

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.

$$\left. \begin{array}{l} \text{Underwood Method} \rightarrow R_{\min} \rightarrow R_{\text{opt}} \\ \text{Fenske's Method} \rightarrow N_{\min} \end{array} \right\} \xrightarrow{\text{Gilliland Correlation}} N_P$$

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

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

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

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:

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

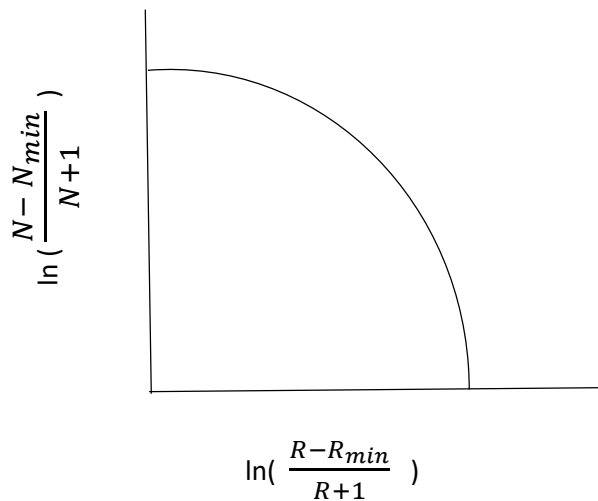
Notes:

1. N_{min} 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 $N_{min} + 1 = 1$
3. If α_{ij} is not constant, take an average value. Geometric average in the case of N_{min} .
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

Gilliland Correlation: Number of Theoretical Plates:

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

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

**Feed Tray Location:**

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

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

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.

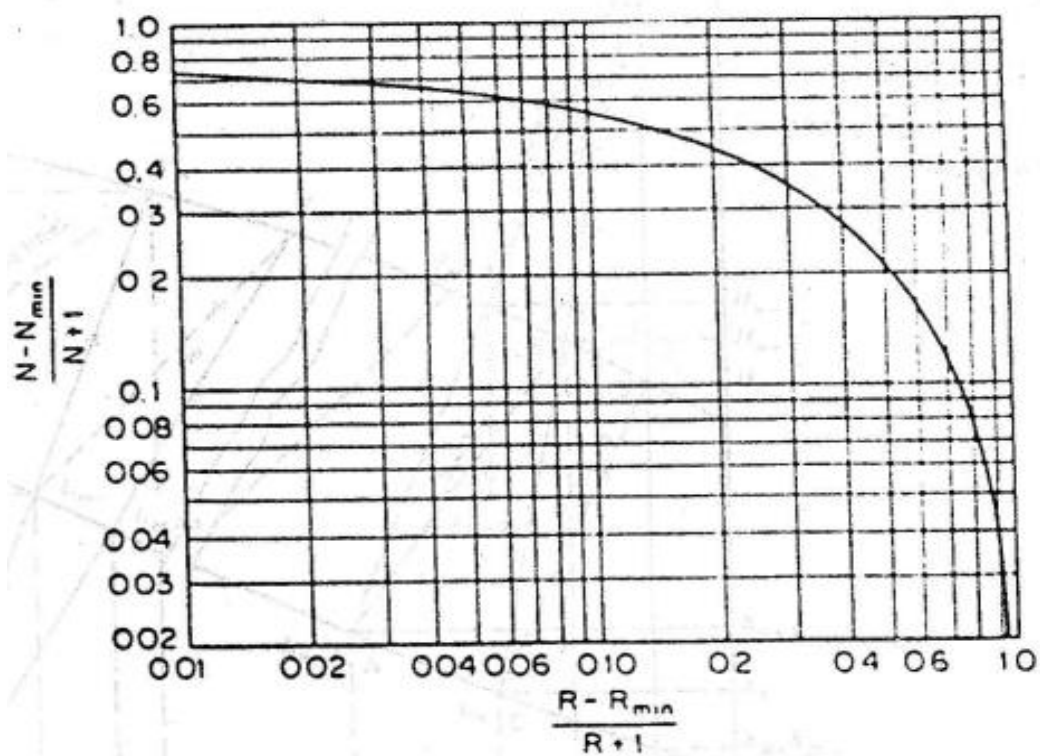


FIG. 8-4 Gilliland correlation relating number of stages to reflux ratio. (From *Chemical Engineering*, McGraw-Hill, 1977.)