Beer Column with Live Steam: Stages and Minimum Steam

Stripping stages, minimum and actual live-steam ratio and top vapour strength of a beer (wash) column fed at the top with live steam at the base, McCabe–Thiele.

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
Beer strength % vol at 20 °C.	8.0000	%
Stillage (bottoms) strength	0.020000	%
Live steam per tonne of beer	180.00	kg/t
Pressure Model fitted at 1 atm; use 0.9–1.2 atm.	101.33	kPa

Calculated results

Parameter	Value	Unit
Beer mole fraction	2.6025	%
Stillage mole fraction	0.006184	%
Minimum steam per tonne of beer	109.49	kg/t
Top vapour mole fraction	13.862	%
Top vapour strength (as condensate)	35.285	%
Theoretical stages	6.6187	
Ethanol recovered overhead	99.762	%

Notes for this case

- Live steam dilutes the stillage; a reboiler avoids that but costs a heat exchanger. Beer solids and CO_2 are ignored.

Formula and method

$$y = \frac{F}{S}(x - x_B), \quad \left(\frac{S}{F}\right)_{min,molar} = \frac{x_F - x_B}{y^*(x_F)}, \quad \left(\frac{S}{F}\right)_{min} = \frac{x_F - x_B}{y^*(x_F)}\, n_F M_W$$

Variables

q_F	Beer strength	-
q_B	Stillage (bottoms) strength	-
S/F	Live steam per tonne of beer	kg/kg
P	Pressure	Pa
x_F	Beer mole fraction	-
x_B	Stillage mole fraction	-
$(S/F)_{min}$	Minimum steam per tonne of beer	kg/kg
y_1	Top vapour mole fraction	-
q_y	Top vapour strength (as condensate)	-
N	Theoretical stages	-
η	Ethanol recovered overhead	-
$y^*(x_F)$	vapour in equilibrium with the beer	-

n_F	moles per kg of beer	kmol/kg
M_W	molar mass of water (steam)	kg/kmol
$F\$, \$S$	beer and live steam, molar flows	kmol/s

Method and standards

McCabe–Thiele for a stripping column with live steam, constant molar overflow.

Assumptions and limits

- Wilson energies fitted at 1 atm; 0.9–1.2 atm only.
- Binary ethanol–water; congeners and dissolved solids ignored.
- Beer fed as saturated liquid on the top tray; beer subcooling is not counted.
- Constant molar overflow with live steam: the differing latent heats of ethanol and water are ignored. The minimum steam assumes the pinch is at the feed.

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)
• Stripping with open steam: operating line through (x_B, 0)
• constant molar overflow (Perry's 9th ed. sec. 13)

Report details

Report reference	FCC-9BXJ-JT8G (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/beer-column-open-steam-stages

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.