

Calculations for Mechanical Smoke Exhaust at Canal Street Hotel

Ambient temperature	76.0°
New ceiling height of cover	60 ft
Bottom height of smoke	45 ft
Convective fraction	0.7
Height of top of fuel (ground)	0 ft
Heat release rate	2000 Btu/s
Wall heat transfer fraction	0.4

Smoke layer depth is 60-45 = 15ft (this is 21% of atrium ceiling above fuel source)

$$Q_c = x_c Q = 0.7 (2000) = 1400 \text{ Btu/s}$$

$$z_1 = 0.533 Q_c^{2/5} = 0.533 (1400)^{0.4} = 9.7 \text{ ft}$$

The smoke layer height z is 45 ft, since $z_1 < z$ the following formula applies:

$$m = 0.022 Q_c^{1/3} z^{5/3} + 0.0042 Q_c = 0.022 (1400^{.33}) (45^{5/3}) + 0.0042 (1400) = 146 \text{ lb/s}$$

$$T_s = T_0 + Q_c (1 - \Omega) / (m C_p) = 76 + 1400 (1 - 0.4) / (146 (0.24)) = 100.0 \text{ °F}$$

$$\rho_s = (0.075)(530) / (T_s) = (0.075)(530) / (100.0 + 460) = 0.0710 \text{ lb/ft}^3$$

$$V = 60m / \rho_p = (60) (146) / 0.0710 = 123,380 \text{ cfm}$$

Q_c = convective heat release rate of fire Btu/s

x_c = convective fraction of heat release

Q = total heat release rate, Btu/s

z = height of smoke layer

z_1 = mean flame height, ft

m = mass flow of exhaust air, lb/s

T_s = absolute temperature of exhaust gases, °R(Kelvin)

T_0 = ambient temperature, °F

Ω = wall heat transfer fraction

C_p = specific heat of plume gases, Btu/lb °F

ρ_s = density of exhaust gases, lbm/ft³

V = volumetric flow of exhaust gases, cfm