Pebble Bed (Rock Bed) Storage: Heat Transfer, Biot Number and NTU

Volumetric heat transfer coefficient, Biot number, number of transfer units and storage capacity of a packed rock bed for solar air heating systems.

Input parameters

Unit system: SI

Parameter	Value	Unit
Bed length in the flow direction	1.0000	m
Bed cross-section	4.0000	m²
Superficial air velocity	0.15000	m/s
Air density	1.1500	kg/m³
Air specific heat	1.0070	kJ/(kg·K)
Equivalent pebble diameter	25.000	mm
Void fraction	40.000	%
Pebble density	2,600.0	kg/m³
Pebble specific heat	0.84000	kJ/(kg·K)
Pebble conductivity	2.0000	W/(m·K)
Pebble surface area per bed volume	0.14400	m²/L
Temperature swing of the bed	40.000	K

Calculated results

Parameter	Value	Unit
Air mass velocity	0.17250	kg/(m²·s)
Volumetric heat transfer coefficient, W/(m³·K)	2,512.5	
Surface coefficient	17.448	W/(m²·K)
Biot number	0.10905	
Number of transfer units	14.464	
Heat stored over the swing	209.66	MJ

Notes for this case

- Löf and Hawley (1948) correlation h_v = 650(G/D)^0.7 in W/(m³·K) with G in kg/(m²·s) and D in m. Bi below 0.1 means negligible gradients inside the pebbles; NTU above about 10 allows the simple infinite-NTU model.
- Bi exceeds 0.1: use the effective NTU with internal resistance (NTU_c).

Formula and method

$$h_v = 650\left(\frac{G}{D}\right)^{0.7}, \quad Bi = \frac{h(D/2)}{k_s}, \quad NTU = \frac{h_v A L}{\dot{m} c_p}$$

$$Q_{st} = (1-\varepsilon)\rho_s c_s A L \Delta T$$

Variables

L	Bed length in the flow direction	m
A	Bed cross-section	m²
V	Superficial air velocity	m/s

ρ_a	Air density	kg/m³
$c_{p,a}$	Air specific heat	J/(kg·K)
D	Equivalent pebble diameter	m
ε	Void fraction	-
ρ_s	Pebble density	kg/m³
c_s	Pebble specific heat	J/(kg·K)
k_s	Pebble conductivity	W/(m·K)
a	Pebble surface area per bed volume	m²/m³
ΔT	Temperature swing of the bed	K
G	Air mass velocity	kg/(m²·s)
h_v	Volumetric heat transfer coefficient, W/(m³·K)	-
h	Surface coefficient	W/(m²·K)
Bi	Biot number	-
NTU	Number of transfer units	-
Q_{st}	Heat stored over the swing	J

Method and standards

Packed-bed heat transfer and storage.

Assumptions and limits

- Randomly packed rocks; Löf–Hawley range of sizes.

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/environmental/solar-thermal/pebble-bed-storage-ntu

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Reopens the calculator with the inputs of this report.