Equipment Sizing Based on Heuristics

Size does matter

James Cameron

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$$V = 2\left[\frac{F_L\tau}{\rho_L}\right]$$

F_L	liquid flow rate leaving the vessel
ρ_L	density of liquid
τ	residence time (5 minutes)

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- As a safety factor, choose the vessel (gauge) pressure to be 50% higher than the actual pressure from the material and energy balance.
- For desired temperature range, consider the required material of construction.

Heat Transfer Equipment

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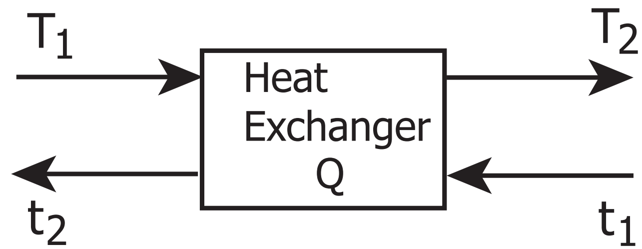

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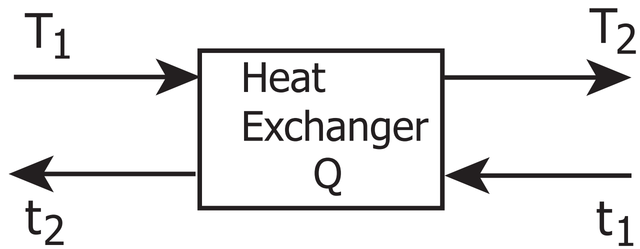

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- Heat transfer area can be found from:

$$Q = UA\Delta T_{lm}$$

where

$$\Delta T_{lm} = \frac{(T_1 - t_2) - (T_2 - t_1)}{ln\left[\dfrac{T_1 - t_2}{T_2 - t_1}\right]}$$

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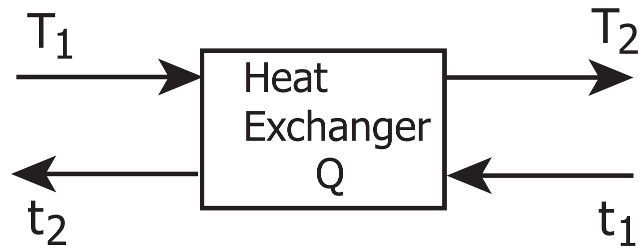

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- The overall heat transfer coefficient, U, can be estimated from heuristics or from standard references (e.g. Perry's Handbook)

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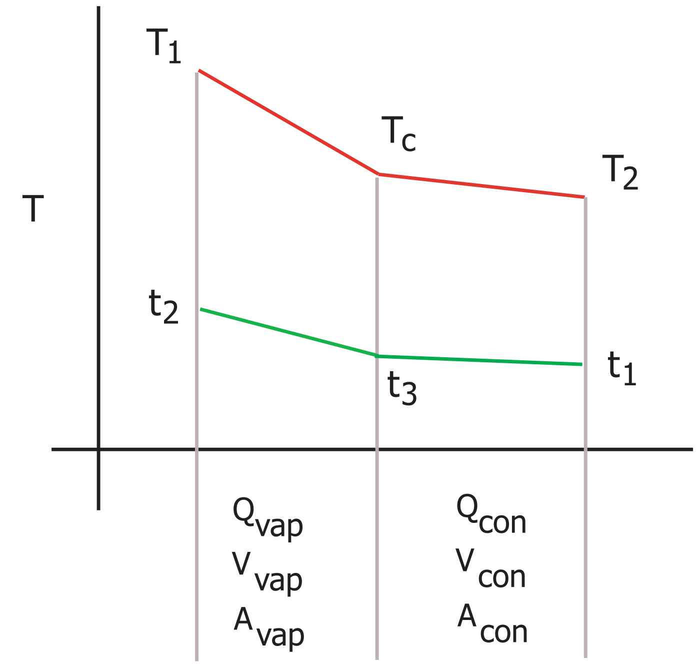

T versus Heat Exchanged

- If there is a phase change, the overall heat transfer coefficient, U, changes.
- This case is modeled as two heat exchangers in series, each with a different U and A.

$$A_{vap} = \frac{Q_{vap}}{U_{vap}\Delta T^a_{lm}}$$

where $$\Delta T^a_{lm} = \frac{(T_1 - t_2) - (T_c - t_3)}{ln\left[\frac{T_1 - t_2}{T_c - t_3}\right]}$$

$$A_{con} = \frac{Q_{con}}{U_{con}\Delta T^b_{lm}}$$

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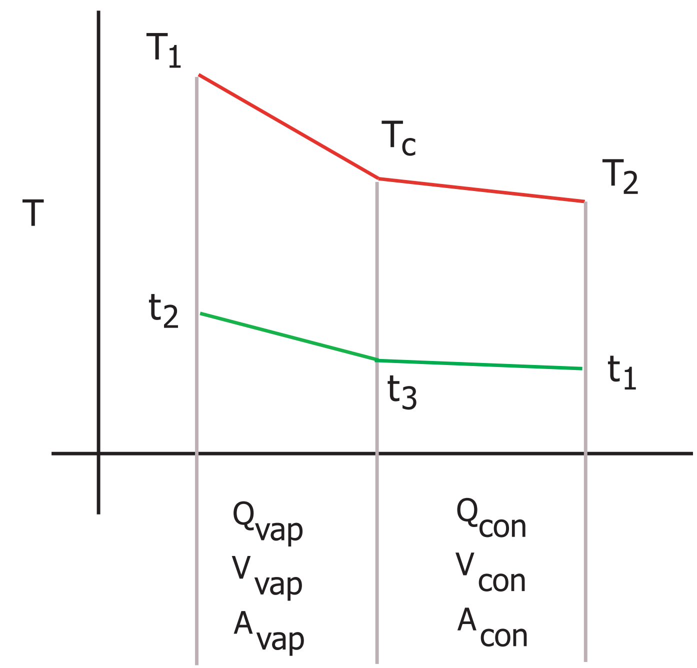

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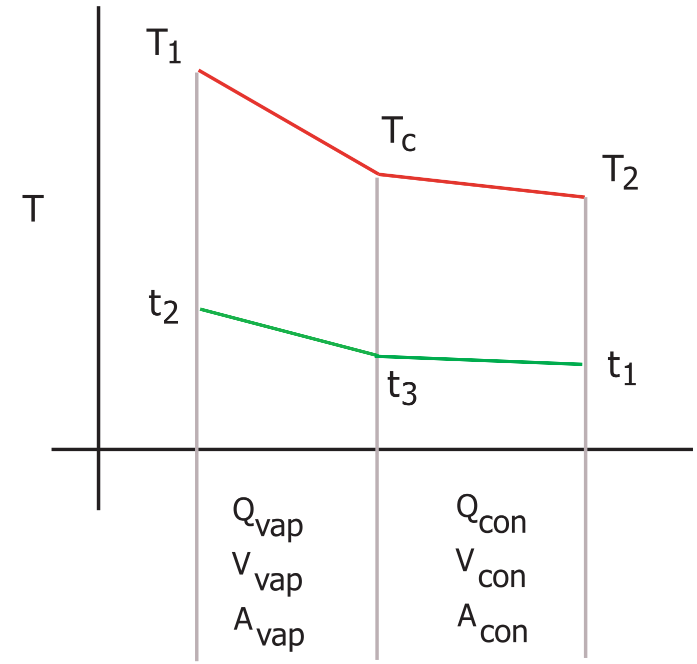

T versus Heat Exchanged

- We choose $10,000\ sq.\ ft.$ as the maximum exchanger area. If more area is required, multiple heat exchangers in parallel are used.

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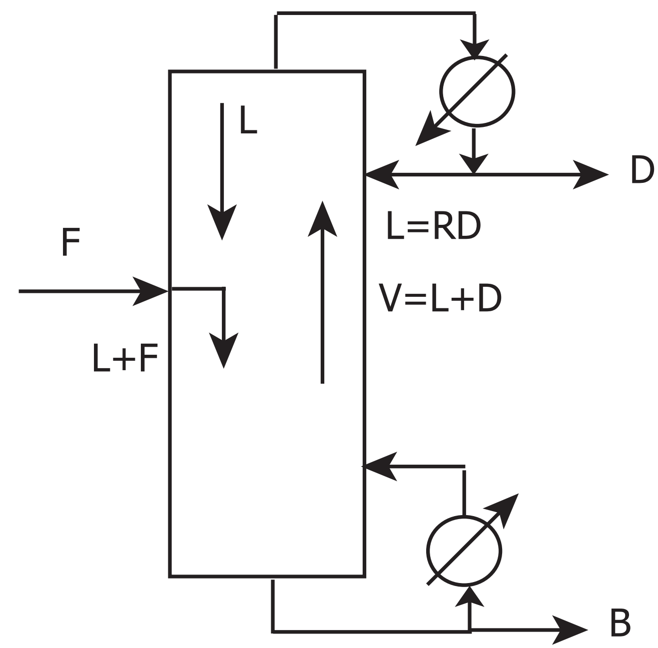

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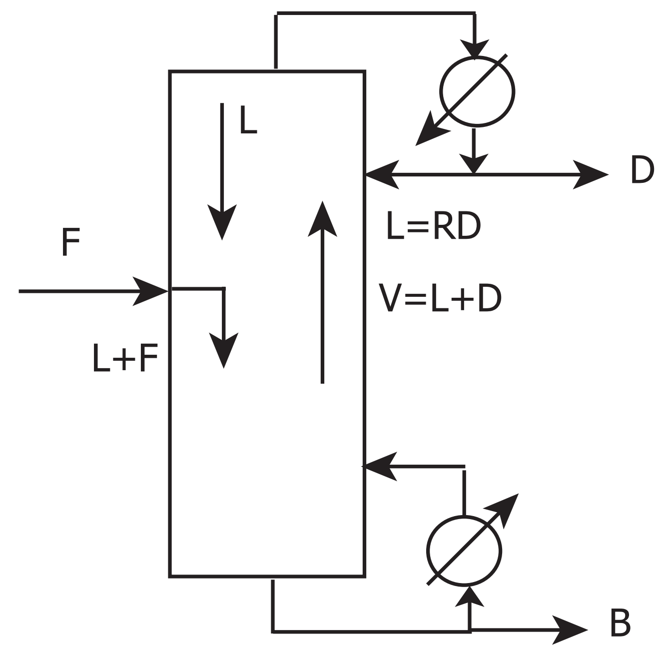
   To determine the diameter, design the column to run at 80% of the flooding velocity.



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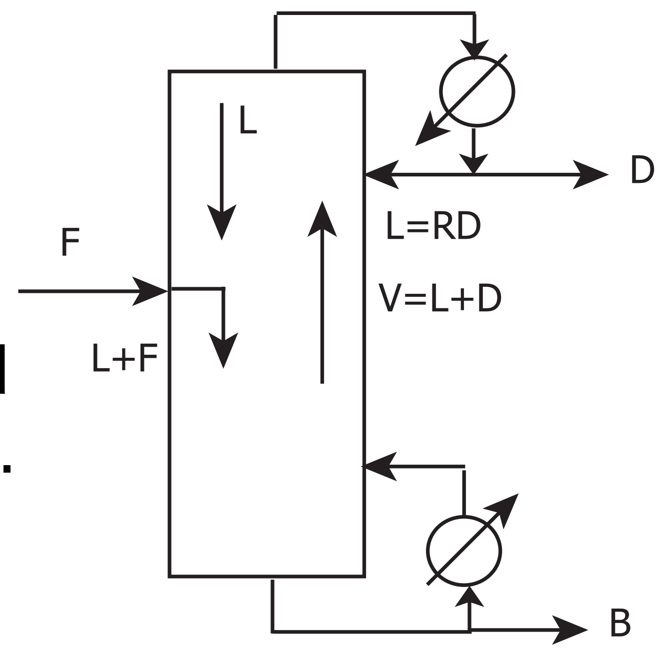
   At the flooding velocity, the vapor flow rate is so high that no net liquid flow occurs and entrainment begins.

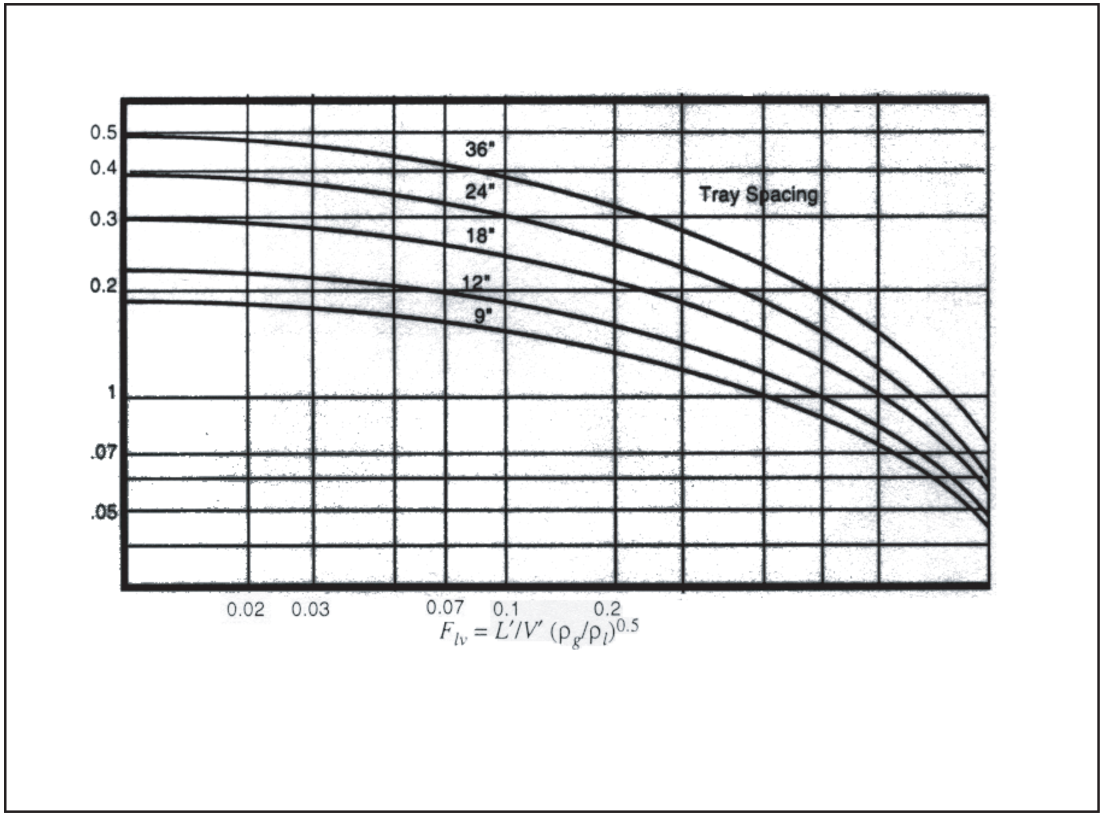


- Calculate dimensionless flow parameter F_{lv}

$$F_{lv} = \frac{L^{'}}{V^{'}} \left(\frac{\rho_g}{\rho_l} \right)^{0.5}$$

where $\frac{L^{'}}{V^{'}}$ is the liquid/gas mass ratio at the point of consideration and $\frac{\rho_g}{\rho_l}$ is the gas/liquid density ratio.

- Calculate capacity parameter $C_{sb,f}$ from the chart below for a given tray spacing:



- Calculate linear flooding velocity (ft/s) from

$$U_{nf} = C_{sb,f} \left(\frac{\rho_l - \rho_g}{\rho_g} \right)^{0.5} \left(\frac{\sigma}{20} \right)^{0.2}$$

where ρ_g and ρ_l are the gas and liquid mass densities and σ is the liquid surface tension in $dynes/cm$.

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- Calculate area of cross-section from $A = \dfrac{V^{'}}{0.8 U_{nf} \epsilon \rho_g}$

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If $D > 20\ ft$, then split the column into two columns running in parallel.

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- Calculate heat duties for condenser and reboiler from energy balance.