Ethanol–Water Column Stages by McCabe–Thiele

Theoretical stages, feed stage and minimum reflux (tangent pinch) of an ethanol–water column with a reboiler, by McCabe–Thiele stepping on a fitted x–y curve.

Method: Ethanol–water VLE at about 1 atm: Wilson equation (Perry's Chemical Engineers' Handbook, 9th ed., sec. 4) with energies 399 and 933 cal/mol fitted to FireCAD ethanol–water x–y–T data at 101.325 kPa; ethanol vapour pressure Perry's 9th ed. Table 2-8; water IAPWS-IF97; Checked against Gmehling and Onken, DECHEMA Chemistry Data Series vol. I/1, as quoted in Perry's 9th ed. sec. 13 (simple batch distillation example); ...

Minimum reflux ratio	Reflux ratio	Theoretical stages (reboiler = 1)	Feed stage from the top
2.3120	**3.0056**	**15.815**	**9.0000**

Input parameters

Unit system: SI

Parameter	Value	Unit
Feed strength % vol at 20 °C.	10.000	%
Distillate strength % vol; must stay below the azeotrope (about 97 % vol).	94.000	%
Bottoms strength % vol.	0.10000	%
Feed condition (1 saturated liquid, 0 saturated vapour) saturated liquid	1.0000	
Reflux as a multiple of the minimum	1.3000	
Pressure Model fitted at 1 atm; use 0.9–1.2 atm.	101.33	kPa

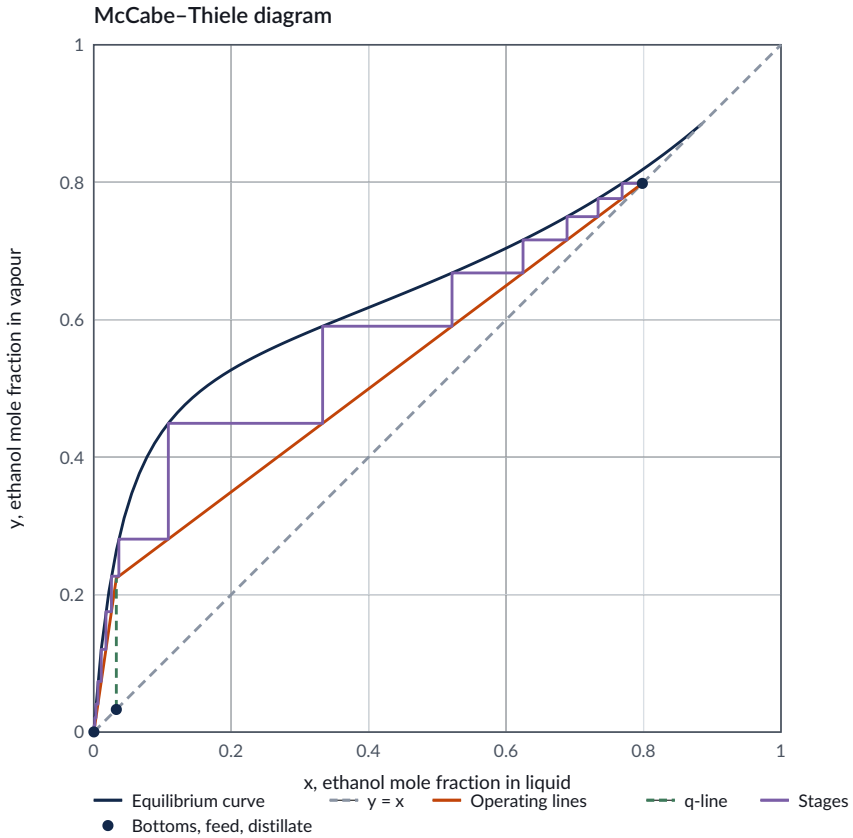
Calculated results

Parameter	Value	Unit
Feed mole fraction	3.2950	%
Distillate mole fraction	79.830	%
Bottoms mole fraction	0.030938	%
Minimum reflux ratio	**2.3120**	
Reflux ratio	**3.0056**	
Theoretical stages (reboiler = 1)	**15.815**	
Feed stage from the top	**9.0000**	

Notes for this case

- Constant molar overflow is assumed; ethanol–water deviates a little from it. Divide by the tray efficiency (Perry's Table 14-12: 75–85 % for ethanol–water sieve trays) for actual trays.

Diagram



Drawn from this calculation's own results.

Formula and method

$$y = \frac{R}{R+1}x + \frac{x_D}{R+1}, \quad \frac{R_{min}}{R_{min}+1} = \max_{x_q \le x < x_D} \frac{x_D - y^*(x)}{x_D - x}$$

Variables

q_F	Feed strength	-
q_D	Distillate strength	-
q_B	Bottoms strength	-
q	Feed condition (1 saturated liquid, 0 saturated vapour)	-
R/R_{min}	Reflux as a multiple of the minimum	-
P	Pressure	Pa
x_F	Feed mole fraction	-
x_D	Distillate mole fraction	-
x_B	Bottoms mole fraction	-
R_{min}	Minimum reflux ratio	-
R	Reflux ratio	-
N	Theoretical stages (reboiler = 1)	-
N_F	Feed stage from the top	-

Method and standards

McCabe–Thiele stepping from the top with the fitted Wilson equilibrium.

Assumptions and limits

- Wilson energies fitted at 1 atm; 0.9–1.2 atm only.

- Binary ethanol–water; congeners and dissolved solids ignored.
- Constant molar overflow; total condenser; saturated reflux. Ethanol–water departs a little from constant molar overflow, so the stage count approximates an enthalpy-balance (Ponchon–Savarit) result.
- The engine accepts the same ranges as the form: q from 0 to 1.5 and 90–125 kPa.

References

• Ethanol–water VLE at about 1 atm: Wilson equation (Perry's Chemical Engineers' Handbook, 9th ed., sec. 4) with energies 399 and 933 cal/mol fitted to FireCAD ethanol–water x–y–T data at 101.325 kPa; ethanol vapour pressure Perry's 9th ed. Table 2-8; water IAPWS-IF97
• Checked against Gmehling and Onken, DECHEMA Chemistry Data Series vol. I/1, as quoted in Perry's 9th ed. sec. 13 (simple batch distillation example)
• McCabe–Thiele method with constant molar overflow (Perry's 9th ed. sec. 13)

Report details

Report reference	FCC-4WJF-ST08 (the same inputs always give the same reference)
Generated	17 November 2026, 19:50 UTC
Calculator	Ethanol–Water Column Stages by McCabe–Thiele
Method last reviewed	13 November 2026
Software release	FireCAD Calc, release of 17 November 2026
Release checks	2 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/sugar-ethanol/ethanol-distillation/ethanol-water-mccabe-thiele

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.