Grain Mash Cooking: Jet Cooker Steam and Flash

Direct steam to heat grain slurry in a jet cooker (IF97), vapour flashed to liquefaction temperature, liquefaction volume and α-amylase (Alcohol Textbook ch. 2).

Method: Jacques; Lyons and Kelsall (eds.); ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Grain (meal) to the slurry	20.000	t/h
Grain share of the slurry Alcohol Textbook ch. 2: modern systems run 29–33 % solids.	31.000	%
Specific heat of the grain solids Starting value with no particular source; use a measured figure for your grain if you have one.	1.5500	kJ/(kg·K)
Slurry temperature	60.000	°C
Jet cooker temperature Alcohol Textbook: 120 °C (columnar), 120–140 °C (U-tube).	120.00	°C
Liquefaction (flash) temperature 80–90 °C.	85.000	°C
Cooking steam pressure (absolute)	8.0000	bar
Liquefaction residence At least 30 min, preferably 60.	60.000	min
Mash density	1,100.0	kg/m³
α-amylase dose (w/w grain) 0.04–0.08 % w/w cereal for high-temperature α-amylase.	0.060000	%

Calculated results

Parameter	Value	Unit
Slurry	64.516	t/h
Slurry specific heat	3.3694	kJ/(kg·K)
Cooking steam	5,759.6	kg/h
Steam per tonne grain	287.98	kg/t
Vapour flashed to liquefaction temperature	3,610.5	kg/h
Liquefaction tank working volume	60.605	m³
α-amylase	12.000	kg/h

Notes for this case

- The flash vapour can heat the incoming slurry; then the net steam is less. Backset and recycled water must be counted in the slurry.

Formula and method

$$M = \frac{G}{x}, \quad c = x c_s + (1 - x) c_w, \quad \dot{m}_s = \frac{M c (T_j - T_0)}{h_g(p_s) - h_f(T_j)}, \quad \dot{m}_f = \frac{(M + \dot{m}_s) c (T_j - T_f)}{h_{fg}(T_f)}$$

Variables

G	Grain (meal) to the slurry	kg/s
x	Grain share of the slurry	-
c_s	Specific heat of the grain solids	J/(kg·K)

T_0	Slurry temperature	K
T_j	Jet cooker temperature	K
T_f	Liquefaction (flash) temperature	K
p_s	Cooking steam pressure (absolute)	Pa
t_r	Liquefaction residence	s
ρ_m	Mash density	kg/m³
e	α-amylase dose (w/w grain)	-
M	Slurry	kg/s
c	Slurry specific heat	J/(kg·K)
$\dot{m}_s$	Cooking steam	kg/s
$\dot{m}_s/G$	Steam per tonne grain	kg/kg
$\dot{m}_f$	Vapour flashed to liquefaction temperature	kg/s
V	Liquefaction tank working volume	m³
$\dot{m}_E$	α-amylase	kg/s
c_w	Specific heat of water, 4.1868 kJ/(kg·K)	J/(kg·K)
h_g, h_f, h_{fg}	Saturated steam, saturated liquid and latent enthalpies (IAPWS-IF97)	J/kg

Method and standards

Heat balance for direct steam injection and adiabatic flash.

Assumptions and limits

- Steam condenses fully in the mash; no heat loss.
- c_w, the specific heat of water, is taken as 4.1868 kJ/(kg·K); the default c_s of 1.55 kJ/(kg·K) is a starting value without a particular source.
- The supply steam is taken as dry saturated at p_s; superheated or wet steam is not handled.

References

• Jacques
• Lyons and Kelsall (eds.)
• The Alcohol Textbook
• 4th ed. (Nottingham University Press, 2003)
• ch. 2 (Kelsall and Lyons)
• cooking systems
• Steam and water enthalpies from IAPWS-IF97

Report details

Report reference	FCC-PGQN-B55A (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/grain-cooking-jet-steam

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Reopens the calculator with the inputs of this report.