Spray Drying: Droplet Evaporation Time (Constant-Rate Period)

Time for a spray droplet to evaporate down to a critical diameter in hot air during the constant-rate period, by the d² law with a Nusselt number of 2.

Method: d² law for droplet evaporation with Nu = 2

Input parameters

Unit system: SI

Parameter	Value	Unit
Initial droplet diameter	80.000	µm
Diameter at which a crust forms (0 = complete evaporation)	50.000	µm
Liquid density	1,100.0	kg/m³
Latent heat of evaporation	2,400.0	kJ/kg
Thermal conductivity of the air film	0.030000	W/(m·K)
Air temperature minus droplet (wet-bulb) temperature	100.00	K

Calculated results

Parameter	Value	Unit
Evaporation time to the critical diameter	429.00	ms
Time for complete evaporation	704.00	ms
Share of the droplet volume evaporated	75.586	%

Notes for this case

• A small droplet moving with the air exchanges heat as if in still air (Nu = 2), so its surface area shrinks linearly in time: d² = d₀² − 8kΔT t/(ρ_l λ). Evaporation of a solution's water continues at this rate until a crust forms at the critical diameter; drying then slows (falling-rate period). The result shows why fine atomisation matters: halving the droplet size cuts the time to a quarter. Droplet temperature is the wet-bulb temperature of the air.

Formula and method

$$t = \frac{\rho_l \lambda \left(d_0^2 - d_c^2\right)}{8 k \Delta T}$$

Variables

d_0	Initial droplet diameter	m
d_c	Diameter at which a crust forms (0 = complete evaporation)	m
ρ_l	Liquid density	kg/m³
λ	Latent heat of evaporation	J/kg
k	Thermal conductivity of the air film	W/(m·K)
ΔT	Air temperature minus droplet (wet-bulb) temperature	K
t	Evaporation time to the critical diameter	s
t_{full}	Time for complete evaporation	s
$1 - (d_c/d_0)^3$	Share of the droplet volume evaporated	-

Method and standards

Droplet evaporation.

Assumptions and limits

- Spherical droplet; no relative velocity; constant air temperature.

References

d² law for droplet evaporation with Nu = 2

Report details

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Release checks	3 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/chemical/drying/spray-drying-droplet-time

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.