

Safety Guideline for Indoor Airborne Transmission of COVID-19

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History: 6-4-2020 (v1), 7-1-2020 (v2), 8-16-2020 (v3) posted on medRxiv 9-1-20, 9-16-2020 (v4),

This version: 11-1-2020 (v5)

For instructions, references and updates, please visit <http://www.mit.edu/~bazant/COVID-19>

Reference: Martin Z. Bazant and John W. M. Bush, medRxiv preprint (2020)

"Beyond Six Feet: A Guideline to Limit Indoor Airborne Transmission of COVID-19"

<https://www.medrxiv.org/content/10.1101/2020.08.26.20182824v1>

Calculated for Max conditions during current theater classes at HATTheatre

Input values in the pink cells.

(Fans operating at 500 ACFM)

12/01/20

Physical Parameters

Floor area, A	775 ft ²	72 m ²	Customer Spaces
Mean ceiling height, H	8.6 ft	2.62128 m	Average
Room volume, V	6665 ft ³	188.732 m ³	Customer Spaces
Outdoor air exchange rate, λ_a	0.1 /hr (ACH)		
Ventilation (outdoor air) flow rate, Q	100 ft ³ /min	18.8732 m ³ /hr	
Recirculation air exchange rate, λ_r	50 /hr (ACH)	(includes HVAC & air filtration units)	Fans @ 500 ACFM
Recirculation (return) flow rate, Q_r	5554.2 ft ³ /min	9436.59 m ³ /hr	
Primary (total) air flow rate, $Q+Q_r$	5654.2 ft ³ /min	9606.49 m ³ /hr	
Primary outdoor air fraction, Z_p	0.0177 (=1.0 natural ventilation, or no recirculation)		
Aerosol filtration efficiency, p_f	0.9 (>0.9997 HEPA, =0.2-0.9 MERVs, =0 no filter)		MERV 6 + MERV 13
Air filtration rate, λ_f	45 /hr		Effective Rate
Relative humidity, RH	45 %		

Physiological Parameters

Mean breathing flow rate, Q_b	1.5 ft ³ /min	0.5 m ³ /hr (=0.5 rest, =1-3 active)	Loud Speaking
Respiratory aerosol radius, r	2 μm	(depends weakly on activity, disease)	Conservative Est.
Humidity-adjusted radius	1.7986 μm		

Disease Parameters

Infectiousness of exhaled air, C_q	150 infection quanta/m ³	(depends on activity, Fig. 2)
Viral deactivation rate, λ_v @ 50% RH	0.3 /hr	3.33333 hour deactivation time
Humidity-adjusted deactivation rate	0.27 /hr	(assume linear in RH) (can increase with UV and chemical disinfectants)

Infectious Aerosol Properties

Effective settling speed, $v_s(r)$	0.3882 mm/sec	1.39747 m/hr.
Concentration relaxation rate, λ_c	45.903 /hr	0.02179 hour relaxation time
Dilution factor, f_d	6E-005 infectiousness of ambient air / exhaled breath	
Infectiousness of room air, $f_d C_q$	0.0087 infection quanta/m ³ in steady state	

Precautionary Parameters

Mask aerosol passage probability, p_m	0.1 (=1 no masks, 0.05-0.5 fabric, <0.05 surgical mask)	Medical Masks
Airborne transmission rate, β_a	4E-005 /hr	(per pair of persons in steady state)
Risk tolerance, ϵ	0.05 (bound on R_{in} , expected transmissions per infector)	Conservative

Safe Room Occupancy

Exposure time, τ	8 hours	(net before testing/removal/recovery)	Max Estimated
Maximum safe occupancy, N_{max}	145 persons	(with transient aerosol buildup)	
	145 persons	(steady state aerosol concentration)	
6 FOOT RULE (CDC)	21 persons		
1 METER RULE (WHO)	71 persons		
Maximum occupancy for outdoor air	20 persons		
Minimum outdoor airflow / person	5 ft ³ /min	2.35974 L/s	Estimated Act OA

Safe Exposure Time

Room occupancy, N 20 persons

Max Estimated

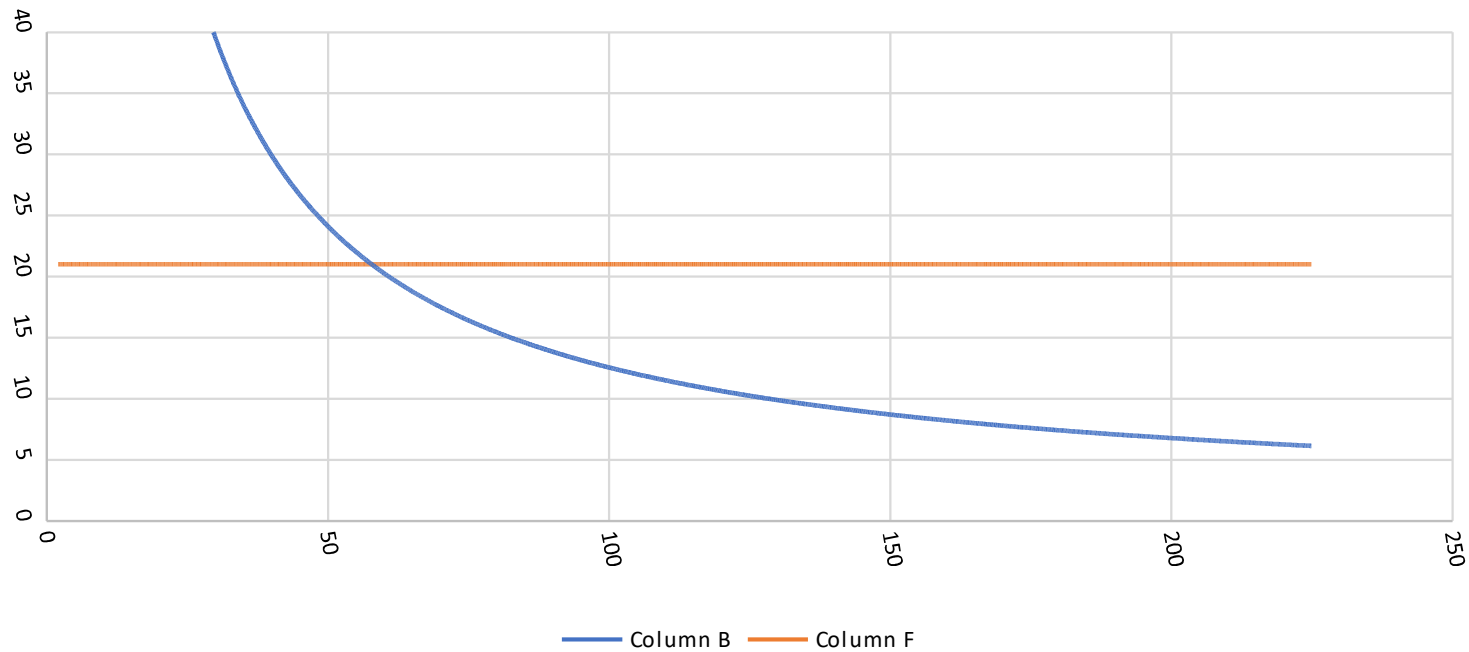
Maximum exposure time, τ_{max} **60.817 hours**

3649 minutes (transient)

60.796 hours

3647.74 minutes (steady state)

COVID-19 Indoor Safety Guideline:
Maximum occupancy vs time (hours)



<https://www.usatoday.com/story/news/factcheck/2020/06/11/fact-check-n-95-filters-not-too-large-stop-covid-19-particles/5343537002/>