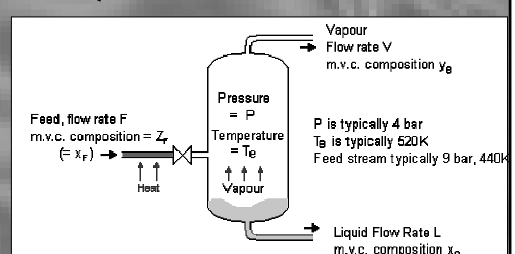
MULTICOMPONENT DISTILLATION

SINGLE STAGE FLASH

- USES TWO PHASE EQUILIBRIUM
  - FLASH
  - BUBBLE POINT
  - DEW POINT
- CAN BE TWO LIQUID PHASES
- USES RELATIVE VOLATILITY



http://www.hills2.u-net.com/chemical/distil/fig1

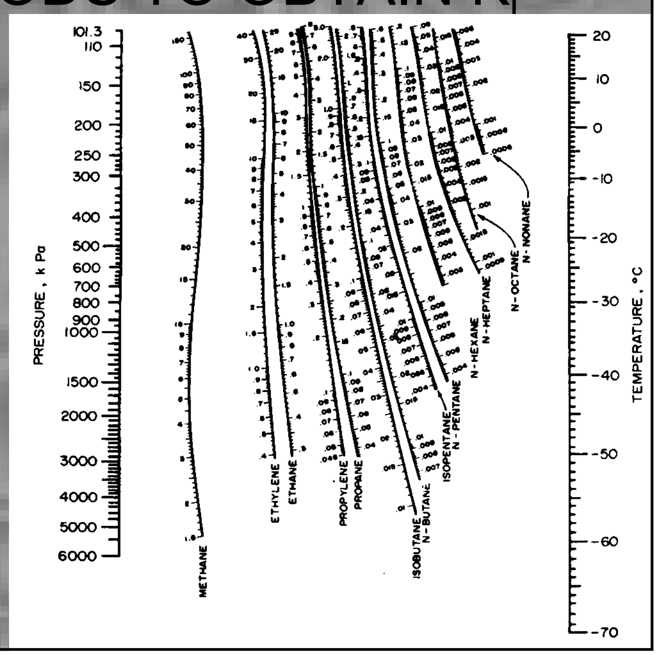
$$y_i = K_i x_i \qquad \alpha_{i,j} = \frac{K_i}{K_j}$$

METHODS TO OBTAIN K_i

- EMPIRICAL DATA
  - SET UP EXPERIMENTS TO MEASURE y = y(x,P,T)
  - DATA CAN BE BASED ON BINARY SETS - SEE PERRY'S SECTION 13 FOR BINARY DATA
  - GENERAL CORRELATIONS FOR SPECIFIC TYPES OF MIXTURES - UNIQUAC

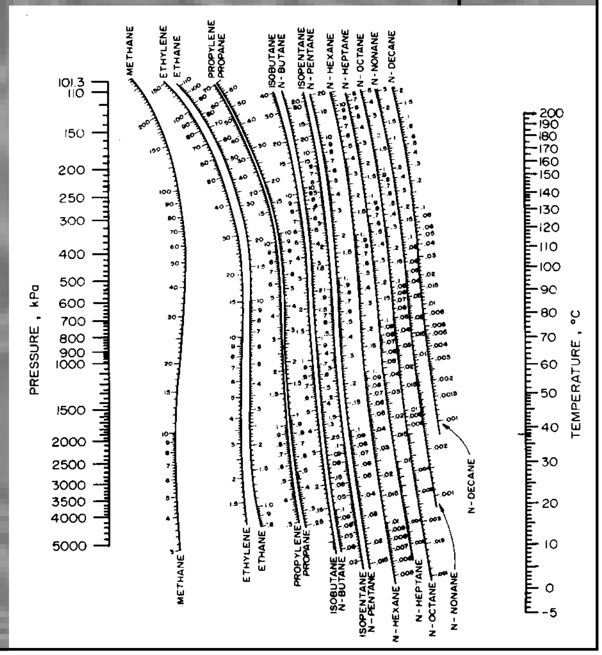
METHODS TO OBTAIN K_i

- DEPRIESTER CHARTS FOR HYDROCARBON SYSTEMS
- LOW TEMPERATURE DATA
- PERRY'S FIGURE 13-14, P. 13-17



METHODS TO OBTAIN K_i

- DEPRIESTER CHARTS FOR HYDROCARBON SYSTEMS
- HIGH TEMPERATURE DATA
- PERRY'S FIGURE 13-14, P. 13-18



METHODS TO OBTAIN K_i

- AIR SEPARATION PLANT DATA

http://www.cryogenic-consulting.com/argon.pdf#search=%22AIR%20SEPARATION%20EQUILIBRIA%22

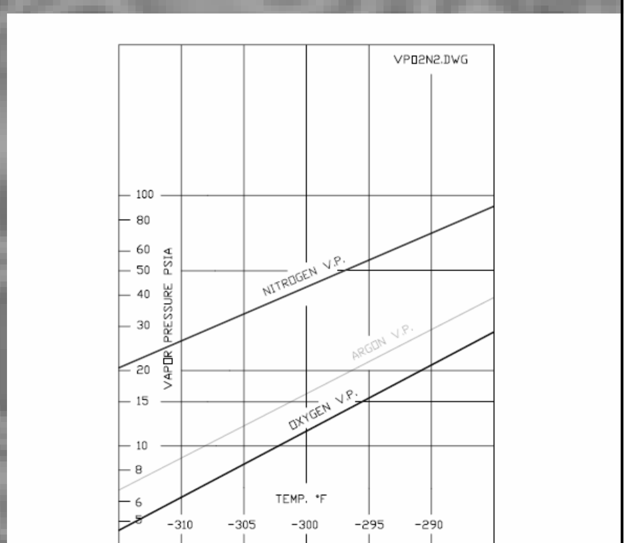


FIGURE 4 O2, N2, ARGON VAPOR PRESSURE

$\sum y_i = 1 = \sum \frac{P_i^{sat} x_i}{P}$

FLASH CALCULATIONS

- BUBBLE POINT PRESSURE (DIRECT)
  - T AND x_i ARE GIVEN, FIND y_i AND P

$$\sum y_i = 1 = \sum_i \frac{x_i \gamma_i P^*_i}{P_{SYS}} = \sum_i K_i x_i \quad (11.7-5)$$

- BUBBLE POINT TEMPERATURE (T & E)
  - P AND x_i ARE GIVEN, FIND y_i AND T

$$\sum y_i = 1 = \sum_i \frac{x_i \gamma_i P^*_i}{P_{SYS}} = \sum_i K_i x_i \quad (11.7-5)$$

FLASH CALCULATIONS

- DEW POINT PRESSURE (DIRECT)
  - T AND y_i ARE GIVEN, FIND P_{SYS} AND x_i

$$\sum x_i = 1 = \sum_i \frac{y_i P_{SYS}}{\gamma_i P^*_i} = \sum_i \frac{y_i}{K_i} \quad (11.7-7)$$

- DEW POINT TEMPERATURE (T & E)
  - P AND y_i ARE GIVEN, FIND T AND x_i

$$\sum x_i = 1 = \sum_i \frac{y_i P_{SYS}}{\gamma_i P^*_i} = \sum_i \frac{y_i}{K_i} \quad (11.7-7)$$

FLASH CALCULATIONS

- PARTIAL FLASH $\sum z_i = 1$
  - P, T AND z_i ARE GIVEN, FIND x_i & y_i
  - FLASH LINES ARE DEVELOPED FOR EACH COMPONENT WITH A COMMON f

$$y_i = \frac{f-1}{f} x_i + \frac{x_{iF}}{f} = K_{REF}\,\alpha_{i,REF}\,x_i \quad (11.7-10)$$

  - SOLVE BY T&E FOR VALUES OF V IN f = V/F

$$\sum_i \frac{x_{iF}}{f(K_{REF}\alpha_{i,REF}-1)+1} = 1 \; OR \; \sum_i \frac{z_i(K_i-1)}{V(K_i-1)+1} = 0$$

MULTICOMPONENT FRACTIONATION

- GENERAL DESIGN CONSIDERATIONS
  - SPECIFY PRESSURE
  - DETERMINE NUMBER OF EQUILIBRIUM STAGES
  - ADJUST NUMBER OF STAGES FOR STAGE EFFICIENCY
  - DESIGN TRAYS
  - DESIGN COLUMN

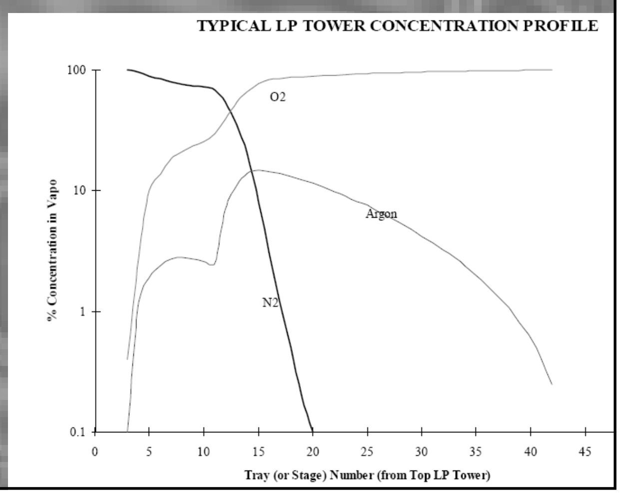
http://www.eia.doe.gov/kids/energyfacts/sources/non-renewable/images/FCCDistCol.jpg

SHORTCUT METHOD - PSEUDOBINARY SEPARATION

- ASSUMES TWO PRIMARY (KEY) COMPONENTS CAN BE USED TO MODEL THE PROCESS
- NO-KEYS ARE DISTRIBUTED BASED ON $\alpha_{i,KEY}$
- KEY COMPONENTS
  - .MUST BE DISTRIBUTED TO DISTILLATE & BOTTOMS
  - .SHOULD BE MAJOR COMPONENTS IN FEED
  - .NON-KEY COMPONENTS
  - .LIGHTER THAN LIGHT ARE ASSUMED TO GO TO DISTILLATE
  - .HEAVIER THAN HEAVY ARE ASSUMED TO GO TO BOTTOMS
  - INTERMEDIATE ARE ASSUMED TO DISTRIBUTE TO DISTILLATE AND BOTTOMS

COMPONENT DISTRIBUTIONS

- EXAMPLE FROM AIR SEPARATION
- KEYS
  - O2
  - N2
- NON-KEY
  - Ar



http://www.cryogenic-consulting.com/argon.pdf#search=%22AIR%20SEPARATION%20EQUILIBRIA%22

SHORTCUT METHOD

- DISTRIBUTE KEYS BASED ON TARGET PRODUCT COMPOSITION
- COMPLETE DISTRIBUTION TO YIELD FEED AND PRODUCT MATRICES
  - x_{Fi}, x_{Di}, x_{Bi}
- CALCULATE N_{MIN} WITH FENSKE EQUATION USING KEY VALUES

$$N_{MIN} = \frac{\ln\left[\dfrac{x_{DLK}\, Dx_{BHK}\, B}{x_{DHK}\, Dx_{BLK}\, B}\right]}{\ln(\alpha_{LK,HK})_{avg}} \qquad (11.7-12)$$

SHORTCUT METHOD

- AVERAGE RELATIVE VOLATILITY, $\alpha_{LK,HK}$
  - FEED VALUE

$$\alpha_{avg} = \alpha_{LK,HK_F}$$

  - TOP/BOTTOM AVERAGE

$$\alpha_{avg} = \frac{\alpha_{LK,HK_D} + \alpha_{LK,HK_B}}{2}$$

  - GEOMETRIC AVERAGES
  - OVERALL
  - TOP/BOTTOM

$$\alpha_{avg} = \sqrt[3]{\alpha_{LK,HK_F}\alpha_{LK,HK_D}\alpha_{LK,HK_B}}$$

$$\alpha_{avg} = \sqrt{\alpha_{LK,HK_D}\alpha_{LK,HK_B}}$$

SHORTCUT METHOD

- CHECK OF NON-KEY DISTRIBUTION
  - USE FENSKE EQUATION RESOLVED FOR NON-KEY RELATIVE TO KEY:

$$\left(\frac{x_{iD}D}{x_{iB}B}\right)=\alpha_{i,HK}\left(\frac{x_{HKD}D}{x_{HKB}B}\right) \qquad (11.7-14)$$

SHORTCUT METHOD

- MINIMUM REFLUX RATIO
  - OPERATING LINES FOR EACH COMPONENT AT TOTAL REFLUX
  - RECTIFICATION SECTION

$$y_{i\infty}=\frac{D}{V_\infty}\frac{x_{Di}}{1-\left(L_\infty/V_\infty K_{i\infty}\right)} \qquad 1.0=\frac{D}{V_\infty}\sum_i\frac{x_{Di}}{1-\left(L_\infty/V_\infty K_{i\infty}\right)}$$

  - STRIPPING SECTION

$$y_{i\infty}=-\frac{B}{\overline{V}_\infty}\frac{x_{Bi}}{1-\left(\overline{L}_\infty/\overline{V}_\infty\overline{K}_{i\infty}\right)} \qquad 1.0=\frac{B}{\overline{V}_\infty}\sum_i\frac{x_{Bi}}{\left(\overline{L}_\infty/\overline{V}_\infty\overline{K}_{i\infty}\right)-1}$$

SHORTCUT METHOD

- UNDERWOOD EQUATIONS COMPLETE BALANCE OVER THE COLUMN

$$1 - q = \sum_i \frac{\alpha_i x_{Fi}}{\alpha_i - \theta}$$

$$R_{dMIN} = \sum_i \frac{\alpha_i x_{Di}}{\alpha_i - \theta}$$

- NUMBER OF θ VALUES ARE (1 + NUMBER OF COMPONENTS BETWEEN KEYS)
- VALUE OF θ IS BETWEEN VALUES OF α_{ij}

SHORTCUT METHOD

- USE GILLILAND OR ERBAR-MADDOX CORRELATIONS TO DETERMINE N FOR A SPECIFIC Rd

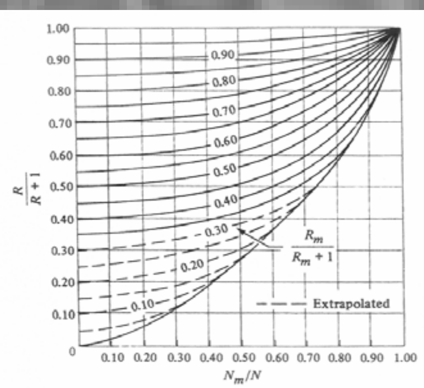


FIGURE 11.7-3. *Erbar–Maddox correlation between reflux ratio and number of stages (R_m based on Underwood method). [From J. H. Erbar and R. N. Maddox,* Petrol. Refiner. **40**(5), 183 (1961). *With permission.*

$$\frac{N - N_{MIN}}{N+1} = 1 - \exp\left[\left(\frac{1+54.4\Psi}{11+117.2\Psi}\right)\left(\frac{\Psi - 1}{\Psi^{0.5}}\right)\right]$$

$$\Psi = \frac{R - R_{MIN}}{R+1}$$

Molokanov, International Chemical Engineering, 12(2), 209, 1972

SHORTCUT METHOD

- LOCATION OF FEED TRAY
- IS CRITICAL TO COLUMN EFFICIENCY
  - LOSS OF SEPARATION
  - INCOMPLETE SEPARATION
- BASIS FOR ESTIMATE

$$\log \frac{N_{RECT}}{N_{STRIP}} = 0.206 \log \left[\left(\frac{x_{HK,F}}{x_{LK,F}} \right) \frac{B}{D} \left(\frac{x_{LK,B}}{x_{HK,D}} \right)^2 \right] \qquad (11.7-21)$$