AtriumCalc

Version 1.0

Atrium Smoke Control Calculator

AtriumCalc consists of a number of routines that are commonly used for analysis of atrium smoke control systems. For AtriumCalc, the term atrium is used in a generic sense to mean any large-volume space.

More Information About AtriumCalc

Frequently Asked Questions

Enter Project Title: Atrium in Our Favorite Building, 10 Main Street, Kloteville, NY

I-P Units

1: Smoke Exhaust w/ Axisymmetric Plume

2: Smoke Exhaust w/ Balcony Spill Plume

3: Smoke Exhaust w/ Window Plume

4: Preventing Plugholing

5: Airflow to Control Smoke

SI Units

1: Smoke Exhaust w/ Axisymmetric Plume

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5: Airflow to Control Smoke

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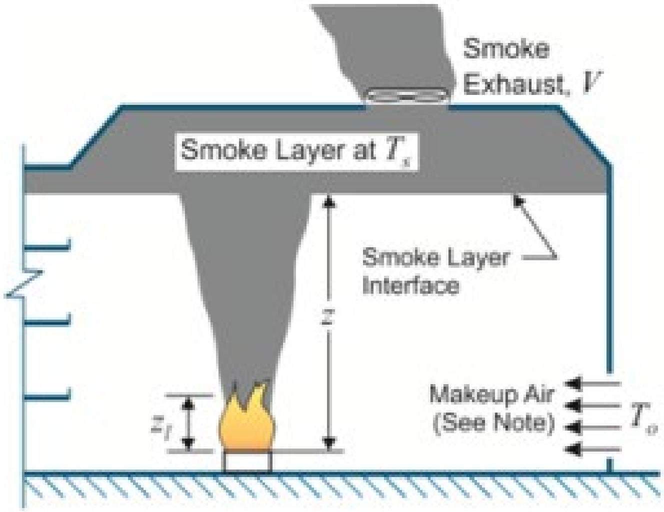
Project: Atrium in Our Favorite Building, 10 Main Street, Kloteville, NY

Routine 1: Atrium Smoke Exhaust with an Axisymmetric Plume



Notes:
1. Makeup air is shown as being supplied by an opening or openings to the outside, but it can also be supplied by mechanical fans.
2. For calculating the volumetric flow rate of smoke exhaust, a value of K_s = 1.0 needs to be used except when another value of K_s is supported by test data or an engineering analysis.
3. For smoke control design, a value of χ = 0.7 is almost always used, and other values should be supported by engineering data.

$$Q_c = \chi Q$$

$$z_l = 0.533 Q_c^{2/5}$$

$$m = 0.022 Q_c^{1/3} z^{5/3} + 0.0042 Q_c \quad \text{for } z > z_l$$

$$m = 0.0208 Q_c^{3/5} z \quad \text{for } z \le z_l$$

$$T_s = T_o + \frac{K_s Q_c}{m C_p}$$

$$\rho_s = \frac{144 p_{atm}}{R(T_s + 460)}$$

$$V = 60 m / \rho_s$$

where

C_p = specific heat (0.24 Btu/lb-°F).

Q = heat release rate of the fire (Btu/s).

Q_c = convective portion of heat release rate of fire (Btu/s).

z = distance from base of fire to smoke layer interface, (ft).

z_l = limiting elevation (ft).

m = exhaust mass flow (lb/s).

R = gas constant (53.34 ft lbf/lbm/°R).

T_s = smoke layer temperature (°F).

T_o = ambient or outdoor temperature (°F).

K_s = fraction of convective HRR in smoke layer.

ρ_s = smoke density (kg/m^3).

p_{atm} = atmospheric pressure (psi).

V = volumetric flow of smoke exhaust (cfm).

χ = convective fraction (dimensionless).

Input:				**Output:**		
	Q =	3,500	Btu/s		Q_c =	2,450 Btu/s
	z =	40.00	ft		z_l =	12.09 ft
	T_o =	92.0	°F		m =	149.0 lb/s
	p_{atm} =	14.70	psi		T_s =	160.5 °F
	K_s =	1.0	(See note 2 above)		ρ_s =	0.06396 lb/ft^3
	χ =	0.70	(Almost always 0.70)		V =	139,822 cfm

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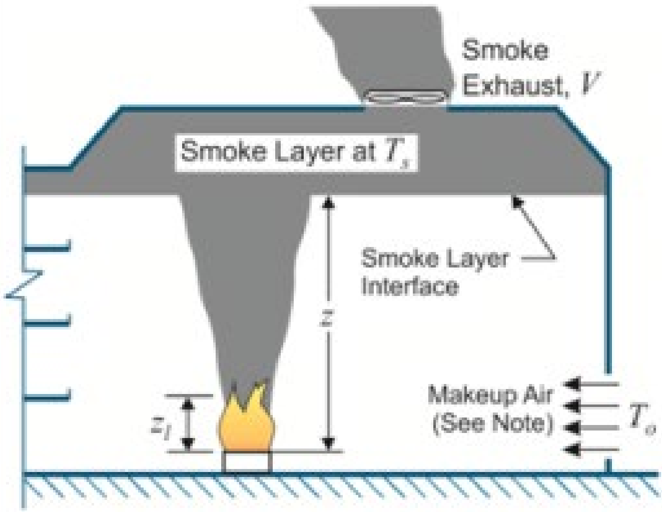
Routine 1: Atrium Smoke Exhaust with an Axisymmetric Plume



Notes:
1. Makeup air is shown as being supplied by an opening or openings to the outside, but it can also be supplied by mechanical fans.
2. For calculating the volumetric flow rate of smoke exhaust, a value of K_s = 1.0 needs to be used except when another value of K_s is supported by test data or an engineering analysis.
3. For smoke control design, a value of χ = 0.7 is almost always used, and other values should be supported by engineering data.

$$Q_c = \chi\, Q$$

$$z_l = 0.166 Q_c^{2/5}$$

$$m = 0.071 Q_c^{1/3} z^{5/3} + 0.0018 Q_c \quad \text{for } z > z_l$$

$$m = 0.032 Q_c^{3/5} z \quad \text{for } z \le z_l$$

$$T_s = T_o + \frac{K_s Q_c}{m C_p}$$

$$\rho_s = \frac{p_{atm}}{R(T_s + 273)}$$

$$V = m / \rho_s$$

where

C_p = specific heat (1.0 kJ/kg-°C).

Q = heat release rate of the fire (kW).

Q_c = convective portion of heat release rate of fire (kW).

z = distance from base of fire to smoke layer interface, (m).

z_l = limiting elevation (m).

m = exhaust mass flow (kg/s).

R = gas constant (287 J/kg K).

T_s = smoke layer temperature (°C).

T_o = ambient or outdoor temperature (°C).

K_s = 1 for steady smoke exhaust.

ρ_s = smoke density (kg/m^3).

p_{atm} = atmospheric pressure (Pa).

V = volumetric flow of smoke exhaust (m^3/s).

χ = convective fraction (dimensionless).

Input:

Q =	4,000	kW
z =	12.00	m
T_o =	30.0	°C
p_{atm} =	101,300	Pa
K_s =	1.0	(See note 2 above)
χ =	0.70	(Almost always 0.70)

Output:

Q_c =	2,800	kW
z_l =	3.97	m
m =	67.98	kg/s
T_s =	71.2	°C
ρ_s =	1.025	kg/m^3
V =	66.3	m^3/s

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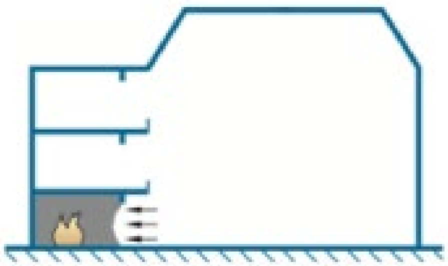
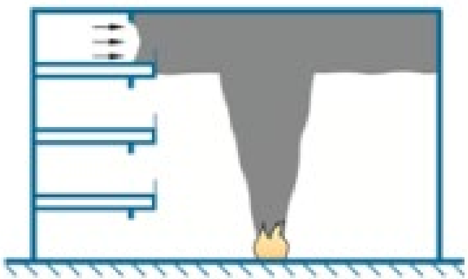
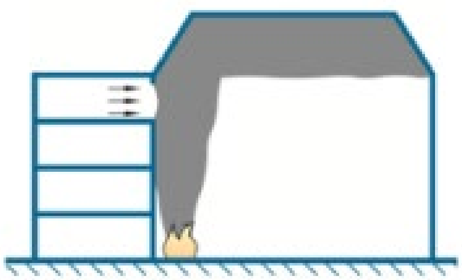
Airflow to Control Smoke



Airflow to a Communicating Space



Airflow to the Smoke Layer



Airflow to the Plume

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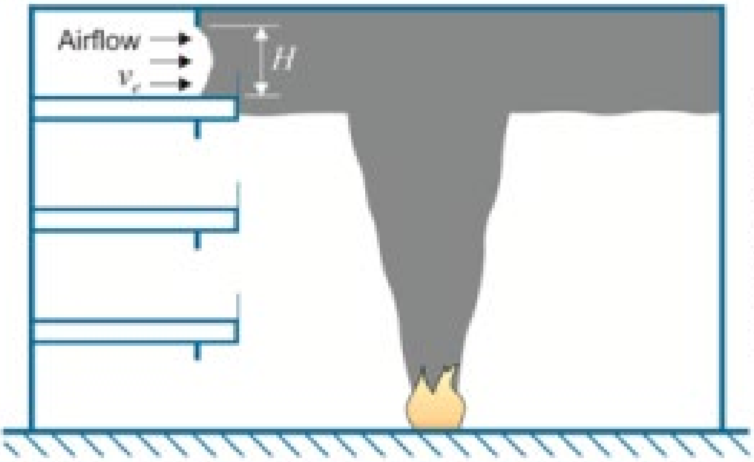
Routine 5B: Airflow to Control Smoke Flow from the Smoke Layer



Notes:
1. Air supply to the communicating space is not shown.
2. The smoke exhaust from the atrium and the makeup air to the atrium are not shown.
3. Airflow is not to be used to control smoke flow when the calculated value of v_e is greater than 200 fpm.

$$v_e = 38\left(gH\frac{T_f - T_o}{T_f}\right)^{1/2}$$

where

A	= area of opening (ft^2).
g	= acceleration of gravity (32.2 ft/s^2).
H	= height of opening (ft).
T_f	= temperature of smoke (°R).
T_o	= ambient temperature (°R).
V	= volumetric rate of airflow ($V = v_e A$) (cfm).
v_e	= limiting average air velocity (fpm).

Note: The temperatures, T_f and T_o, can be determined from routine 1, 2 or 3.

Input:			**Output:**	
H =	8.00	ft	v_e =	157.5 fpm
T_o =	72.0	°F	V =	7,875 cfm
T_f =	110.0	°F		
A =	50.0	ft^2		

Note: The limiting average air velocity does not the exceed the upper limit of 200 fpm.

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