Distillation Minimum Stages (Fenske) and Minimum Reflux

Minimum theoretical stages at total reflux by the Fenske equation and minimum reflux ratio for a binary distillation with a saturated liquid feed.

Method: M.R. Fenske (1932); Ind. Eng. Chem. 24; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Light key in the distillate (mole fraction)	95.000	%
Light key in the bottoms	5.0000	%
Light key in the feed (saturated liquid)	50.000	%
Relative volatility (mean)	2.5000	
Operating reflux as a multiple of the minimum	1.3000	

Calculated results

Parameter	Value	Unit
Minimum theoretical stages (including the reboiler)	6.4269	
Vapour in equilibrium with the feed	71.429	%
Minimum reflux ratio	1.1000	
Operating reflux ratio	1.4300	

Notes for this case

- Constant relative volatility and constant molar overflow; a pinch away from the feed (non-ideal mixtures) raises the real minimum reflux.

Formula and method

$$N_{min} = \frac{\ln\left[\frac{x_D}{1-x_D} \cdot \frac{1-x_B}{x_B}\right]}{\ln \alpha}$$

$$y_F^* = \frac{\alpha x_F}{1+(\alpha-1)x_F}, \quad R_{min} = \frac{x_D - y_F^*}{y_F^* - x_F}$$

Variables

x_D	Light key in the distillate (mole fraction)	-
x_B	Light key in the bottoms	-
x_F	Light key in the feed (saturated liquid)	-
α	Relative volatility (mean)	-
R/R_{min}	Operating reflux as a multiple of the minimum	-
N_{min}	Minimum theoretical stages (including the reboiler)	-
y_F^*	Vapour in equilibrium with the feed	-
R_{min}	Minimum reflux ratio	-
R	Operating reflux ratio	-

Method and standards

Fenske's equation at total reflux with a constant relative volatility; the minimum reflux comes from the pinch where the rectifying line meets the equilibrium curve at the feed composition.

Assumptions and limits

- Constant α, constant molar overflow, saturated liquid feed (q = 1); there is no feed-condition input. For other feeds use the q-line and minimum reflux calculators.

References

- M.R. Fenske (1932)
- Ind. Eng. Chem. 24
- Minimum reflux at the feed pinch (McCabe–Thiele, binary, saturated liquid feed)

Report details

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Release checks	3 reference cases of this calculator, computed independently, are checked on every release

Results are for engineering estimation. Verify critical designs against the referenced standards and your own data.

This calculator online

https://calc.firecad.com/chemical/separation/fenske-minimum-stages

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.