Time to Heat a Particle or Fuel Feed in a Fluidised Bed

Time for a particle (fuel, sorbent or make-up) to approach bed temperature from the gas-to-particle coefficient, with the 99 % time (Basu Eqs. 3.3–3.4).

Method: Basu; Circulating Fluidized Bed Boilers: Design; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Particle specific heat	0.84000	kJ/(kg·K)
Particle density	2,500.0	kg/m³
Mean particle diameter (surface-volume)	0.30000	mm
Gas-to-particle heat transfer coefficient	200.00	W/(m²·K)
Bed (gas) temperature	850.00	°C
Initial particle temperature	30.000	°C
Particle temperature to reach	800.00	°C
Particle thermal conductivity About 1 to 3 W/(m·K) for sand and limestone, 0.2 to 0.3 for coal, 0.1 to 0.2 for biomass. Used only for the Biot number check.	1.5000	W/(m·K)

Calculated results

Parameter	Value	Unit
Time to reach T_p	1.4686	s
Time to close 99 % of the gap	2.4097	s
Biot number h d_p/(6 k_p)	0.006667	

Formula and method

$$t = \frac{C_p \rho_p d_p}{6 h_{gp}} \ln \frac{T_g - T_{p0}}{T_g - T_p}, \quad t_{99\%} = 0.765 \frac{C_p \rho_p d_p}{h_{gp}}$$

Variables

C_p	Particle specific heat	J/(kg·K)
ρ_p	Particle density	kg/m³
d_p	Mean particle diameter (surface-volume)	m
h_{gp}	Gas-to-particle heat transfer coefficient	W/(m²·K)
T_g	Bed (gas) temperature	K
T_{p0}	Initial particle temperature	K
T_p	Particle temperature to reach	K
t	Time to reach T_p	s
$t_{99\%}$	Time to close 99 % of the gap	s
k_p	Particle thermal conductivity	W/(m·K)
Bi	Biot number h d_p/(6 k_p)	-

Method and standards

Lumped-capacity heating of a sphere.

Assumptions and limits

- Uniform particle temperature; constant h.

- Valid only for a Biot number Bi = h d_p / (6 k_p) below about 0.1, which the calculator shows and warns about. For coarse coal of several millimetres internal conduction slows heating and the time shown is too short.

References

- Basu
- Circulating Fluidized Bed Boilers: Design
- Operation and Maintenance (Springer, 2015)
- ch. 3
- Eqs. (3.3) and (3.4) (lumped particle heating)

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/boilers-power-plant/fluidised-bed/particle-heating-time

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.