Ethanol–Water Minimum Stages at Total Reflux

Minimum theoretical stages to go from a bottoms to a distillate strength at total reflux by stepping on the ethanol–water curve (Fenske with variable volatility).

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; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Distillate strength	94.000	%
Bottoms strength	0.10000	%
Pressure Model fitted at 1 atm; use 0.9–1.2 atm.	101.33	kPa

Calculated results

Parameter	Value	Unit
Distillate mole fraction	79.830	%
Bottoms mole fraction	0.030938	%
Minimum stages (reboiler = 1)	7.6104	

Formula and method

$$y_{n+1} = x_n, \quad x_n = x^*(y_n)$$

Variables

q_D	Distillate strength	-
q_B	Bottoms strength	-
P	Pressure	Pa
x_D	Distillate mole fraction	-
x_B	Bottoms mole fraction	-
N_{min}	Minimum stages (reboiler = 1)	-

Method and standards

Stepping between the equilibrium curve and the diagonal.

Assumptions and limits

- Wilson energies fitted at 1 atm; 0.9–1.2 atm only.
- Binary ethanol–water; congeners and dissolved solids ignored.
- Near the azeotrope (above about 94 % vol) N_min depends strongly on the accuracy of the fitted curve there; a note says so.

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)
• Total reflux: operating line on the diagonal (Perry's 9th ed. sec. 13, Fig. 13-25)

Report details

Report reference	FCC-1X48-PB5P (the same inputs always give the same reference)
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Calculator	Ethanol–Water Minimum Stages at Total Reflux
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-total-reflux-stages

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.