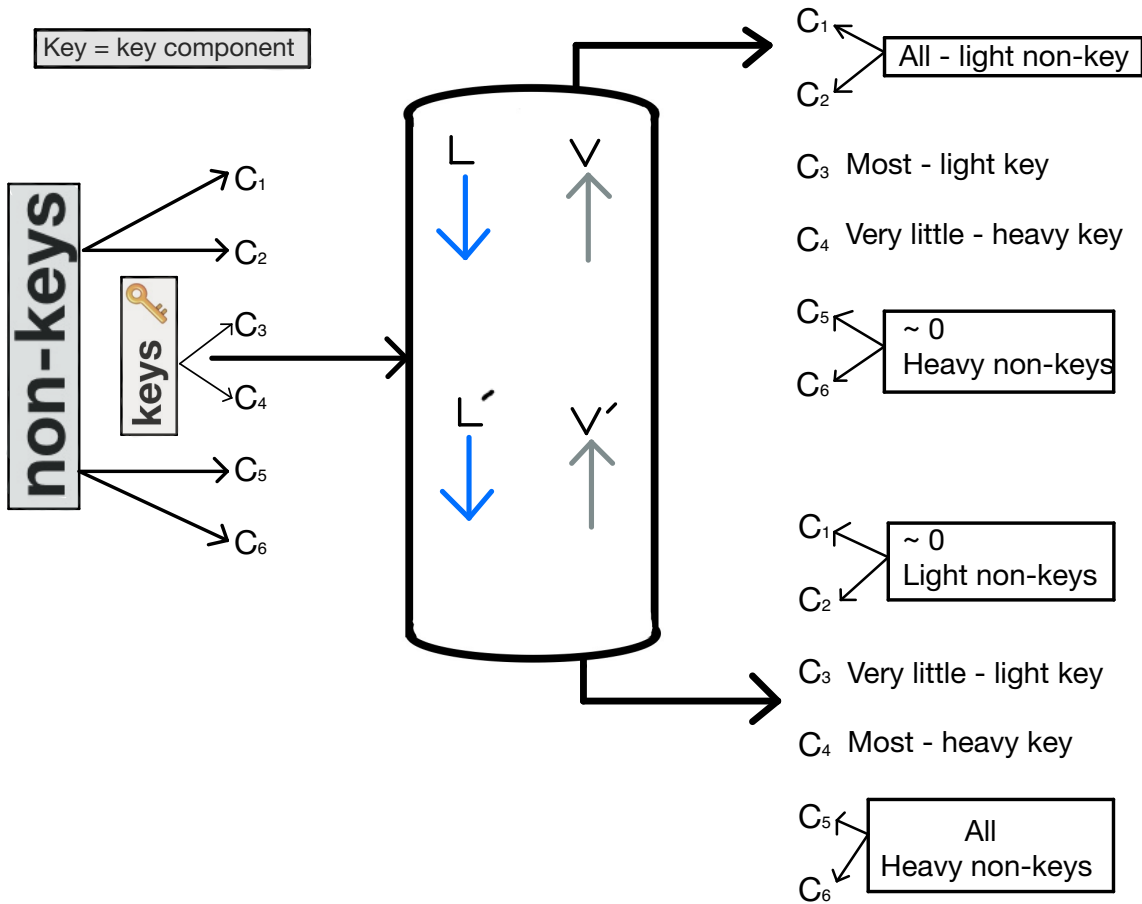


# Chapter 8

## Multicomponent Distillation - The Design Problem

Consider on a qualitative basis the distillation of a hydrocarbon mixture (C<sub>1</sub>-C<sub>6</sub>) designed to separate the mixture between C<sub>3</sub> and C<sub>4</sub>



Degree of Freedom Analysis:

Compared to the binary case, there is an extra degree of freedom for each additional component

$$DOF = R + 8$$

# of feed components

Specify the Design Problem:

$R + 7$  {

- R feed flows
- Feed enthalpy (counts as two:  $T_f$  and  $Q_f$ )
- Column pressure and feed pressure
- Reflux ratio ( $r$ )

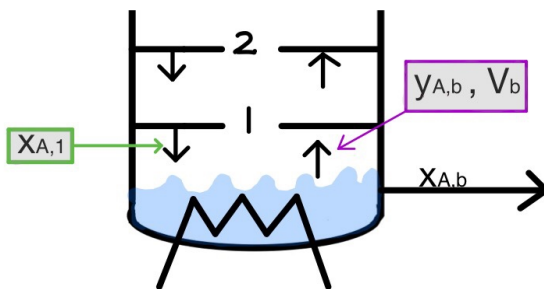
Two specifications related to the desired separation  
ex: % recovery of light key in distillate and % recovery of heavy key in bottom product.

**Objective:** Calculate  $n$  and  $m$  by adjusting the feed plate location

▶ Design the column using the remaining DOFs as the independent variables.

Operation at infinite reflux: The Fenske Equation

Consider the bottom of the column for the case of a binary mixture:



**Nomenclature**

$n$  = # of plates above the feed plate including the feed plate.  
 $m$  = # of plates below the feed plate.  
 A figure illustrating  $n$  and  $m$  can be found in Lecture 7.

Equilibrium in the Reboiler:

$$\left( \frac{y_A}{y_B} \right)_b = \alpha_{AB} \left( \frac{x_A}{x_B} \right)_b$$

Material Balance:

$$V_b y_{Ab} = L_1 x_{A1} - x_{Ab} b$$

At infinite reflux  $b$  is small and  $V_b \approx L_1$

so  $y_{A,b} = x_{A1}$  and  $\left( \frac{x_A}{x_B} \right)_i = \alpha_{AB} \left( \frac{x_A}{x_B} \right)_b$

Similarly for Stages 1 and 2:  $\left(\frac{X_A}{X_B}\right)_2 = \alpha_{AB} \left(\frac{X_A}{X_B}\right)_1 = \alpha_{AB}^2 \left(\frac{X_A}{X_B}\right)_0$

For N Stages:  $\left(\frac{X_A}{X_B}\right)_d = (\alpha_{AB})^{N_{min}} \left(\frac{X_A}{X_B}\right)_b$

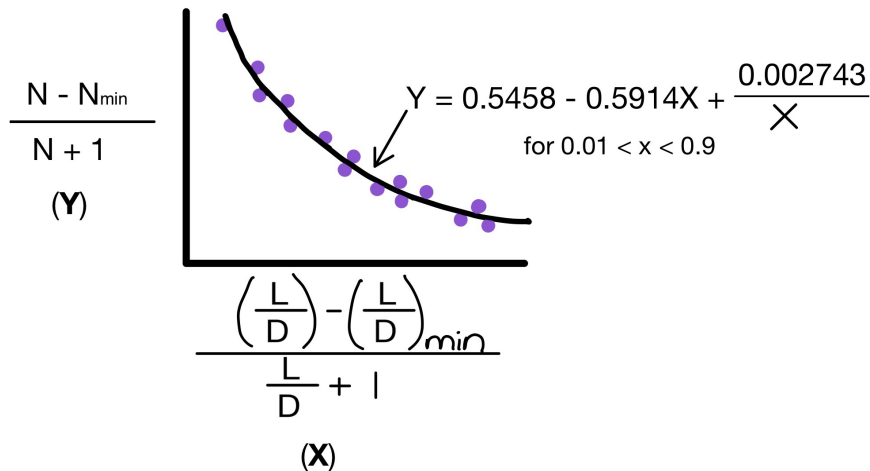
or  $N_{min} = \frac{\log \left[ \left(\frac{X_A}{X_B}\right)_d / \left(\frac{X_A}{X_B}\right)_b \right]}{\log(\alpha_{AB})}$

For a multicomponent system, the above equations also apply with A and B taken as the 2 key components


### "Short-Cut" methods for a multicomponent distillation column design

 See chapter 7 of Wankat for additional details

The Gilliland Correlation:




●  $N_{min}$  can be determined from the Fenske Equation

●  $\left(\frac{L}{D}\right)_{min}$  can be determined from the Underwood Equation  see Chapter 7.2 of Wankat

When the "non-key" components are entirely in one product or the other

$$V_f = \sum_{i=1}^N \frac{\alpha_i F z_i}{\alpha_i - \phi} \quad \text{then} \quad V_{min} = \sum_{i=1}^N \frac{\alpha_i D y_{i,D}}{\alpha_i - \phi}$$

 solve for value of  $\phi$  between values of the key component

## "FUG" interface in ChemSep:

The screenshot displays the ChemSep (TM) software interface for a multicomponent example. The main window is titled "ChemSep (TM) - multicomponent\_example.sep" and features a menu bar (File, Edit, Solve, Analysis, Databanks, Tools, Help) and a toolbar with various icons. On the left, a tree view shows the project structure, with "FUG" selected under the "Results" folder. The main panel is titled "Fenske-Underwood-Gilliland Analysis" and contains the following data:

Auto select key comp's

Light	Benzene	Recovery in D	0.95	X <sub>lb</sub> = 0.0166676	X <sub>ld</sub> = 0.949843
Heavy	Toluene	Recovery in B	0.95	X <sub>hd</sub> = 0.0499917	X <sub>hb</sub> = 0.316684

Relative volatility: Geometric average      Design RR/RRmin: 1.2

Relative volatility = 2.292839      q feed = 1

Minimum number of stages (Fenske) = 7.096821      D = 0.250041 (kmol/s)

Minimum reflux ratio (Underwood) = 1.570468      B = 0.749959 (kmol/s)

Number of Stages (Eduljee) = 16.47214      phi = 1.478696

Reflux ratio (Eduljee) = 1.884562      err = -0.0000248674

Feed stage (Fenske) = 8.236072

The status bar at the bottom indicates "Saved", "Converged 14 iterations", and the file path "C:\Users\frey\save\_dell\chem\_sep\multicomponent\_example.sep".