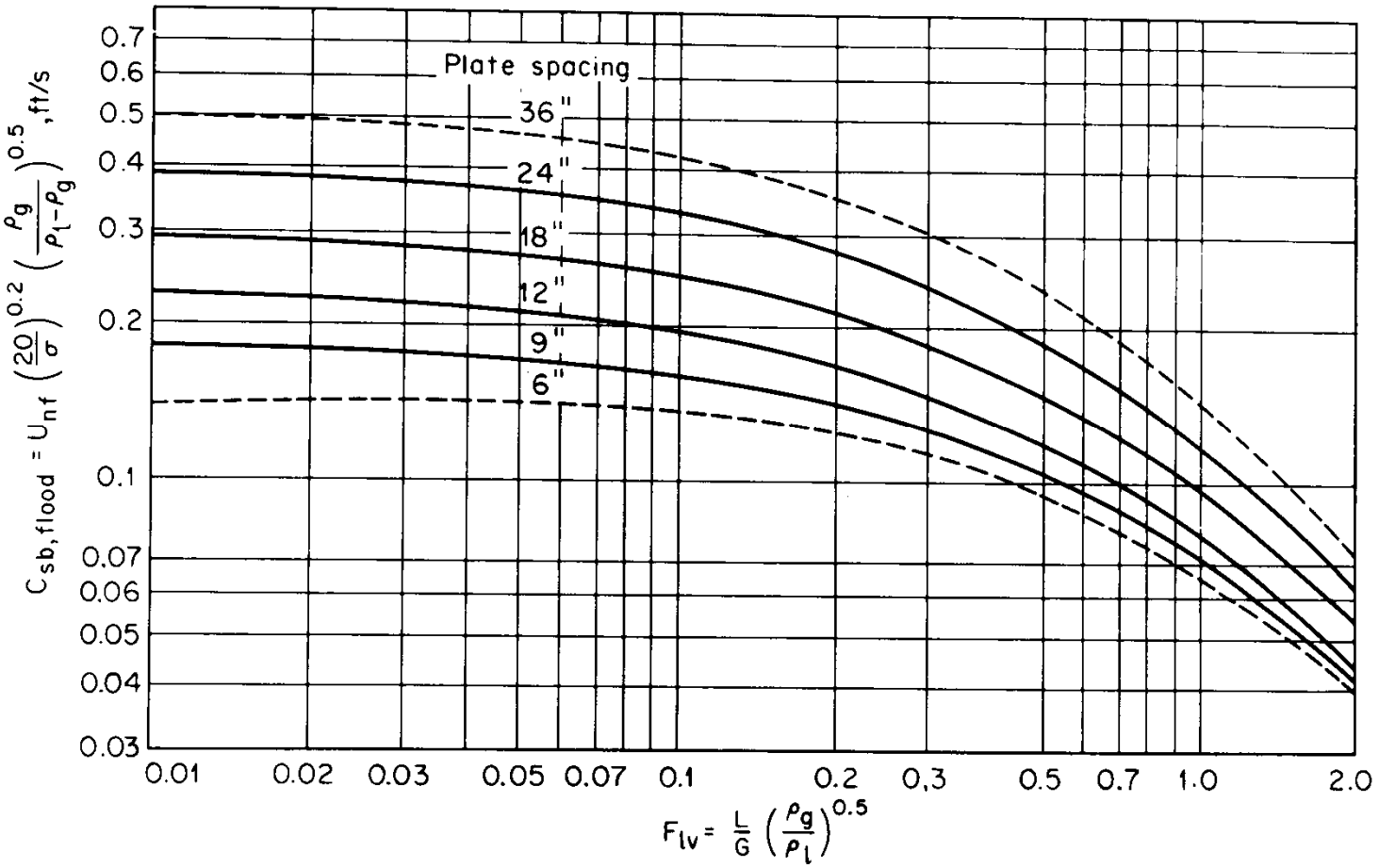
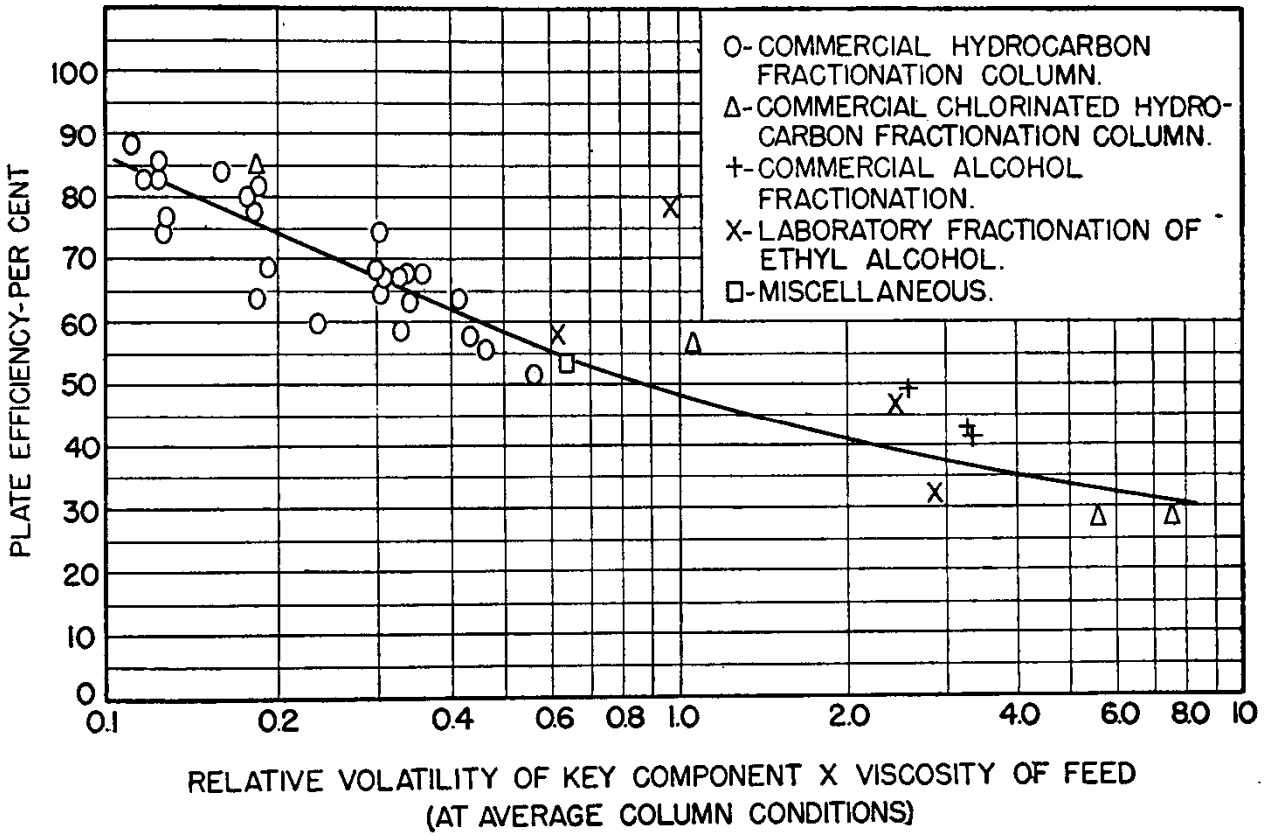


Figure 10-16 Capacity factor for flooding of sieve trays from Fair and Matthews (1958).

Overall Efficiency

- O'Connell correlation (in absence of data based on experience with similar columns)

$$E_o = 0.52782 - 0.27511\, log_{10}(\alpha\mu) + 0.044923[log_{10}(\alpha\mu)]^2$$



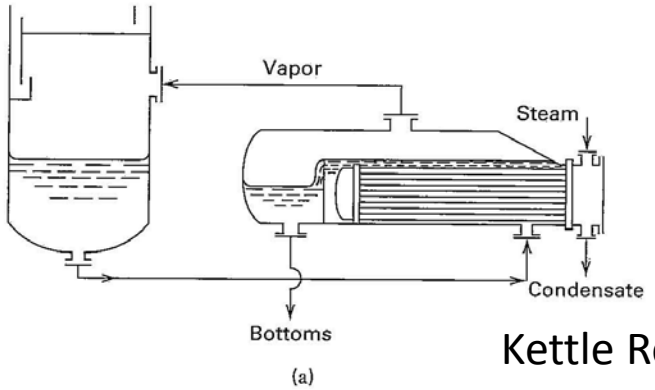
$$E_o = \frac{N_{equil}}{N_{actual}}$$

Tray Sizing on Simulator

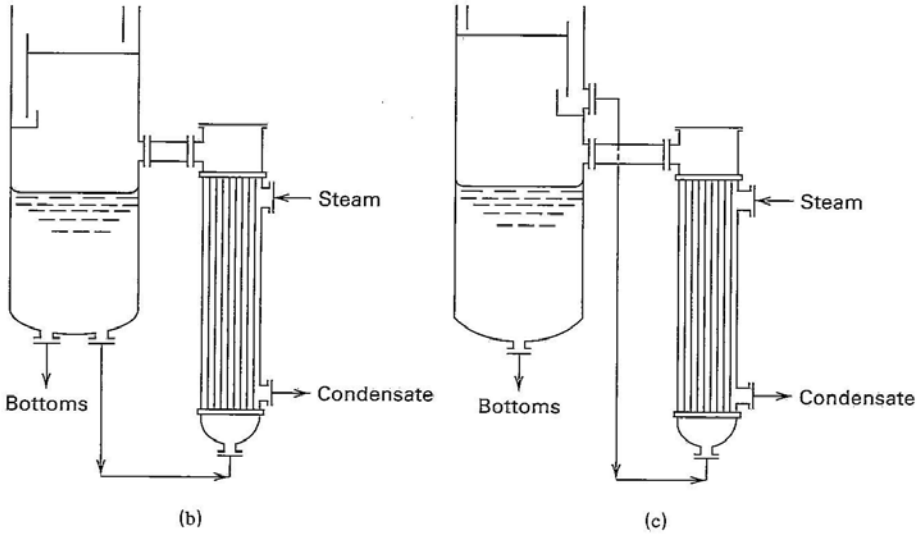
Tray Efficiency

- Can calculate as part of tray sizing
- Can also estimate from “first principles”
- Possible to include as part of distillation simulation
  - Manual entry of individual tray efficiencies- does not appear to be coupled to efficiency calculation in ChemCAD (under convergence menu)
  - Calculation assuming mass transfer control rather than equilibrium

Types of Equipment



Kettle Reboiler



Thermosyphon Reboilers

http://www.inspection-for-industry.com/heat-exchanger-theory.html

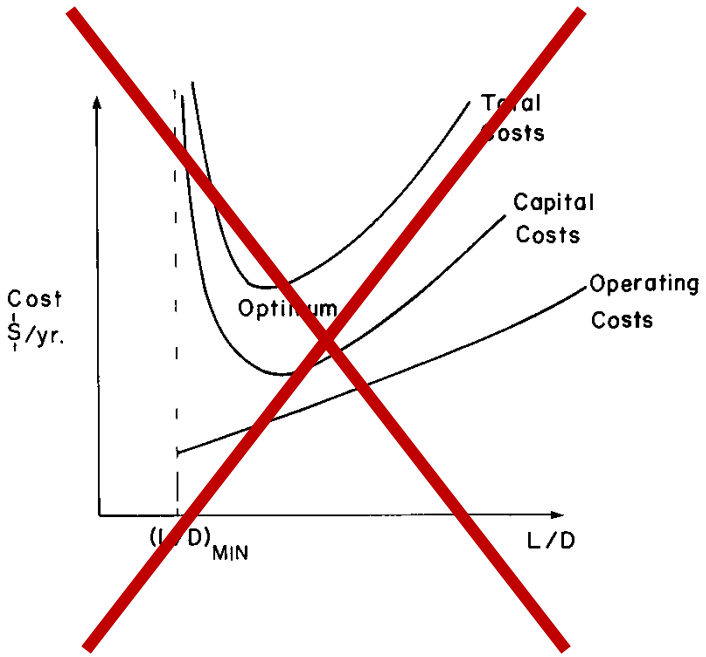
Impact of Pressure

- Vapor density increases with pressure
- T increases with pressure
- u_{flood} decreases with pressure

- **Net result**: Column diameter decreases with increasing pressure
- Cost of column actually lower for pressures below 6 bar; modestly higher for pressures up to 20 bar.

Economic Trade-offs

- Capital costs vs. operating costs



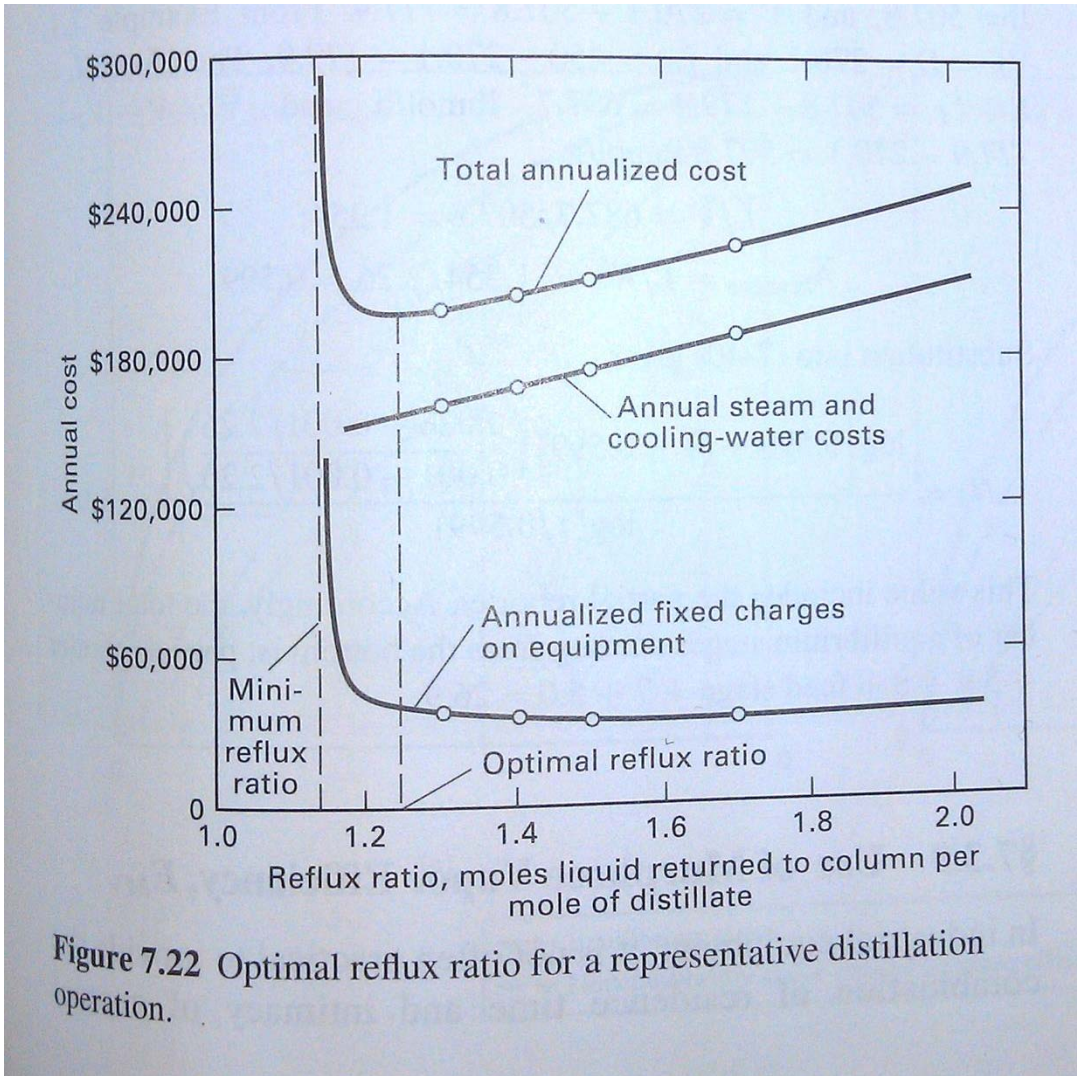


Figure 7.22 Optimal reflux ratio for a representative distillation operation.