CFB Furnace Voidage Profile and Solids Inventory

Exit voidage, mean upper-furnace voidage and solids inventory of a CFB furnace from dense and dilute voidages and the decay constant (Basu Eqs. 2.17–2.20).

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

Input parameters

Unit system: SI

Parameter	Value	Unit
Furnace cross-section	50.000	m²
Furnace height	30.000	m
Height of the inflexion (secondary air level)	5.0000	m
Dense-bed voidage below h_i	85.000	%
Dilute asymptotic voidage	99.500	%
Decay constant	0.50000	1/m
Particle density	2,500.0	kg/m³

Calculated results

Parameter	Value	Unit
Voidage at the furnace exit	99.500	%
Mean voidage above h_i	98.340	%
Solids inventory	145.62	t
Mean suspension density above h_i	41.500	kg/m³

Notes for this case

- Mean upper voidage is the exact average of the exponential profile between h_i and H. The decay constant is per metre of height in every unit system.
- The mean suspension density above h_i is above about 30 kg/m³, the top of the usual upper-furnace range: check the decay constant and the voidages.

Formula and method

$$\varepsilon_e = \varepsilon_d - (\varepsilon_d - \varepsilon_a)e^{-a(H-h_i)}, \quad \bar{\varepsilon}_s = \varepsilon_d - \frac{(\varepsilon_d - \varepsilon_a)(1 - e^{-a(H-h_i)})}{a(H-h_i)}$$

$$W = A\rho_p[h_i(1-\varepsilon_a) + (H-h_i)(1-\bar{\varepsilon}_s)], \quad \rho_{susp} = \rho_p(1-\bar{\varepsilon}_s)$$

Variables

A	Furnace cross-section	m²
H	Furnace height	m
h_i	Height of the inflexion (secondary air level)	m
ε_a	Dense-bed voidage below h_i	-
ε_d	Dilute asymptotic voidage	-
a	Decay constant, per metre of height	1/m
ρ_p	Particle density	kg/m³
ε_e	Voidage at the furnace exit	-
ε_s	Mean voidage above h_i	-
W	Solids inventory	kg
ρ_{susp}	Mean suspension density above h_i	kg/m³

Method and standards

Basu's exponential voidage model, averaged analytically.

Assumptions and limits

- Uniform cross-section.
- The decay constant is entered per metre even when heights are shown in feet; convert a per-foot value by multiplying by 3.281.
- A note appears when the mean suspension density above h_i exceeds about 30 kg/m³.

References

• Basu
• Circulating Fluidized Bed Boilers: Design
• Operation and Maintenance (Springer, 2015)
• ch. 2
• Eqs. (2.17) to (2.20) (exponential decay of voidage above the inflexion)

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/boilers-power-plant/fluidised-bed/fast-bed-voidage-inventory

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.