Multiple-Effect Evaporator Design (Hugot)

Evaporation, brix, Dessin coefficient and heating surface of each effect of a 3- to 5-effect evaporator with vapour bleeding, by Hugot's method (pp. 588–591).

Method: Hugot; Handbook of Cane Sugar Engineering; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Clear juice to the evaporator	100.00	t/h
Clear juice brix	13.000	%
Syrup brix	65.000	%
Number of effects	4.0000	
Dessin factor	0.001000	
Heating steam temperature (effect 1)	120.00	°C
Vapour temperature leaving effect 1	111.00	°C
Vapour temperature leaving effect 2	100.00	°C
Vapour temperature leaving effect 3	85.000	°C
Vapour temperature leaving effect 4	55.000	°C
Vapour temperature leaving effect 5	55.000	°C
Boiling-point rise in effect 1 (brix and head)	0.80000	K
Boiling-point rise in effect 2 (brix and head)	1.3000	K
Boiling-point rise in effect 3 (brix and head)	2.1000	K
Boiling-point rise in effect 4 (brix and head)	6.1000	K
Boiling-point rise in effect 5 (brix and head)	6.1000	K
Vapour bled from effect 1	11,204	kg/h
Vapour bled from effect 2	3,515.0	kg/h
Vapour bled from effect 3	6,050.0	kg/h
Vapour bled from effect 4	0	kg/h

Calculated results

Parameter	Value	Unit
Total evaporation	80,000	kg/h
Vapour to the condenser	10,904	kg/h
Evaporation of effect 1 (= heating steam, Rillieux)	31,673	kg/h
Evaporation of effect 2	20,469	kg/h
Evaporation of effect 3	16,954	kg/h
Evaporation of effect 4	10,904	kg/h
Evaporation of effect 5	0	kg/h
Brix leaving effect 1	19.026	%
Brix leaving effect 2	27.164	%
Brix leaving effect 3	42.066	%

Parameter	Value	Unit
Brix leaving effect 4	65.000	%
Brix leaving effect 5	0	%
Heating surface of effect 1	696.82	m²
Heating surface of effect 2	481.39	m²
Heating surface of effect 3	436.96	m²
Heating surface of effect 4	316.72	m²
Heating surface of effect 5	0	m²
Total heating surface	1,931.9	m²

Notes for this case

- Hugot's example (100 t/h juice, 13 to 65 brix, quadruple 120/111/100/85/55 °C) gives 697, 482, 437 and 317 m², about 1 930 m² in all.

Formula and method

$$E = J\left(1 - \frac{B_0}{B_s}\right) = nx + \sum_{i<n} iP_i, \quad q_i = x + \sum_{k \geq i} P_k, \quad B_i = \frac{B_0 J}{J - \sum_{k \leq i} q_k}$$

$$b_i = \frac{B_{i-1} + B_i}{2}, \quad c_i = f(100 - b_i)(T_{i-1} - 54), \quad \Delta_i = T_{i-1} - T_i - d_i, \quad S_i = \frac{q_i}{c_i \Delta_i}$$

Variables

J	Clear juice to the evaporator	kg/s
B_0	Clear juice brix	-
B_s	Syrup brix	-
n	Number of effects	-
f	Dessin factor	-
T_0	Heating steam temperature (effect 1)	K
T_1	Vapour temperature leaving effect 1	K
T_2	Vapour temperature leaving effect 2	K
T_3	Vapour temperature leaving effect 3	K
T_4	Vapour temperature leaving effect 4	K
T_5	Vapour temperature leaving effect 5	K
d_1	Boiling-point rise in effect 1 (brix and head)	K
d_2	Boiling-point rise in effect 2 (brix and head)	K
d_3	Boiling-point rise in effect 3 (brix and head)	K
d_4	Boiling-point rise in effect 4 (brix and head)	K
d_5	Boiling-point rise in effect 5 (brix and head)	K
P_1	Vapour bled from effect 1	kg/s
P_2	Vapour bled from effect 2	kg/s
P_3	Vapour bled from effect 3	kg/s
P_4	Vapour bled from effect 4	kg/s
E	Total evaporation	kg/s
x	Vapour to the condenser	kg/s
q_1	Evaporation of effect 1 (= heating steam, Rillieux)	kg/s
q_2	Evaporation of effect 2	kg/s
q_3	Evaporation of effect 3	kg/s

q_4	Evaporation of effect 4	kg/s
q_5	Evaporation of effect 5	kg/s
B_1	Brix leaving effect 1	-
B_2	Brix leaving effect 2	-
B_3	Brix leaving effect 3	-
B_4	Brix leaving effect 4	-
B_5	Brix leaving effect 5	-
S_1	Heating surface of effect 1	m²
S_2	Heating surface of effect 2	m²
S_3	Heating surface of effect 3	m²
S_4	Heating surface of effect 4	m²
S_5	Heating surface of effect 5	m²
S	Total heating surface	m²

Method and standards

Hugot's multiple-effect method with Dessin's coefficient.

Assumptions and limits

- Juice enters at its boiling point; add the first-vessel heating surface separately.
- Rillieux idealisation: 1 kg of steam or vapour evaporates 1 kg, so the steam to effect 1 equals q_1; flash, heat losses and changing latent heat are ignored.
- In the Dessin coefficient b_i is the mean of the brix entering and leaving the effect, in per cent.
- The boiling-point rises d_i are entered, not computed from brix and liquid head.

References

• Hugot
• Handbook of Cane Sugar Engineering
• 3rd ed. (Elsevier, 1986)
• ch. 32
• multiple-effect calculations
• eqns 32.20 and 32.31 and the example of pp. 588–591

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/sugar-ethanol/evaporation/multiple-effect-evaporator-design

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Reopens the calculator with the inputs of this report.