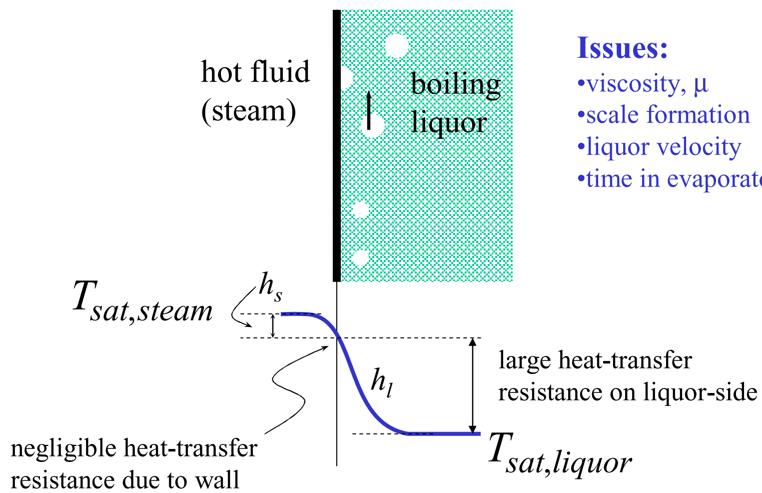
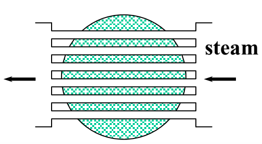
## Evaporators

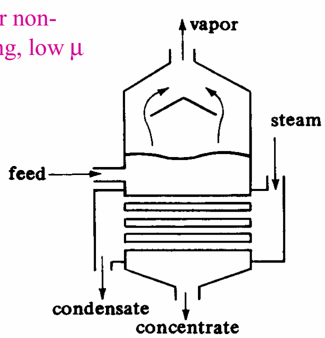



**Issues:**
- viscosity, μ
- scale formation
- liquor velocity
- time in evaporator



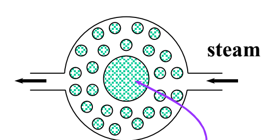
- steam in tubes
- liquor on outside
- inexpensive, but poor liquid circulation
- good for non-depositing, low μ fluids

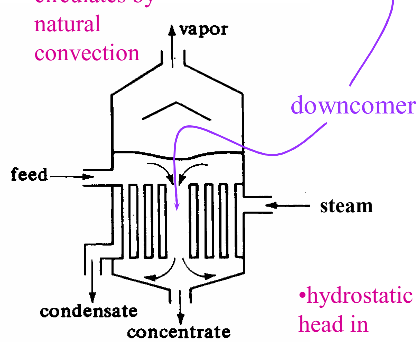



horizontal-tube evaporator

- liquor in tubes
- steam on outside
- liquid circulates by natural convection




vertical-tube evaporator

- hydrostatic head in tubes prevents boiling in tubes

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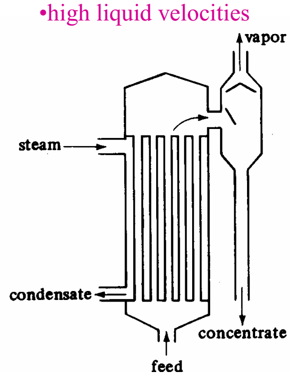
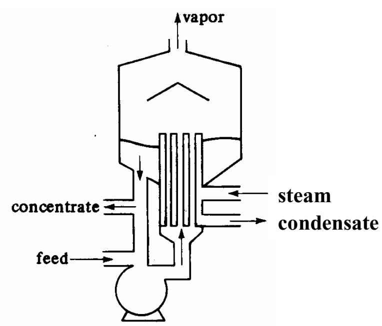
- liquor in tubes
- steam on outside
- liquid circulates by natural convection
- single pass
- high liquid velocities




long-tube vertical evaporator

- liquor in tubes
- steam on outside
- liquid circulates by forced convection
- good for high μ fluids




forced-circulation evaporator

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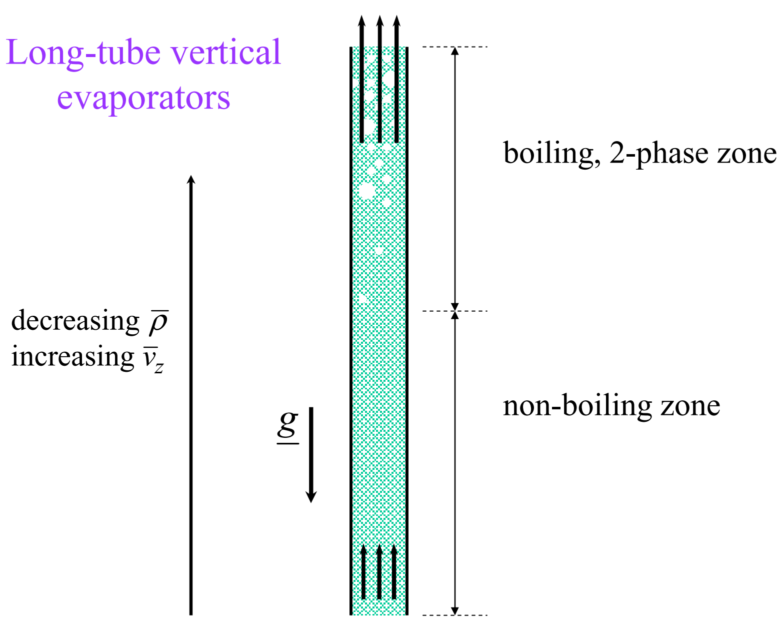
## Long-tube vertical evaporators



## Forced Convection
(turbulent; little or no vaporization)

## Natural convection
(non-boiling zone)

$$\mathrm{Nu} = 0.028\,\mathrm{Pr}^{\frac{1}{3}}\,\mathrm{Re}^{0.8}\left(\frac{\mu_{\mathrm{b}}}{\mu_{\mathrm{w}}}\right)^{0.14}$$

$$\mathrm{Nu} = \frac{hD}{k} \qquad \mathrm{Re} = \frac{DV\rho}{\mu} \qquad \mathrm{Pr} = \frac{\hat{C}_p\mu}{k}$$

$$\mu^{0.33}\mu^{-0.8} = \mu.^{-0.47}$$

μ goes up, *h* goes down,
*h* does not depend on ΔT

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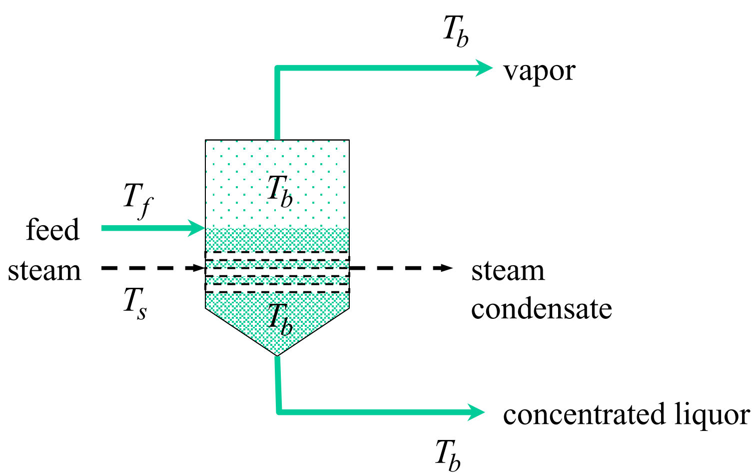
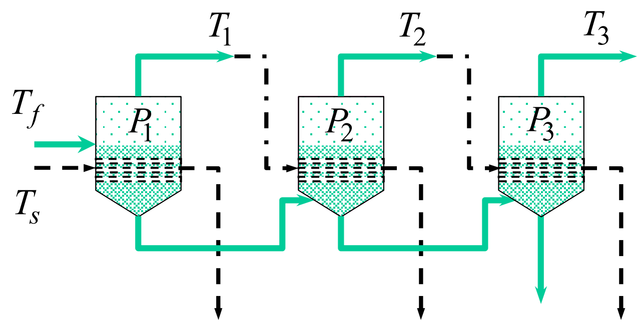
## Single-Effect Evaporators



## Multiple-Effect Evaporators

For each effect the vapor product becomes the source of heat for the subsequent effect

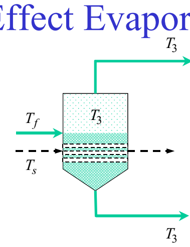
$$P_1 > P_2 > P_3$$
$$T_1 > T_2 > T_3$$

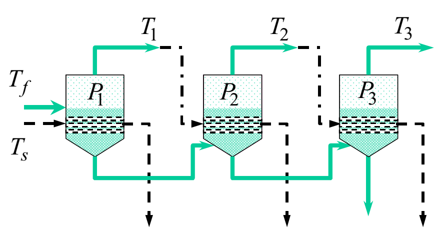





## Compare Single- and Multiple-Effect Evaporators

$$Q = UA(T_s - T_3)$$




$$q_1 = UA(T_s - T_1)$$
$$q_2 = UA(T_1 - T_2)$$
$$q_3 = UA(T_2 - T_3)$$

$$Q = \sum q_i = UA(T_s - T_3)$$

same capacity = same amount of heat transferred
(but we did not have to pay for it all = more efficient)