Rectifier Minimum Reflux and Vapour Load to 95 % vol

Minimum and design reflux ratio, vapour and reflux flows of an ethanol rectifier fed with beer-column vapour, for a product strength in % vol (tangent pinch).

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
Product strength	95.000	%
Feed (vapour) strength, as condensate	45.000	%
Feed condition (0 saturated vapour)	0	
Reflux multiple	1.3000	
Product at 20 °C Enter in m³/day or L/day in the unit list.	4.1667	m³/h
Pressure Model fitted at 1 atm; use 0.9–1.2 atm.	101.33	kPa

Calculated results

Parameter	Value	Unit
Minimum reflux ratio	3.6928	
Design reflux ratio	4.8006	
Distillate	82.061	kmol/h
Vapour to the condenser	476.01	kmol/h
Vapour mass flow	19,611	kg/h
Reflux	393.94	kmol/h

Notes for this case

- Close to the azeotrope the equilibrium curve nearly meets the diagonal, so R_min and the vapour load are very sensitive to small errors in the fitted curve: treat them as approximate.

Formula and method

$$\frac{R_{min}}{R_{min}+1} = \max \frac{x_D - y^*(x)}{x_D - x}, \quad V = (R+1)D, \quad L = RD$$

Variables

q_D	Product strength	-
q_F	Feed (vapour) strength, as condensate	-
q	Feed condition (0 saturated vapour)	-
R/R_{min}	Reflux multiple	-
$\dot{V}_P$	Product at 20 °C	m³/s
P	Pressure	Pa
R_{min}	Minimum reflux ratio	-
R	Design reflux ratio	-
D	Distillate	mol/s
V	Vapour to the condenser	mol/s

$\dot{m}_V$	Vapour mass flow	kg/s
L	Reflux	mol/s

Method and standards

Tangent-pinch minimum reflux with the fitted Wilson equilibrium; distillate moles from the product's R 22 density.

Assumptions and limits

- Wilson energies fitted at 1 atm; 0.9–1.2 atm only.
- Binary ethanol–water; congeners and dissolved solids ignored.
- Above about 94 % vol the product is close to the model azeotrope; small errors in the fitted equilibrium curve then change R_min a lot, and 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)
• Minimum reflux by the tangent to the equilibrium curve (Perry's 9th ed. sec. 13, McCabe–Thiele limiting cases)

Report details

Report reference	FCC-T5G5-KHQC (the same inputs always give the same reference)
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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-rectifier-minimum-reflux

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.