Multiple-Effect Evaporator Steam Consumption and Economy

Steam needed and steam economy of a forward-feed multiple-effect evaporator, from feed, concentrations, number of effects and steam and last-effect pressures.

Method: Effect-by-effect energy balance; IAPWS-IF97 latent heats

Input parameters

Unit system: SI

Parameter	Value	Unit
Feed flow	10.000	t/h
Solids in the feed	5.0000	%
Solids in the product	50.000	%
Number of effects	3	
Heating steam pressure (absolute, saturated)	2.0000	bar
Pressure in the last effect (absolute)	0.15000	bar
Feed temperature	60.000	°C
Specific heat of the liquor	3.9000	kJ/(kg·K)

Calculated results

Parameter	Value	Unit
Water evaporated	9.0000	t/h
Heating steam needed	3.5951	t/h
Steam economy (kg water per kg steam)	2.5034	kg/kg
Vapour from the last effect to the condenser	3.1187	t/h
Boiling temperature in the first effect	98.131	°C

Notes for this case

- Equal temperature drops, no boiling-point rise and no heat losses: real economies are a little lower.

Formula and method

$$E = F\left(1 - \frac{x_f}{x_p}\right)$$

$$S h_{fg}(T_s) + F c_p (T_f - T_1) = V_1 h_{fg}(T_1)$$

$$V_{i-1} h_{fg}(T_{i-1}) + L_{i-1} c_p (T_{i-1} - T_i) = V_i h_{fg}(T_i)$$

$$\sum V_i = E$$

Variables

F	feed flow	kg/s
x_f	solids in the feed	-
x_p	solids in the product	-
N	number of effects	-
p_s	heating steam pressure	Pa
p_N	last-effect pressure	Pa
T_f	feed temperature	K

c_p	liquor specific heat	J/(kg·K)
T_s	heating steam saturation temperature	K
T_i	boiling temperature in effect i	K
T_1	boiling temperature in the first effect	K
h_{fg}	latent heat of water	J/kg
V_i	vapour from effect i	kg/s
L_i	liquor leaving effect i	kg/s
E	water evaporated	kg/s
S	heating steam	kg/s
E/S	steam economy	kg/kg
V_N	vapour to the condenser	kg/s

Method and standards

Forward feed: liquor flows from the first to the last effect with the vapour. Boiling temperatures fall in equal steps from the steam to the last-effect saturation temperature; each effect is heated by the previous effect's vapour, condensing at its saturation temperature (latent heats from IAPWS-IF97). The balances are linear in the steam flow, which is solved so the total evaporation matches.

Assumptions and limits

- No boiling-point rise and no heat losses. For strong liquors (such as a 50 % solids product) the boiling-point rise eats into the temperature drops and the real economy is noticeably lower than shown.
- Equal temperature drops per effect; liquor specific heat constant.
- Forward feed; vapour bleeds to other users not included.

References

- Effect-by-effect energy balance
- IAPWS-IF97 latent heats

Report details

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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/evaporator-steam-economy

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.