

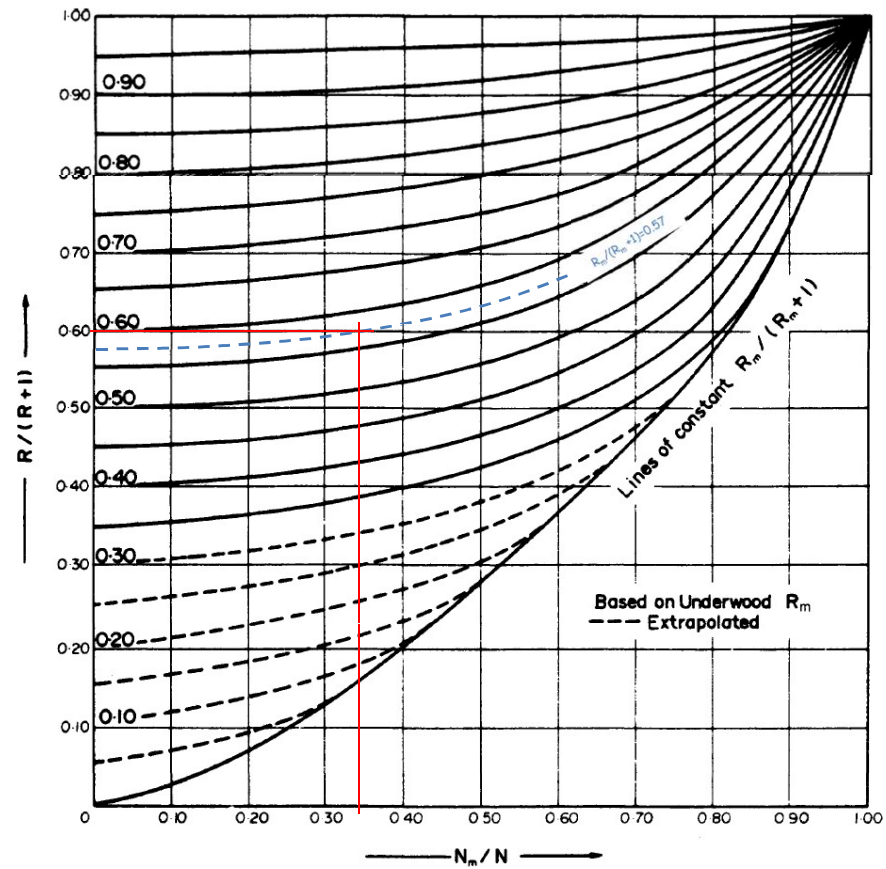
CEN416
PROCESS DESIGN II

Empirical correlations methods

The two most frequently used empirical methods for estimating the stage requirements for multicomponent distillations are the correlations published by **Gilliland** (1940) and by **Erbar and Maddox** (1961).

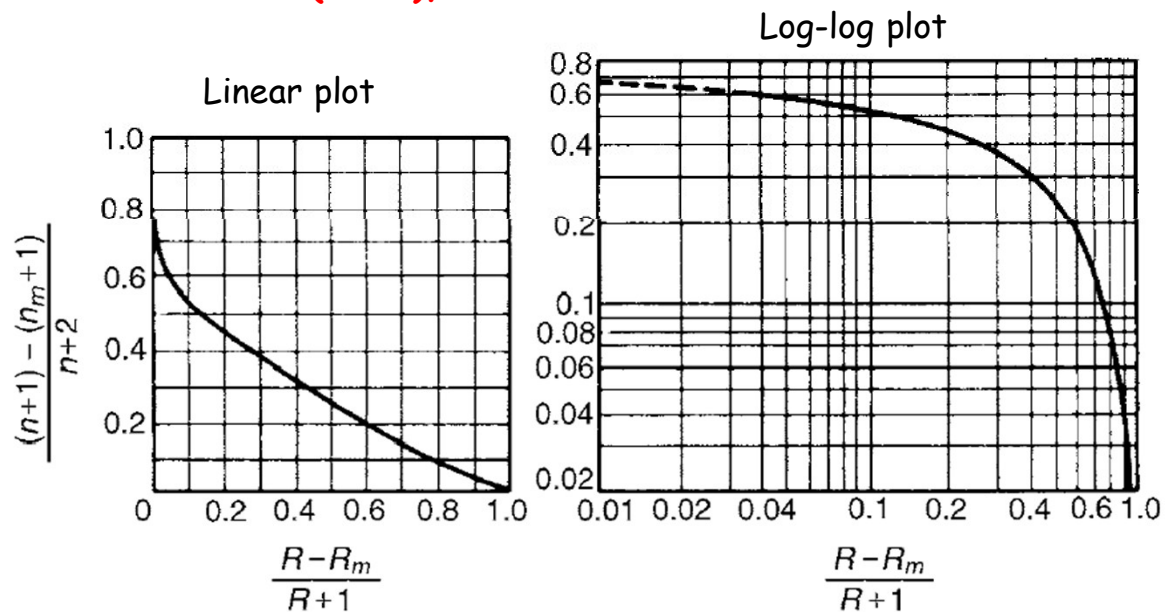
These relate the number of ideal stages required for a given separation, at a given reflux ratio, to the number at total reflux (minimum possible) and the minimum reflux ratio (infinite number of stages).

Number of stages calculation



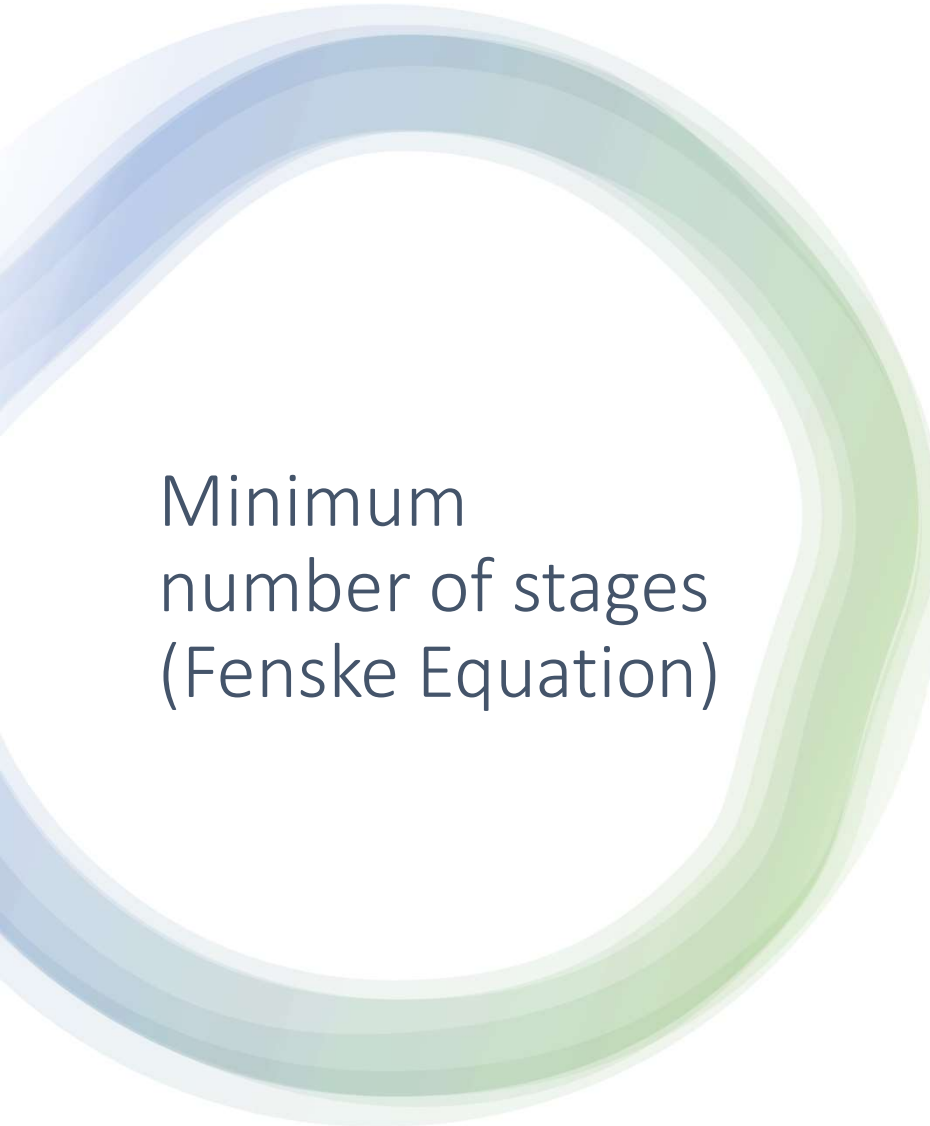
Number of stages calculation

Gilliland correlation (1940), C&R II Vol.



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

where: $\Psi = \frac{R - R_m}{R + 1}$



Minimum number of stages (Fenske Equation)

$$\left[\frac{x_i}{x_r} \right]_d = \alpha_i^{N_m} \left[\frac{x_i}{x_r} \right]_b$$

where $[x_i/x_r]$ = the ratio of the concentration of any component i to the concentration of a reference component r , and the suffixes d and b denote the distillate (tops) (d) and the bottoms (b),

N_m = minimum number of stages at total reflux, including the reboiler,

α_i = average relative volatility of the component i with respect to the reference component.

- The Fenske equation (Fenske, 1932) can be used to estimate the minimum stages required at total reflux.
- The derivation of this equation for a binary system is given in C-R Vol. 2, Chapter 11. The equation applies equally to multicomponent systems and can be written as:

Minimum number of stages (Fenske Equation)

$$N_m = \frac{\log \left[\frac{x_{LK}}{x_{HK}} \right]_d \left[\frac{x_{HK}}{x_{LK}} \right]_b}{\log \alpha_{LK}}$$

where α_{LK} is the average relative volatility of the light key with respect to the heavy key, and x_{LK} and x_{HK} are the light and heavy key concentrations.

Large relative volatilities and feed location

If there is a wide difference between the relative volatilities at the top and bottom of the column the use of the average value in the Fenske equation will underestimate the number of stages.

The feed concentration is taken as the base concentration for the rectifying section and as the top concentration for the stripping section, and estimating the average relative volatilities separately for each section.

REFERENCES

1. Sinnott, R.K. 1999, *Coulson's & Richardson's Chemical Engineering, Volume 6, Chemical Engineering Design*, ButterWorth Heinemann, Oxford.
2. Turton R., Bailie R.C., Whitin W.C., Shaeiwitz J.A. 1998, *Analysis, Synthesis and Design of Chemical Processes*, Prentice Hall, New Jersey.