Short Cut Methods:

In the design of distillation columns, it is important to know two very important limiting conditions:

Minimum Reflux Ratio (R_{min}) : Corresponding to infinite number of plates

Minimum Number of Plates (N_{min}) : Corresponding to total reflux

Since the actual operation lies between those two conditions.

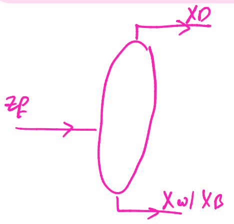
Those two conditions may be estimated by short cut methods which can then be used to obtain reasonable approximations of the actual operating conditions based on them.

then ⇒ $R_{opt} = 1 \sim 1.2\, R_{min}$.

Underwood Method → R_{min} → R_{opt}
Fenske's Method → N_{min}
} Gilliland Correlation → N_P

Minimum Reflux Ratio (R_{min}): Undrerwood's Method

This condition occurs for infinite number of stages. The following equation can be developed based on material and equilibrium relations:



$$R_{min} = \frac{1}{(\alpha_{ij} - 1)} \left[\frac{x_{Di}}{Z_{Fi}} - \alpha_{ij} \frac{x_{Dj}}{Z_{Fj}} \right]$$

i ⇒ MVC, j ⇒ LVC

α_{ij} ⇒ average relative volatility.

Minimum Number of Plates: Fenske's Method

This situation occurs under conditions of total reflux where the operating lines coincide with the 45° line. The following equation can be developed based on material and equilibrium relations:

$$N_{min} + 1 = \frac{log \left[\frac{x_{Di}}{x_{Dj}} \cdot \frac{x_{Bj}}{x_{Bi}} \right]}{\log \alpha_{ij}}$$

→ independent on feed conditions

+1: for reboiler (as stage)

Notes:

1. Nmin does not depend on feed composition. It depends on the degree of separation of the two key components I and j and their relative volatilities.
2. A single stage separation corresponds to Nmin +1 = 1
3. If α_{ij} is not constant, take an average value. Geometric average in the case of Nmin.
4. For binary separation *i* is the mvc and *j* is the lvc
5. For multicomponent separation *i* is the lkc and *j* is the hkc (→ heavy) (light key component)

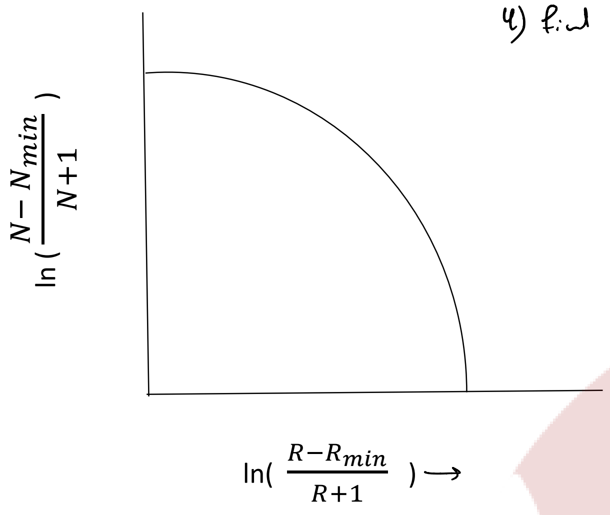
A LKC
B
C
D
E → heavier than heavy key comp HHKC

Gilliland Correlation: Number of Theoretical Plates:

$$R_{min} \rightarrow R_{opt} \rightarrow \frac{R - R_{min}}{R + 1}$$

From chart obtain $\frac{N - N_{min}}{N+1} \rightarrow N$

1) $R_{min} \Rightarrow 1.2 \sim 2\ R_{opt}$
2) then $R_{opt} = \frac{R - R_{min}}{R+1}$
3) take log R_{opt}
3) from chart find $\log \frac{N - N_{min}}{N+1}$
4) find N.



Feed Tray Location:

Apply Fenske's correlation with $x_{Bk's}$ replaced by feed compositions:

Between top + feed.

$$(N_{min})_{above\ feed} = \frac{\log\left[\frac{x_{Di}}{x_{Dj}} \cdot \frac{Z_{Fj}}{Z_{Fi}}\right]}{\log \alpha_{ij}}$$

The ratio between stages above the feed to the total stages predicts the percentage of all trays that should be located above the feed point.

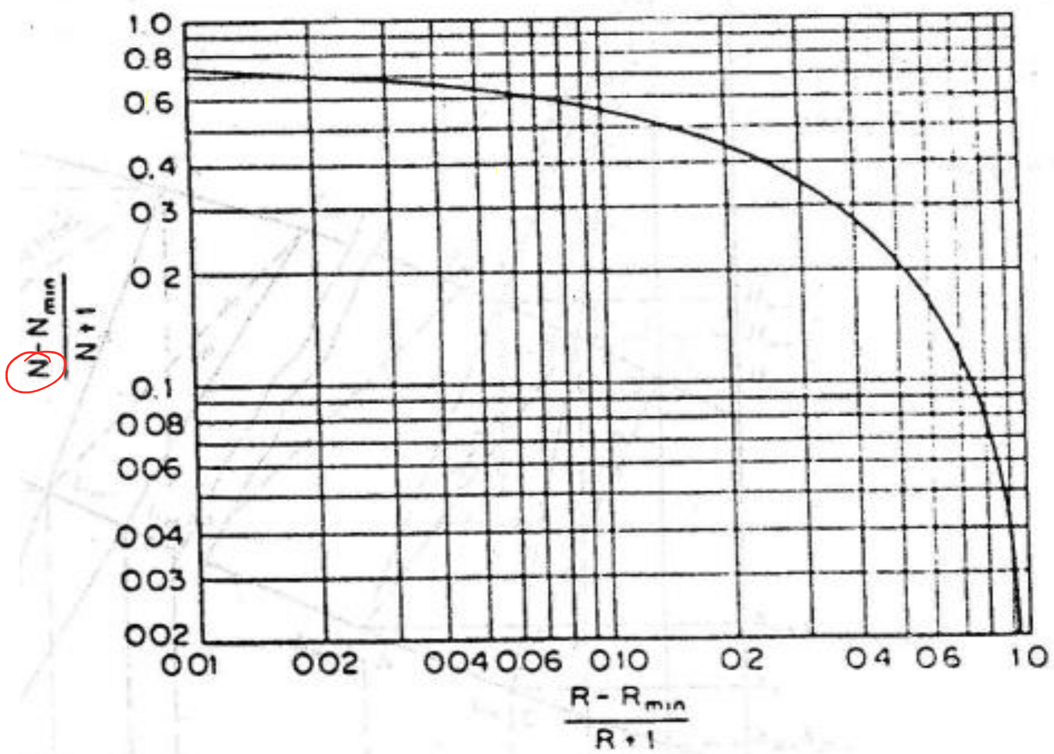


FIG. 8-4 Gilliland correlation relating number of stages to reflux ratio. *(From Chemical Engineering, McGraw-Hill, 1977.)*