CE 407 9/14/2017

FEED PLATE LOCATION

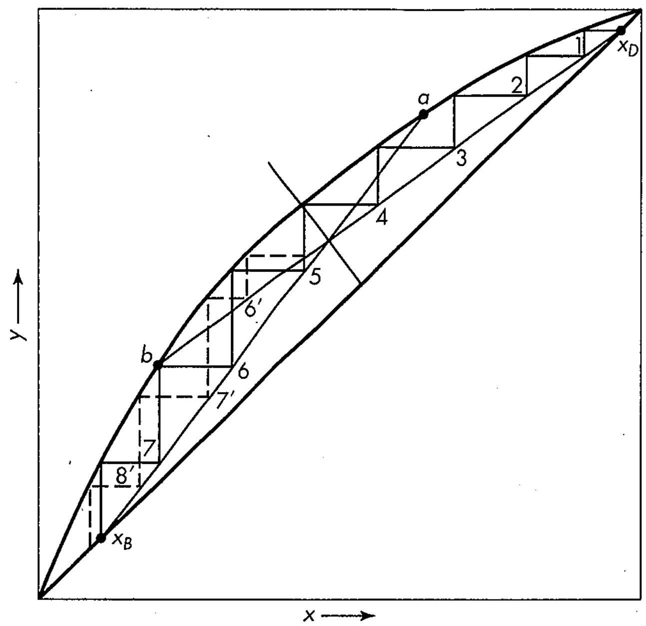


FIGURE 21.13
Optimum feed plate location: ——, with feed on plate 5 (optimum location); ------, with feed on plate 7.

- Plates below feed plate are stripping and are analyzed versus the lower OP LINE. Plates above are analyzed versus the upper, rectifying line.
- Feed Should enter AS CLOSE TO INTERSECTION OF The 2 OPERATING LINES AS POSSIBLE
- INEFFICENT PLATES RESULT IF FEED IN WRONG LOCATION
- CONSIDER PROVIDING MULTIPE FEED PORTS FOR FUTURE FLEXIBILITY

HEATING & COOLING REQUIREMENTS

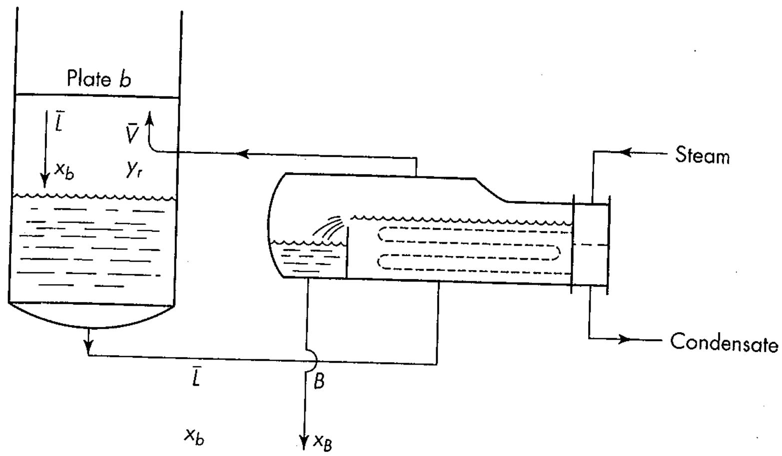


FIGURE 21.9
Material-balance diagram for bottom plate and reboiler.

REBOILER

- Temperature of $\bar{L} \approx$ temp $\bar{V}$
- HEAT Required to raise temperature of $\bar{L} \ll \lambda$

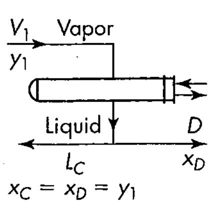
$$\dot{m}_S = \frac{\bar{V}\lambda}{\lambda_S}$$

$\dot{m}_S$ = steam consumption
$\bar{V}$ = VAPOR RATE from REBOILER
λ_S = latent heat of steam
λ = molal latent heat of mixture

BE VERY AWARE of UNITS!

CONDENSER

ASSUME WATER IS COOLING MEDIUM AND CONDENSATE IS NOT SUBCOOLED



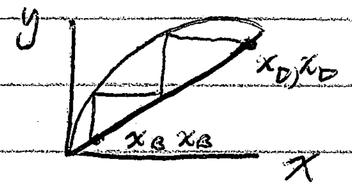
$$\dot{m}_W = \frac{V\lambda}{(T_2 - T_1)\,C_{pw}}$$

$\dot{m}_W$ = Flow RATE of COOLING WATER
$(T_2 - T_1)$ = TEMPERATURE RISE of COOLING WATER
C_{pw} = SPECIFIC HEAT of COOLING WATER
V = VAPOR RATE TO CONDENSER
λ = molal latent heat of MIXTURE

MINIMUM NUMBER of PLATES

SIMILAR TO GAS ABSORPTION w/ HIGH LIQUID FLOW, HIGH REFLUX RATIO, R_D, MINIMIZES # of STAGES

As $R_D \rightarrow \infty$, SLOPE OF RECTIFYING LINE $R_D/(R_D+1) \rightarrow 1$ and LIES ON XY AXIS



VERY EFFICIENT!*

* EXCEPT THAT $V = L$ and $F = D = B = 0$ ∴ NO PRODUCT.

SPECIAL ANALYTICAL CASE

- α_{AB} is ~ CONSTANT OVER TEMPERATURE RANGE
- IDEAL MIXTURES FOLLOWING RAOULT'S LAW
- BINARY MIXTURE

$$\alpha_{AB} = \frac{y_{Ae}/x_{Ae}}{y_{Be}/x_{Be}} = \frac{y_{Ae}/x_{Ae}}{(1-y_{Ae})/(1-x_{Ae})}$$

Rearrange

$$\frac{y_{Ae}}{1-y_{Ae}} = \alpha_{AB}\frac{x_{Ae}}{1-x_{Ae}}$$

FOR PLATE $n+1$
$$\frac{y_{n+1}}{1-y_{n+1}} = \alpha_{AB}\frac{x_{n+1}}{1-x_{n+1}}$$

MINIMUM NUMBER of PLATES CONT'D

$$\frac{y_{n+1}}{1-y_{n+1}} = \alpha_{AB} \frac{x_{n+1}}{1-x_{n+1}}$$

Recall OP LINE $y_{n+1} = \frac{R_D}{R_D+1} x_n + \frac{x_D}{R_D+1}$

As $R_D \to \infty$ $y_{n+1} = x_n$

So $$\frac{x_n}{1-x_n} = \alpha_{AB} \frac{x_{n+1}}{1-x_{n+1}}$$

$$\frac{x_1}{1-x_1} = \alpha_{AB} \frac{x_2}{1-x_2}$$

$$\frac{x_2}{1-x_2} = \alpha_{AB} \frac{x_3}{1-x_3}$$

$\vdots$

$$\frac{x_{n-1}}{1-x_{n-1}} = \alpha_{AB} \frac{x_n}{1-x_n}$$

For total condenser $y_1 = x_D$

$$\frac{x_D}{1-x_D} = \alpha_{AB} \frac{x_1}{1-x_1}$$

$$\frac{x_D}{1-x_D} = \alpha_{AB} \left(\alpha_{AB} \frac{x_2}{1-x_2} \right)$$

$$\frac{x_D}{1-x_D} = \alpha_{AB} \alpha_{AB} \left(\alpha_{AB} \frac{x_3}{1-x_3} \right)$$

$\vdots$

$$\frac{x_D}{1-x_D} = (\alpha_{AB})^n \frac{x_n}{1-x_n}$$

AT BOTTOM DISCHARGE WE REACH x_B at N_{min} plates plus 1 more ITERATION FOR Reboiler

$$\frac{x_D}{1-x_D} = (\alpha_{AB})^{N_{min}+1} \frac{x_B}{1-x_B}$$

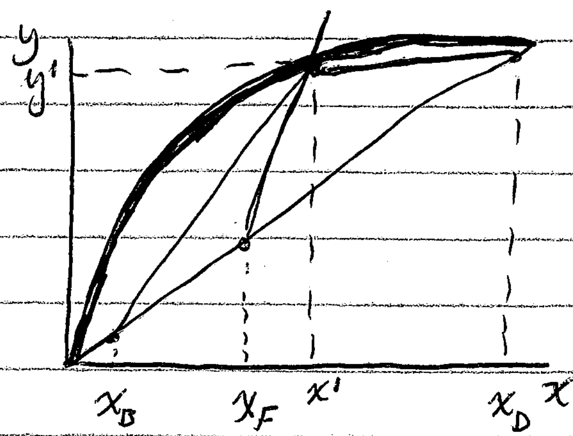
$$\frac{\left(\frac{x_D}{1-x_D}\right)}{\left(\frac{x_B}{1-x_B}\right)} = (\alpha_{AB})^{N_{min}+1}$$

$$\ln\left[x_D(1-x_B)/x_B(1-x_D)\right] = (N_{min}+1)\ln(\alpha_{AB})$$

(4) FENSKE EQ $$N_{min} = \frac{\ln\left[x_D(1-x_B)/x_B(1-x_D)\right]}{\ln(\alpha_{AB})} - 1$$

MINIMUM REFLUX

IF OP LINES INTERSECT EQ LINE
THEN WE REQUIRE AN INFINITE # of PLATE



SLOPE of Rect Line

$$= \frac{R_{D\,min}}{R_{D\,min}+1}$$

$$\text{SLOPE} = \frac{\text{RISE}}{\text{RUN}} = \frac{x_D - y'}{x_D - x'}$$

$$\frac{R_{D\,min}}{R_{D\,min}+1} = \frac{x_D - y'}{x_D - x'} \xrightarrow{\text{ALGEBRA}} \boxed{R_{D\,min} = \frac{x_D - y'}{y' - x'}}$$

OR DRAW LINE FROM (x_D, x_D) THROUGH FEED/EQ INTERSECT
INTERCEPT = $x_D/(R_D+1)$

$R_{D\,min}$ may BE DEFINED AS A TANGENT TO EQ CURVE IF CURVE IS CONCAVE UPWARD!

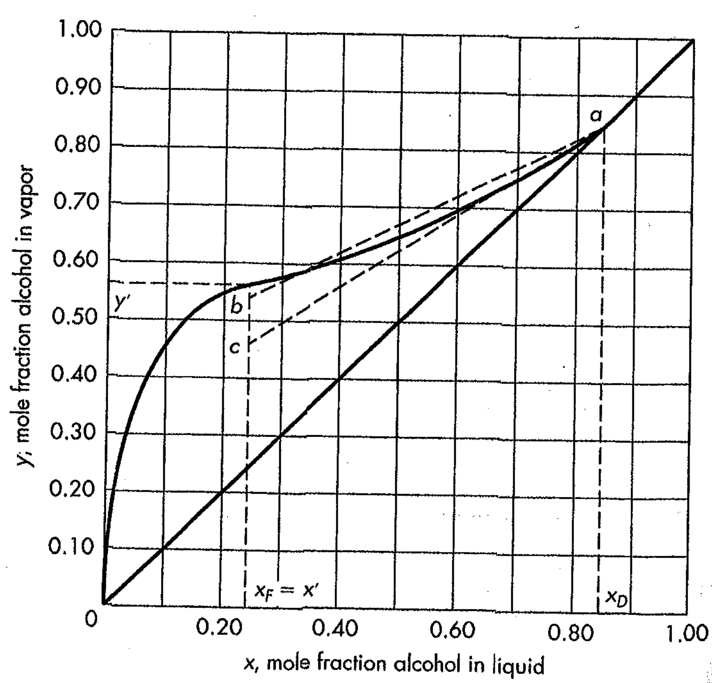


FIGURE 21.18
Equilibrium diagram (system ethanol-water).

OPTIMUM REFLUX RATIO

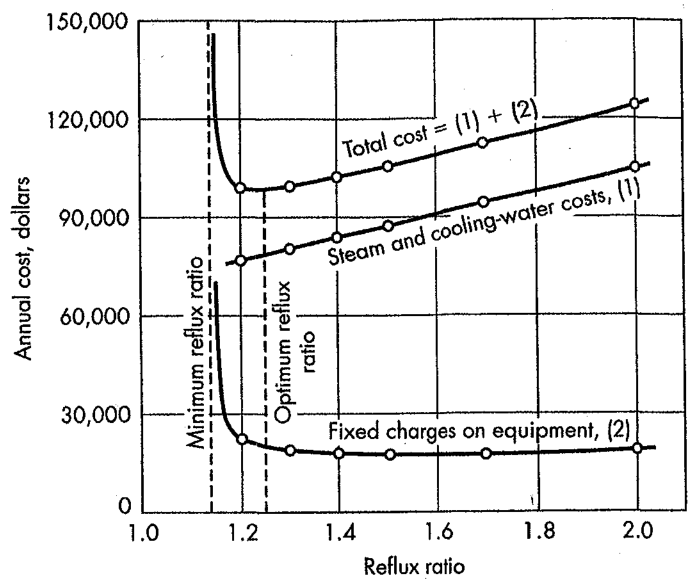


FIGURE 21.19
Optimum reflux ratio. (*By permission from M. S. Peters and K. D. Timmerhaus, Plant Design and Economics for Chemical Engineers, 3rd ed., 1980, McGraw-Hill.*)

- DEPENDENT ON COST OF ENERGY

NEARLY PURE PRODUCTS

McCABE Thiele DIAGRAM MAY PROVE DIFFICULT
Due to small steps near $x=0$ or $x=1$

- BREAK OUT THESE SECTIONS INTO SEPARATE DIAGRAMS

- USE KREMSER EQUATION FOR FINAL STEPS