Fire Plume Smoke Production and Extract Rate (Zukoski, Heskestad)

Flame height and plume mass flow at a clear height above a fire, the smoke temperature rise and the volume a smoke extract system must remove.

Method: Axisymmetric fire plume correlations; Heskestad; ...

Input parameters

Unit system: SI

Parameter	Value	Unit
Total heat release rate	2.5000	MW
Convective fraction	70.000	%
Fire diameter	3.0000	m
Clear height above the fire base	6.0000	m
Ambient temperature	20.000	°C

Calculated results

Parameter	Value	Unit
Mean flame height	2.3133	m
Plume mass flow at the clear height	16.951	kg/s
Smoke temperature rise	102.73	K
Smoke volume flow to extract	19.010	m³/s

Notes for this case

• Heskestad flame height L_f = 0.235Q^(2/5) − 1.02D (Q in kW, m); Zukoski plume ṁ = 0.071Q_c^(1/3)z^(5/3) (kg/s, kW, m) above the flame. Smoke temperature rise ΔT = Q_c/(ṁc_p); extract volume = ṁ/ρ_s with ρ_s ≈ 353/T. Smoke production rises steeply with clear height, so keeping the layer high costs a lot of extract. Design fires and codes come from the user's fire engineering basis.

Formula and method

$$L_f = 0.235\dot{Q}^{2/5} - 1.02D, \quad \dot{m}_p = 0.071\dot{Q}_c^{1/3} z^{5/3}, \quad \Delta T_s = \frac{\dot{Q}_c}{\dot{m}_p c_p}$$

Variables

$\dot{Q}$	Total heat release rate	W
χ_c	Convective fraction	-
D	Fire diameter	m
z	Clear height above the fire base	m
T_0	Ambient temperature	K
L_f	Mean flame height	m
$\dot{m}_p$	Plume mass flow at the clear height	kg/s
ΔT_s	Smoke temperature rise	K
$\dot{V}_s$	Smoke volume flow to extract	m³/s

Method and standards

Smoke production.

Assumptions and limits

- Axisymmetric plume in quiescent air; above the mean flame height.

References

Axisymmetric fire plume correlations, Heskestad, Fire plumes, flame height and air entrainment, in SFPE Handbook of Fire Protection Engineering (method)

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/hvac/ducts/smoke-plume-mass-flow

Open this case on calc.firecad.com →

Reopens the calculator with the inputs of this report.