Optimising Ventilation for Infection Prevention & Control in Healthcare Settings

SUCCESSION, SUSTAINABILITY, AND THE ADVANCEMENT OF INFECTION PREVENTION AND CONTROL

ACIPC
Australasian College for Infection Prevention and Control

ACIPC INTERNATIONAL CONFERENCE

17–20 NOV 2024

MELBOURNE CONVENTION AND EXHIBITION CENTRE, VIC & ONLINE

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AIRAH

ASHRAE

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Research to Practice, Offering Practical Evidence-Based Solutions

PREZANT ENVIRONMENTAL

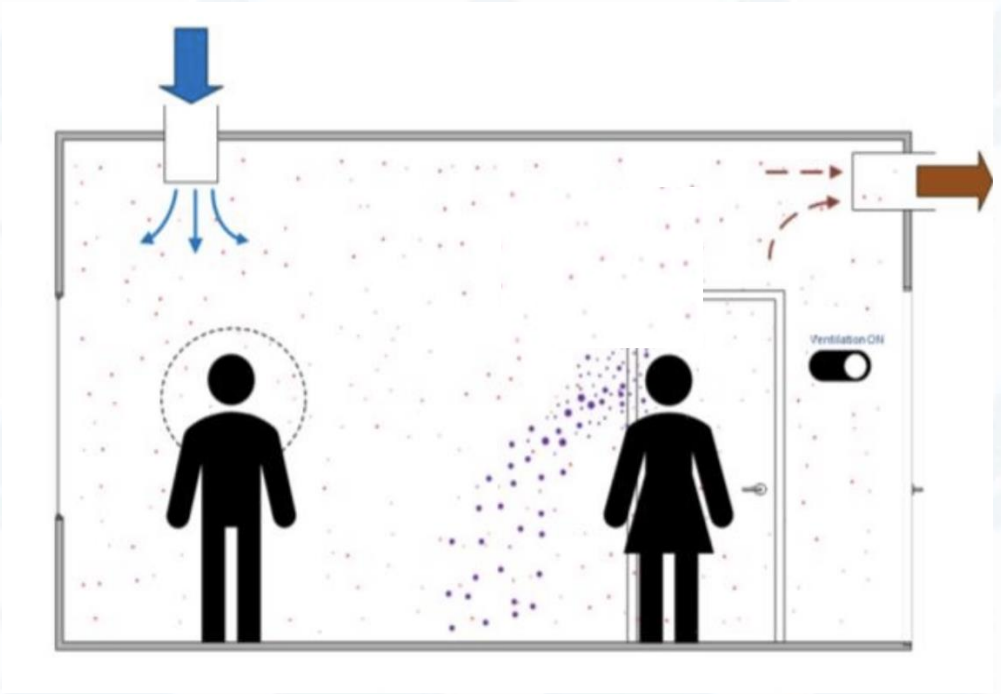
Ventilation Considerations for Infection Control in Health Care

1. Ventilation Can & Does Impact Airborne Transmission of Disease

2. Control airflow by managing and monitoring differential pressure

3. Outdoor ventilation can dilute or remove infective aerosols…but…

4. ASHRAE offers a structured approach with ASHRAE 241-2023 including health care

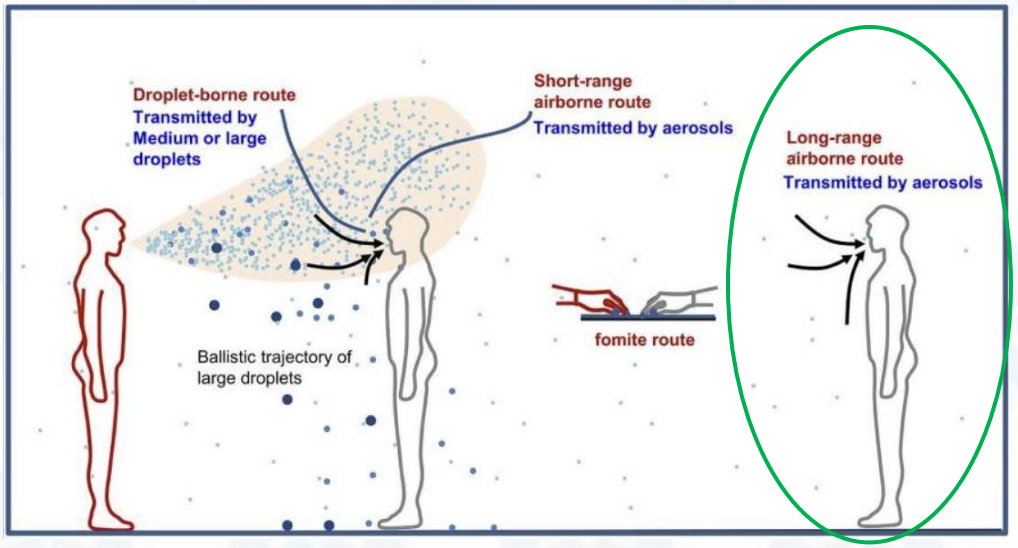


PREZANT ENVIRONMENTAL

Ventilation Considerations for Infection Control in Health Care

1 Ventilation Can & Does Impact Airborne Transmission of Disease

Movement of Air Carries Infective and Non-Infective Inhalable Particulate



Aspergillus sp. spores
Respiratory fluid particles

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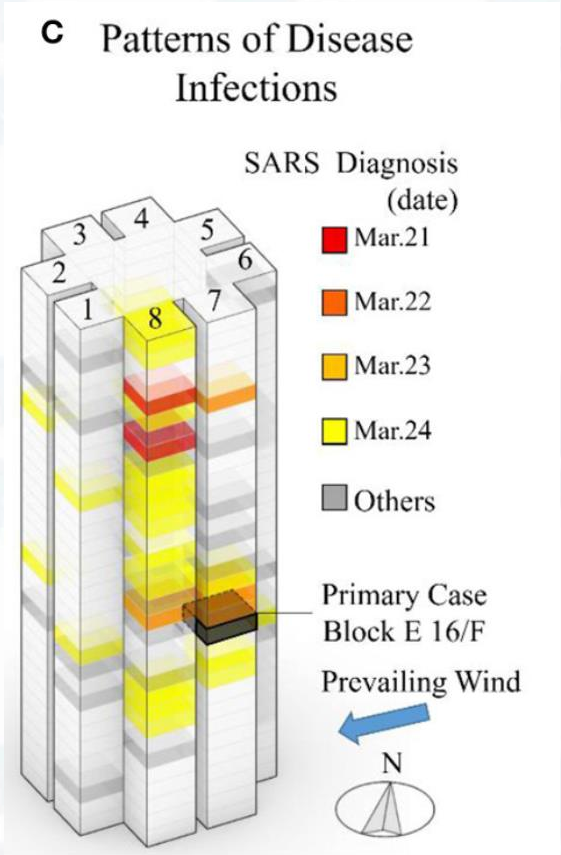

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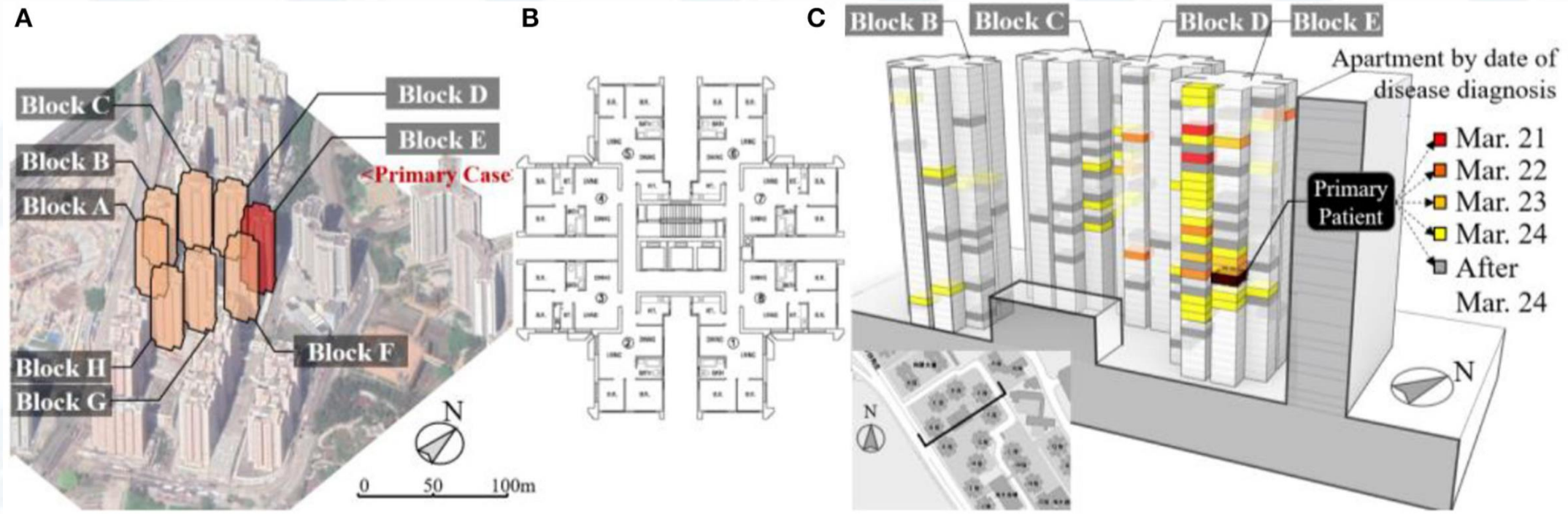

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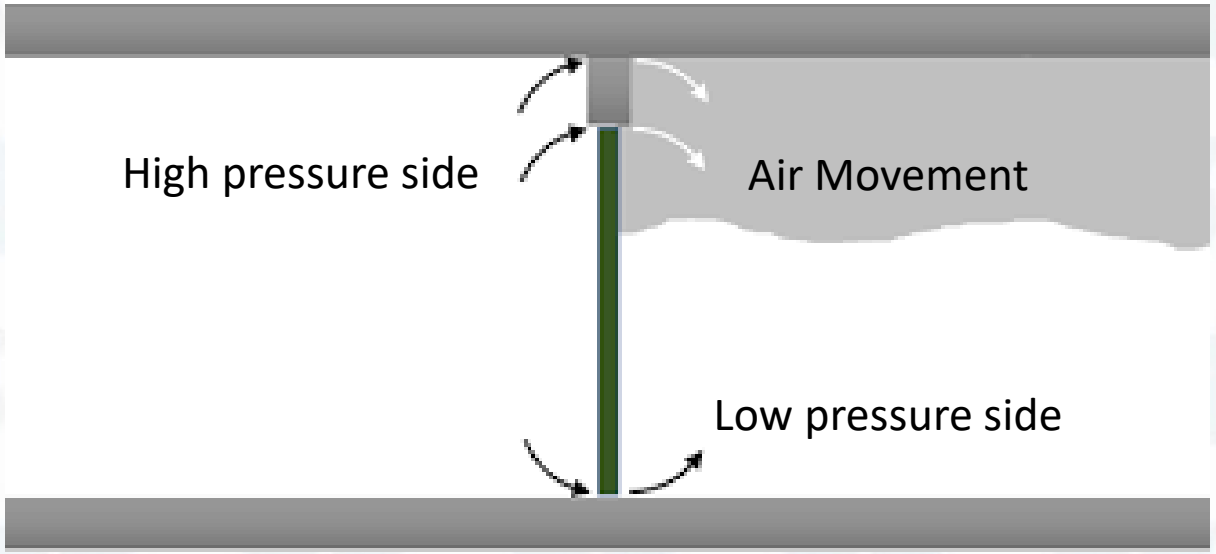

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Pressure Management During Construction Works in Health Care

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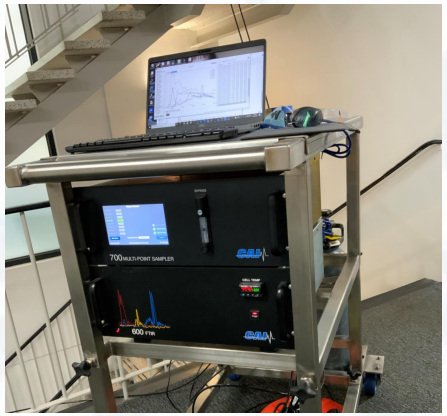
Three QC Technologies for Monitoring/Verifying Pressure During Works

1. Differential Pressure Monitoring (continuous, 24/7 during activity)

2. Particulate Monitoring (continuous, 24/7 during activity)

3. Tracer Testing to Determine Isolation and Measure ACH



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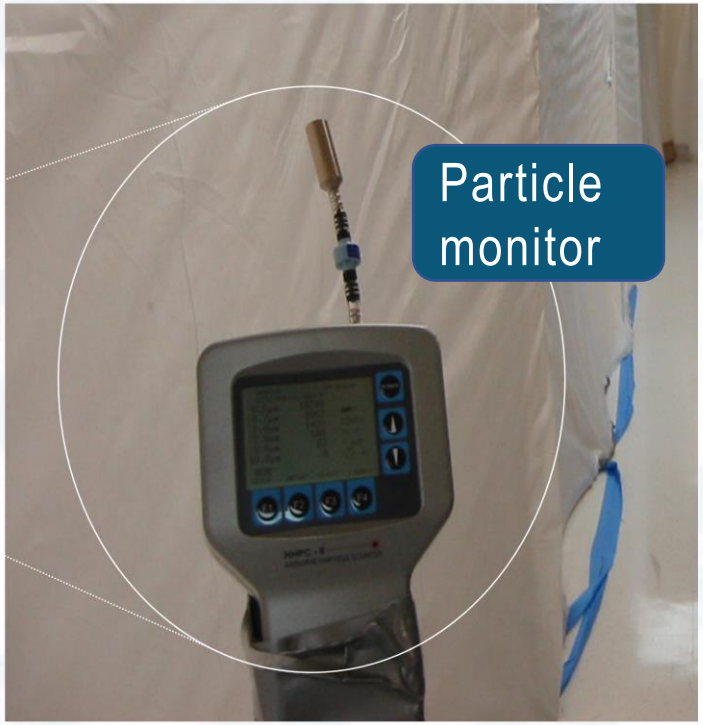
Verifying Integrity of Isolation & Pressurization

Micromanometer

Differential Pressure monitor

Soft wall



Particle monitor

Hard wall

Active Operating Room with Expansion; 24/7 pressure monitoring; 24/7 particle monitoring & *verified maintenance of pressurization*

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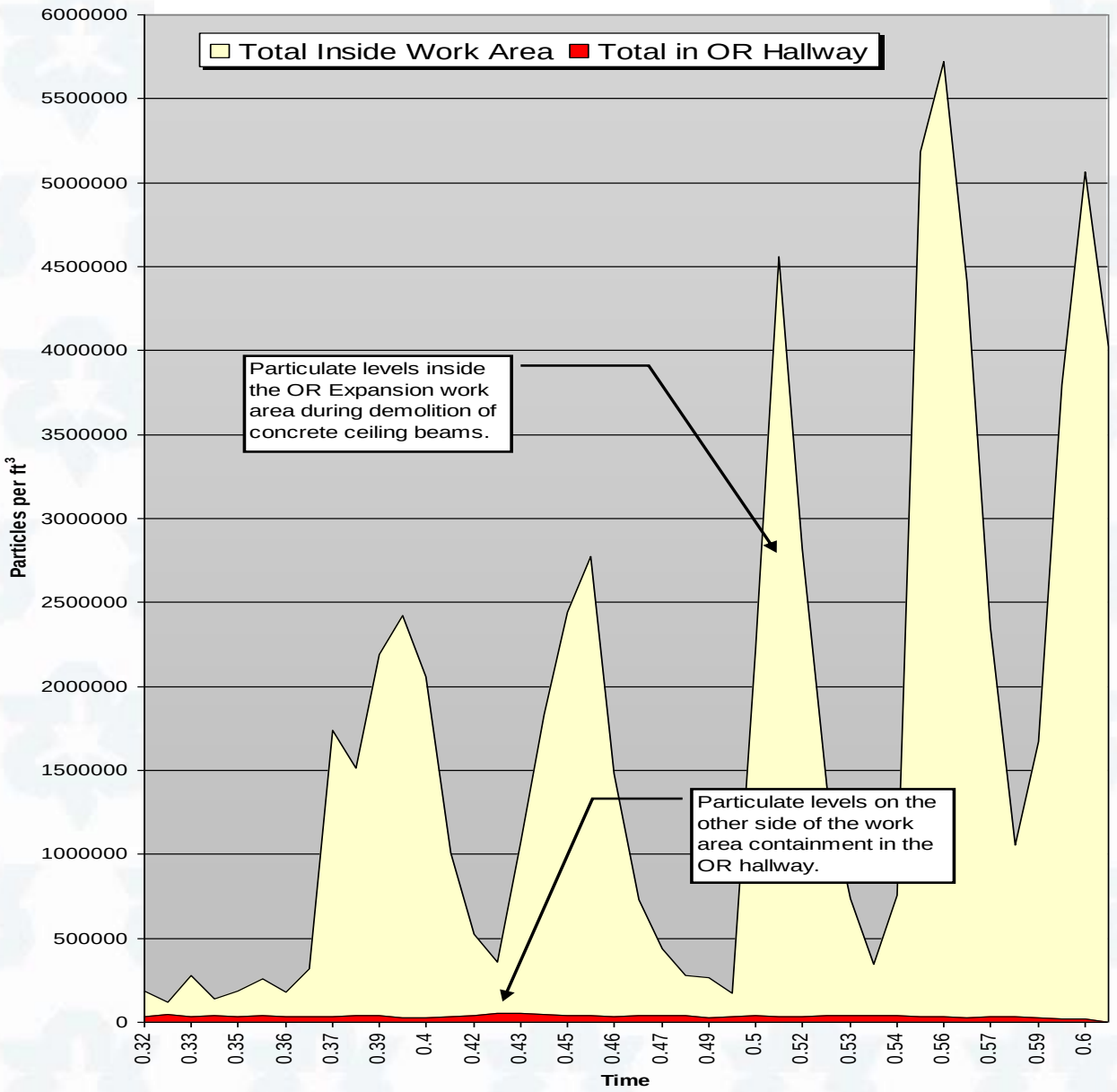
Particle Monitoring

Critical immediate feedback is provided by real-time particle monitoring – isolate and verify



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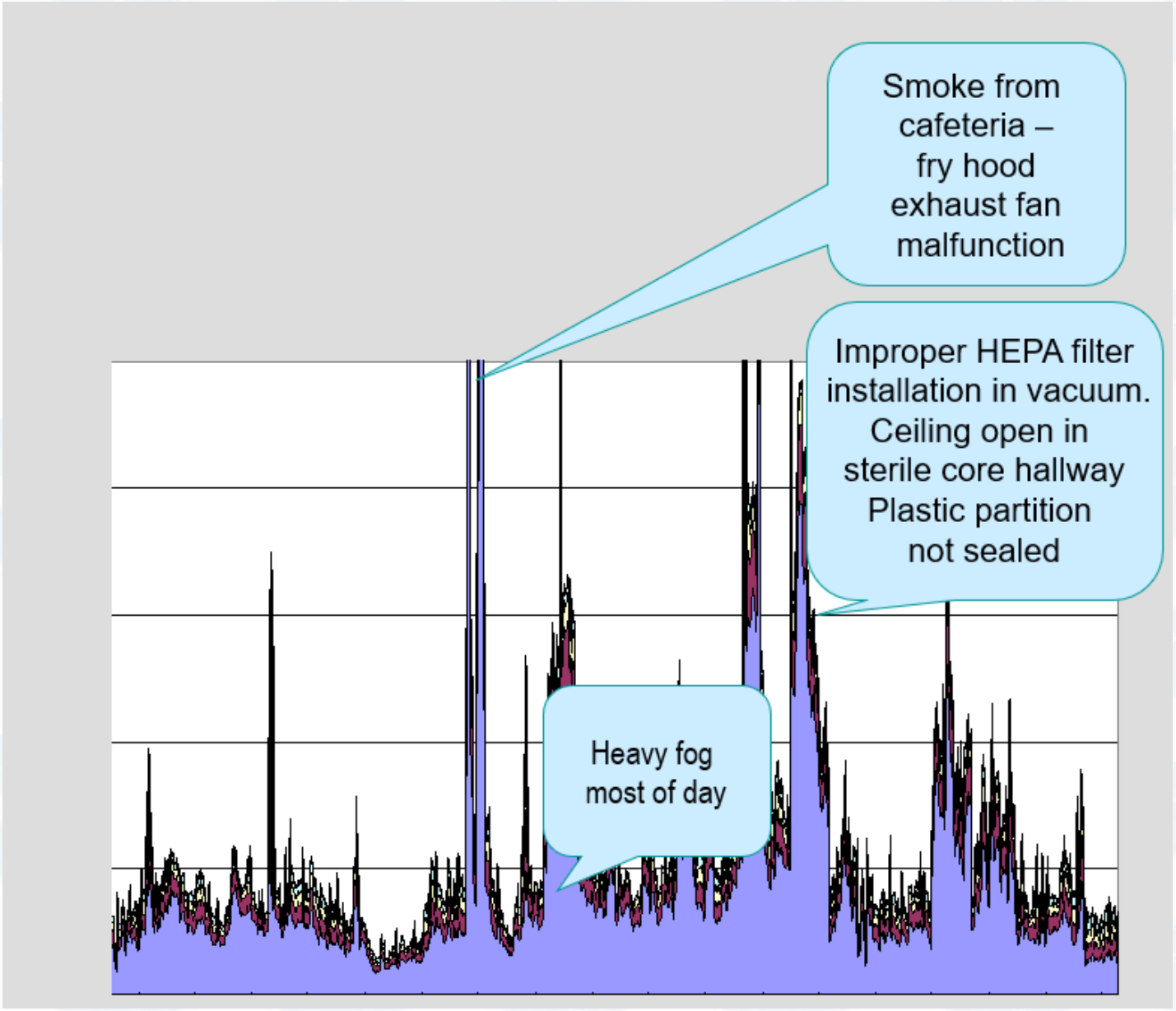

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Particle Monitoring

Critical immediate feedback is provided by real-time particle monitoring – isolate and verify

Filtered discharge is verified to be free of particulate

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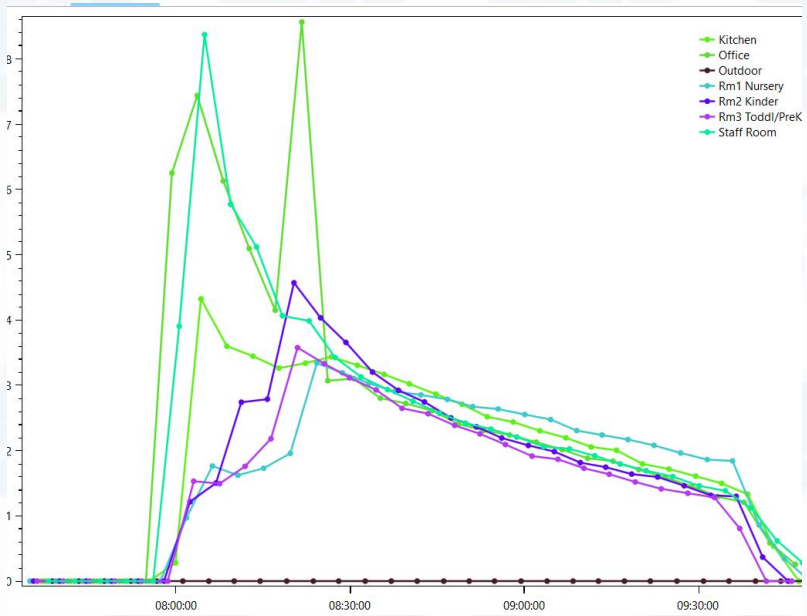
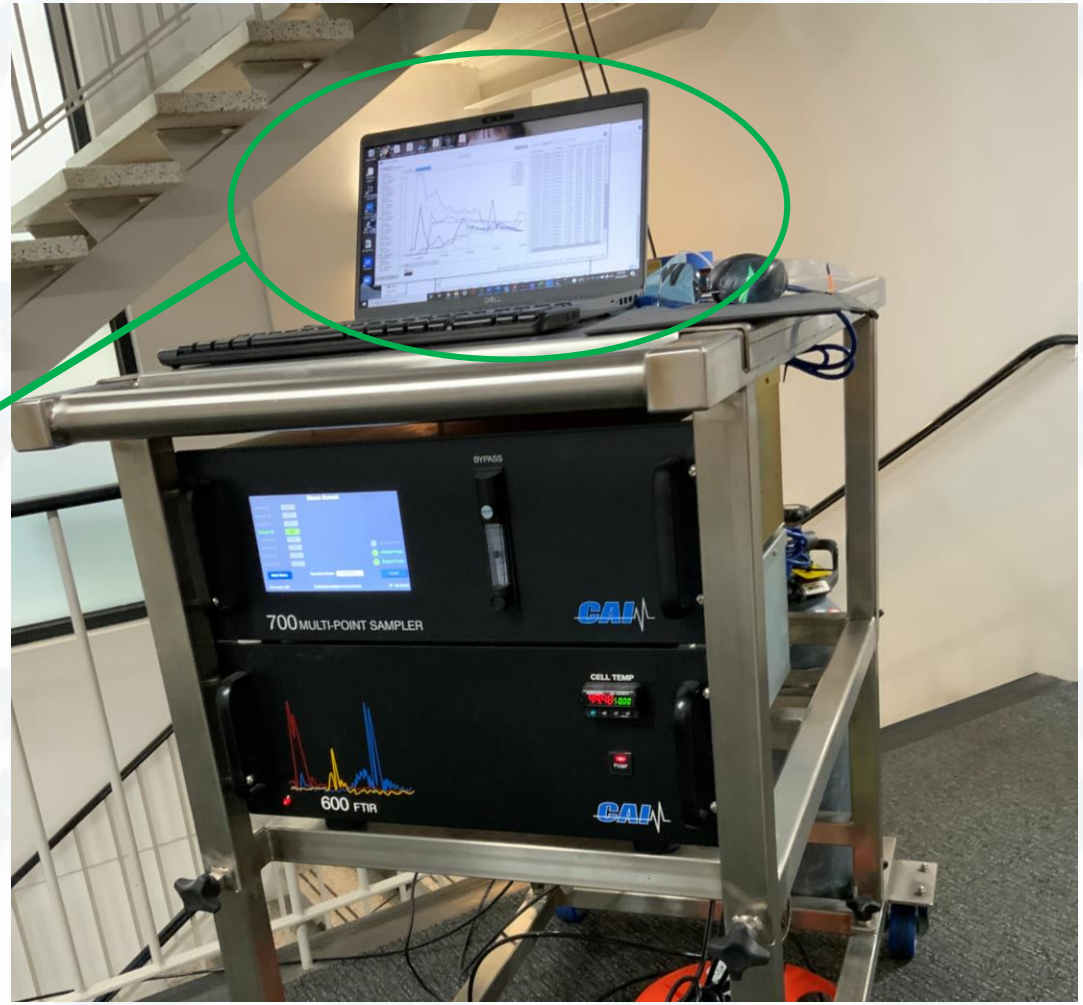
Tracer Testing for Verifying Isolation

Using SF_6 as a tracer gas, isolation can be verified with a true *performance* test

tracer gas testing can also verify ACH





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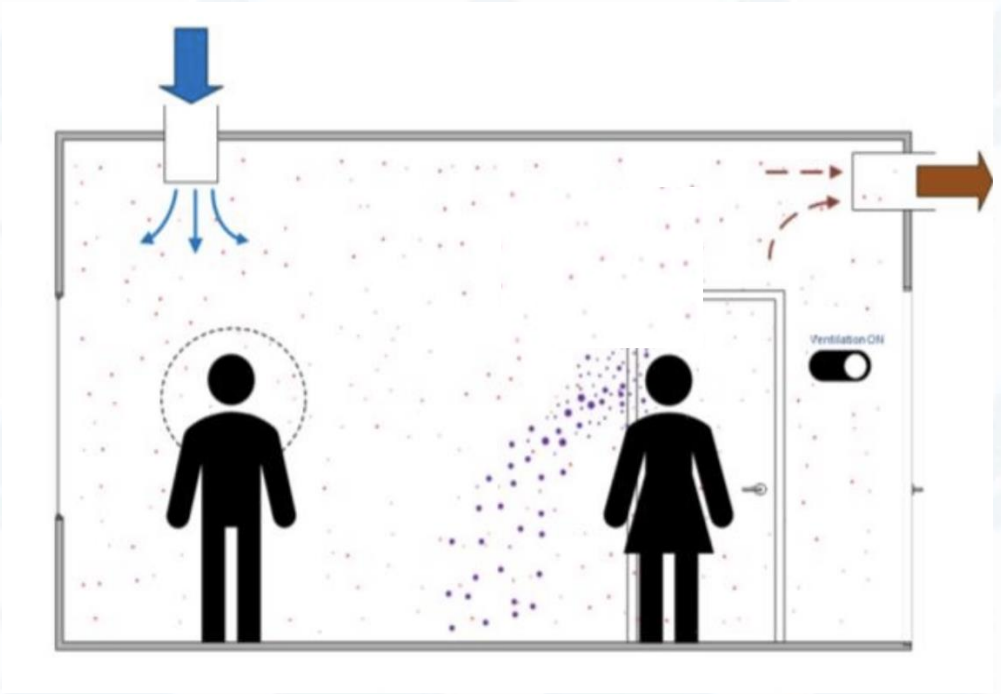

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Run Your System at 100% Outdoor Air

"Increasing the amount of outdoor air the system delivers can further dilute particle concentration and transmission risks."

ASHRAE Journal October 2021 Mitigating COVID-19 in Public Spaces

"Increase the introduction of outdoor air: Open outdoor air dampers beyond minimum settings to reduce or eliminate HVAC air recirculation."

U.S. CDC Ventilation in Buildings June 2021

"It is also recommended that 100% fresh air should be supplied with HEPA or UVGI filters installed in the passenger's breathing area.."

Elsaid, A., M., A Critical Review of heating, ventilation, and air conditioning (HVAC) systems within the context of a global SARS-CoV-2 epidemic, Process Safety & Environmental Protection, November 2021

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Current (Nov. 2023) Recommendations for Air Changes per Hour

"In standard hospital rooms, a minimum of 6 ACH is required. In negative-pressure isolation rooms, 12 ACH is required. Large volume spaces with very few occupants (e.g., a warehouse) may not require 5 ACH and spaces with high occupancy or higher-risk occupants may need higher than 5 ACH."

Victoria Department of Health, COVID-19 Infection Prevention and Control Guidelines, Ventilation, November 2024

Accessed: https://www.health.vic.gov.au/covid-19-infection-prevention-control-guidelines/ventilation#61-air-changes-per-hour-ach

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Current *Confusing* Recommendations for "Ventilation"

"DEFINITION

Ventilation

Ventilation is a term with different meanings to different people. For the purpose of this webpage, "ventilation" includes:

Indoor air movement and dilution of viral particles through mechanical or nonmechanical (also called natural) means.

Filtration through central heating, ventilation and air conditioning (HVAC) systems and/or in-room air cleaners (portable or permanently mounted).*

Air treatment with Ultraviolet Germicidal Irradiation (UVGI) systems (also called Germicidal Ultraviolet or GUV).*"

*** These air cleaning techniques are sometimes referred to as "equivalent ventilation."**

Updated May 12, 2023, Accessed: https://www.health.vic.gov.au/covid-19-infection-prevention-control-guidelines/ventilation#61-air-changes-per-hour-ach

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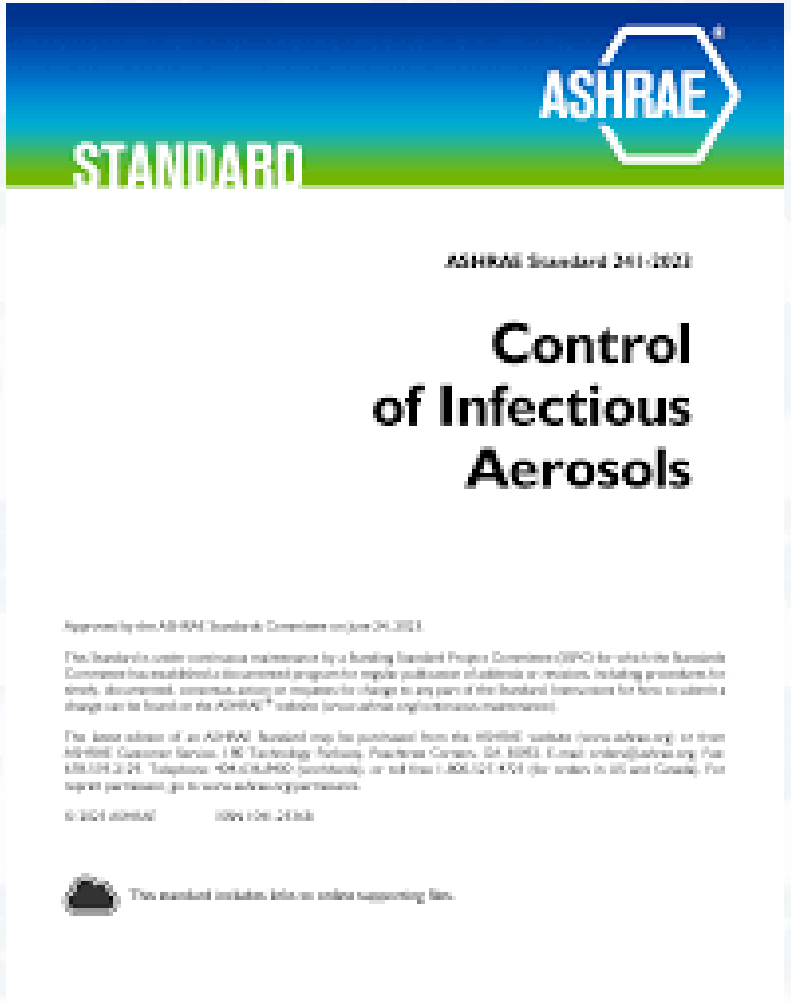
Should We Just Bring in More Outdoor Air to Manage Infection Risk?

1. Recommendations of high outdoor air flow rates conflict with sustainability goals
2. Not all HVAC systems can sustain high outdoor air flow rates
3. There is a new framework for making sense of these recommendations



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ASHRAE 241 Control of Infectious Aerosols – June 2023

GOAL

Establish minimum requirements (**equivalent clean airflow (V_{ECAi})** for control of infectious aerosols to reduce risk of disease transmission including requirements for both outdoor air system and air cleaning system design, installation, commissioning, O and M

ASHRAE 241 is a “switch” that can be turned on as needed

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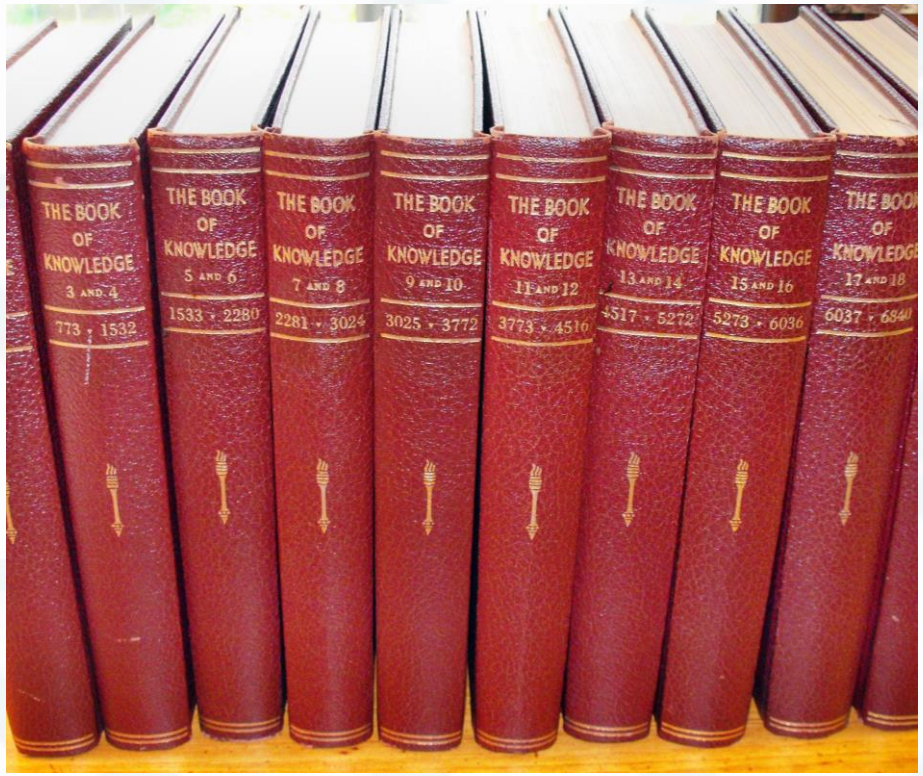
DEFINITIONS

Equivalent clean airflow (V_{ECAi})

the theoretical flow rate of pathogen-free air that, if distributed uniformly within the breathing zone, would have the same effect on infectious aerosol concentration as the sum of **actual outdoor airflow**, *filtered airflow*, and *inactivation of infectious aerosols*

Each of these is expressed in a common metric, ACH, and they can therefore be added together to get a $\mathbf{V_{ECAi}}$



PREZANT ENVIRONMENTAL

ASHRAE 241 Control of Infectious Aerosols – June 2023

GOAL

Establish minimum requirements (equivalent **clean** airflow) for control of infectious aerosols to reduce risk of disease transmission including requirements for both outdoor air system and air cleaning system design, installation, commissioning, O and M

New & Existing Buildings

Doesn't

- Maintain Acceptable Air Quality
- Work for all Infective Agents
- Only Addresses Long Range
- Determine When to Implement Proposed Control Strategies

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Definitions

Infection risk management mode (*IRMM*):
the mode of operation in which measures to reduce infectious aerosol exposure documented in a **building readiness plan** are active

Who determines when to invoke IRMM (turn on the switch)?

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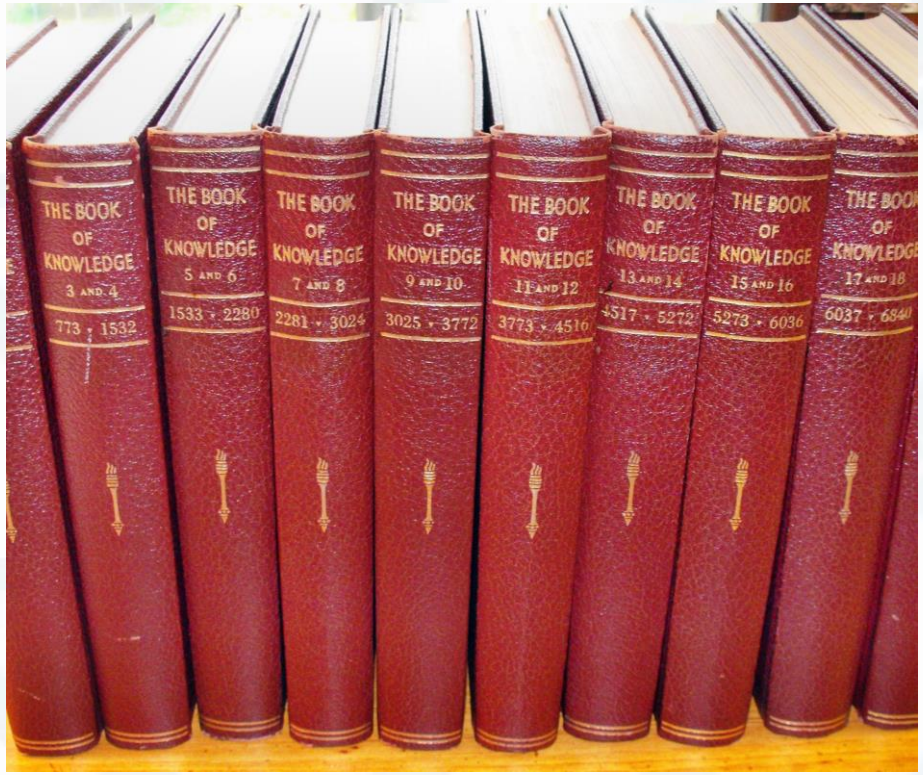
Definitions

Building readiness plan (BRP)

a plan documenting the engineering and non-engineering controls that the facility systems will use for the facility to achieve its goals.



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There are 2 important equations in ASHRAE 241
Equation 5-1 & Equation 6-1

$$V_{ECAi} = ECA_i \times P_{Z,IRMM}$$

Equation 5-1

$$\sum [z_f \times (V_{OT} + V_{MVS})] + \sum V_{ACS} + V_{NV} \geq V_{ECAi}$$

Equation 6-1

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Equation 6-1

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Equivalent Clean Airflow for Infection Risk Mitigation Equation 5-1

Minimum equivalent clean airflow rate required in the breathing zone for each occupiable space to mitigate long-range transmission risk in *IRMM* (V_{ECAi}) shall be determined in accordance with Equation 5-1.

Total flow to space in L/s (V_{ECAi}) = Per person table 5-1 value for the space (ECAi) x number of persons ($P_{Z,IRMM}$)

$$V_{ECAi} = ECA_i \times P_{Z,IRMM}$$

Equation 5-1

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TABLE 5-1 ASHRAE 241-2023

Table 5-1 Minimum Equivalent Clean Airflow per Person in Breathing Zone in IRMM

Occupancy Category	ECAi	
	cfm/person	L/s/person
Correctional Facilities		
Cell	30	15
Dayroom	40	20
Commercial/Retail		
Food and beverage facilities	60	30
Gym	80	40
Office	30	15
Retail	40	20
Transportation waiting	60	30
Educational Facilities		
Classroom	40	20
Lecture hall	50	25
Industrial		
Manufacturing	50	25
Sorting, packing, light assembly	20	10
Warehouse	20	10
Health Care		
Exam room	40	20
Group treatment area	70	35
Patient room	70	35
Resident room	50	25
Waiting room	90	45
Public Assembly/Sports and Entertainment		

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TABLE 5-1

Table 5-1 Minimum Equivalent Clean Airflow per Person in Breathing Zone in IRMM

Occupancy Category	ECAi cfm/person	ECAi L/s/person
Correctional Facilities		
Cell	30	15
Dayroom	40	20
Commercial/Retail		
Food and beverage facilities	60	30
Gym	80	40
Office	30	15
Retail	40	20
Transportation waiting	60	30
Educational Facilities		
Classroom	40	20
Lecture hall	50	25
Industrial		
Manufacturing	50	25
Sorting, packing, light assembly	20	10
Warehouse	20	10
Health Care		
Exam room	40	20
Group treatment area	70	35
Patient room	70	35
Resident room	50	25
Waiting room	90	45

$$V_{ECAi} = ECA_i \times P_{Z,IRMM}$$

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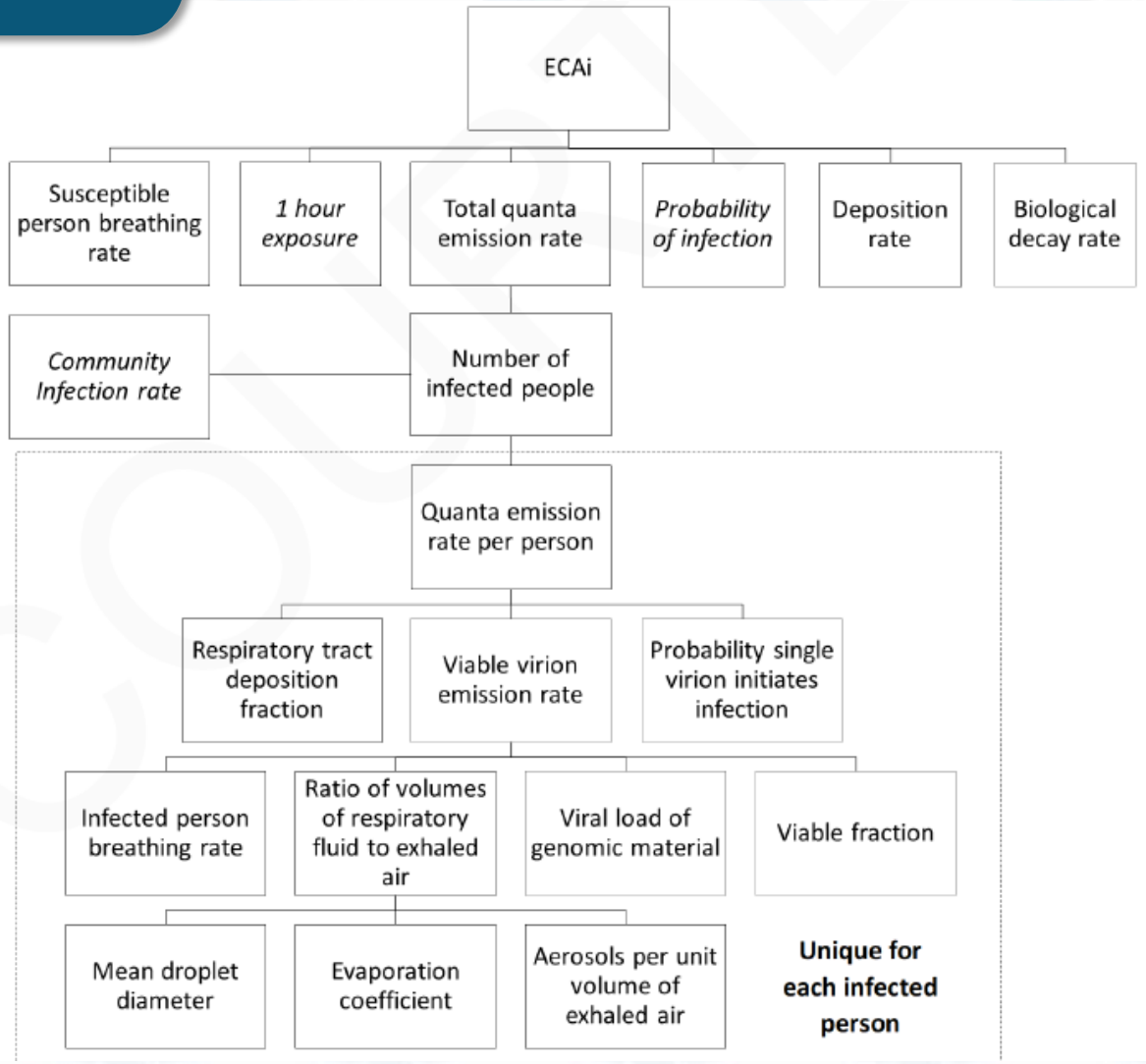
APPENDIX D – DERIVATION OF THE ECA_i

A range of possibilities (statistical distribution) was created for each of these 15-20 variables, then a Monte Carlo model was run with 10,000 random combinations of each criteria

Each of the 10,000 runs yielded an overall probability of infection



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APPENDIX D – DERIVATION OF THE ECA_i

If the airflow is adjusted to meet the requirements of Eq. 5-1, then the risk of infection will be less than 1% probability >95% of time

Eq. 5.1 $$V_{ECAi} = ECA_i \times P_{Z,IRMM}$$

the risk of infection was equalised across all occupancies for a one-hour period

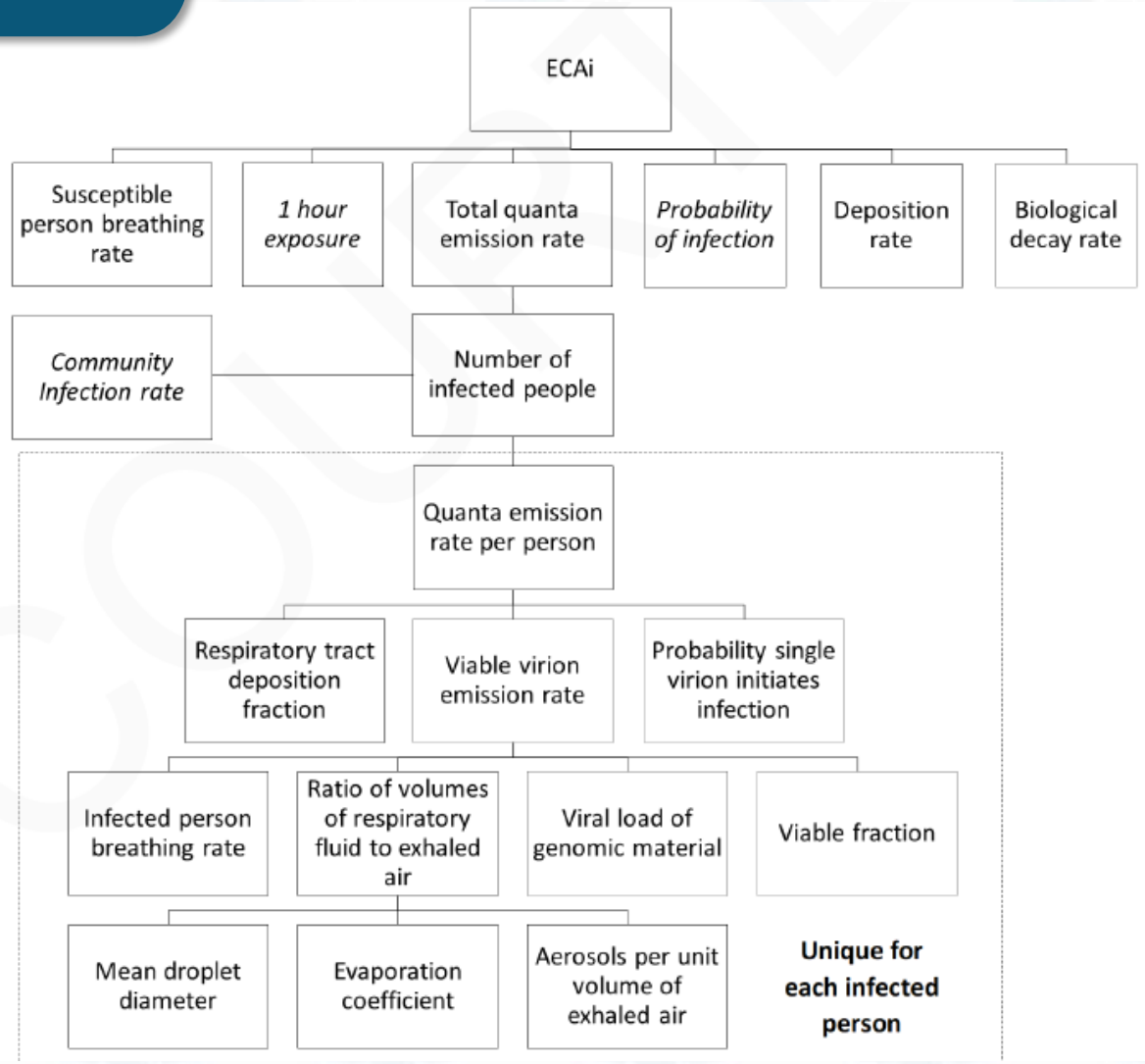

TABLE 5-1 (CONTINUED)

Default occupancy is based on persons per 100 m^2

Occupancy Category	ECAi	62.1
	L/s/person	occupancy
Correctional Facilities		
Cell	15	25
Dayroom	20	30
Commercial/Retail		
Food and Beverage Facilities	30	70
Gym	40	7-40
Office	15	5
Retail	20	15
Transportation Waiting	30	100
Educational Facilities		
Classroom	20	25-35
Lecture Hall	30	150

Default occupancy is based on persons per 100 m^2

Occupancy Category	ECAi	62.1
	L/s/person	occupancy
Industrial		
Manufacturing	25	7
Sorting, packing, light assembly	10	7
Warehouse	10	n/a
Healthcare		
Exam room	20	-
Group treatment area	35	-
Patient room	35	-
Resident room	25	-
Waiting room	45	-

Default occupancy is based on persons per 100 m^2

Occupancy Category	ECAi	62.1
	L/s/person	occupancy
Public Assembly/Sports & Entertainment		
Auditorium	25	150
Place of Religious Worship	25	120
Museum	30	40
Convention	30	
Spectator Area	25	150
Residential		
Common Space	5	n/a
Dwelling unit	15	1/bedroom

5.1.3 Where the occupancy category for a proposed space or zone involves group vocalization above a conversational level, the *equivalent clean airflow* rate required per person in *IRMM* shall be multiplied by a factor of 2.

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Table 5-1 versus AS1668.2-2012

Occupancy Description	AS1668.2 Outdoor Air L/s/person	ASHRAE 241 ECA_i L/s/person
Exam Room		20
Group Treatment Area		35
Patient room		35
Resident room		25
Waiting room		45
Cons. Rooms	10	
Waiting Areas	10	
Operating rooms	20	
Delivery rooms	20	
Patient rooms	10	
Phys. Therapy	10	

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EQUIVALENT CLEAN AIRFLOW FOR INFECTION RISK MITIGATION
Equation 6-1

$$\sum [z_f \times (V_{OT} + V_{MVS})] + \sum V_{ACS} + V_{NV} \geq V_{ECAi}$$ Equation 6-1

[Add up all the outdoor air + cleaning sources to exceed V_{ECAi}]

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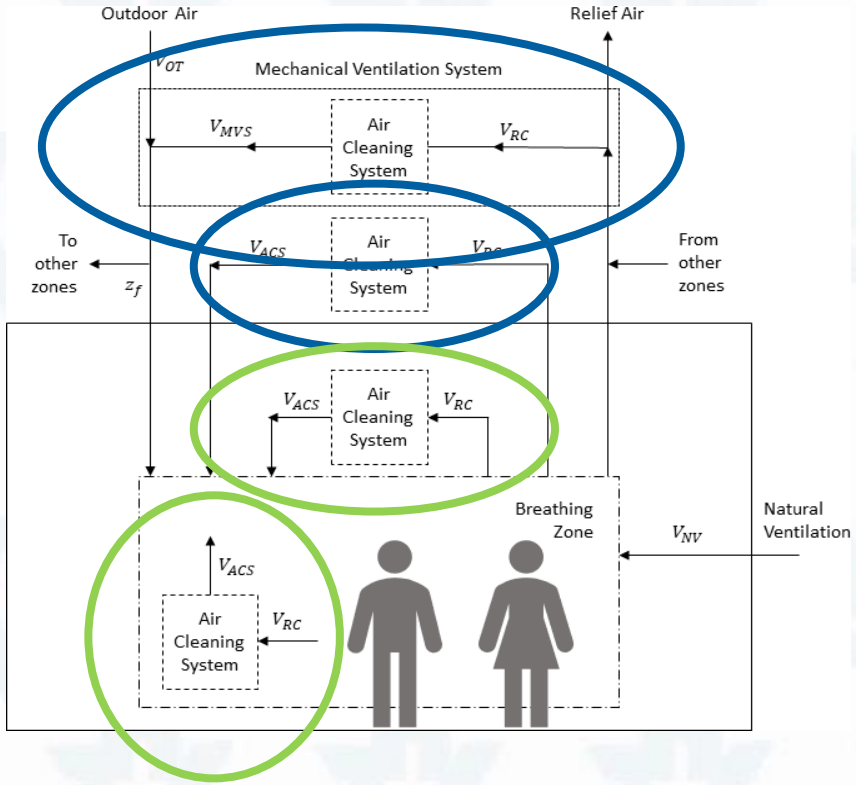
Sum of all Cleaning Devices Must Meet or Exceed V_{ECAi} Equation 6-1 & Figure 6-1

Add up the contribution of all the cleaning devices and ensure that they exceed the target V_{ECAi} value



How Can You Exceed the V_{ECAi} in Addition to OA?

$$V_{ECAi} = ECA_i \times P_{Z,IRMM}$$ Equation 5-1

Increase OA to get better dilution (go from 10 l/s/p to 35 l/s/p for an exam room)

Reduce occupancy to get a smaller overall room requirement

Upgrade filtration to get “clean” air via central or local (portable) filtration

Use uV or another technology to reduce particulate to get “clean” air

Use another validated technology to get “clean” air

$$\sum [z_f \times (V_{OT} + V_{MVS})] + \sum V_{ACS} + V_{NV} \geq V_{ECAi}$$ Equation 6-1

Sum it all up!

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AND THAT'S STANDARD 241……in a nutshell (Equation 5-1 & Equation 6-1)

$$V_{ECAi} = ECA_i \times P_{Z,IRMM}$$

Equation 5-1

$$\sum [z_f \times (V_{OT} + V_{MVS})] + \sum V_{ACS} + V_{NV} \geq V_{ECAi}$$

Equation 6-1

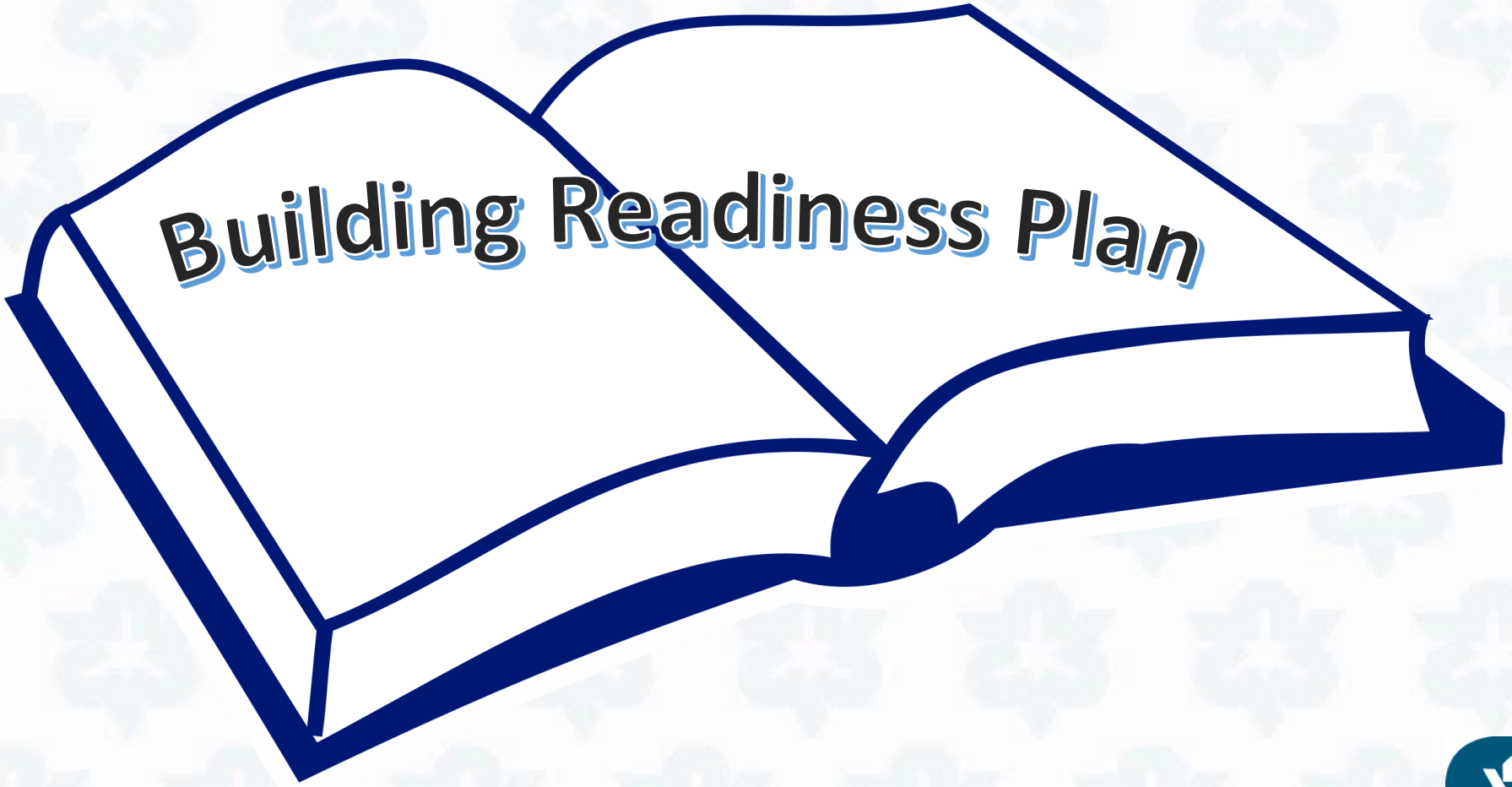
PREZANT ENVIRONMENTAL

The Devil is in the Details – The Complexities

You need to inventory the system present to implement

All the pre-planning, BRP, & verification can be quite cumbersome

Assessment Planning and Implementation
Building Readiness Plan (BRP)



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BUILDING READINESS PLAN

8.1 Building Readiness Plan (BRP). The BRP shall be created after the assessment, planning, and implementation phases to describe the engineering and non-engineering controls that the facility's systems will use to achieve its target equivalent clean airflow for infection control ($V_{ECAi,target}$). The BRP shall be either a standalone document or a section of an existing emergency operations planning document. The BRP shall be reviewed annually or when there are changes to the engineering controls or a modification to the $V_{ECAi,target}$ used by the facility and its systems, whichever is more frequent.

a. The engineering controls section shall include the operations and maintenance (O&M) procedures (including operating schedules), ventilation system operating schedules and airflow values, air cleaning technologies used with included locations, filtration MERV rating and rack sizing, final design drawings, critical asset inventory management plan, maintenance schedules based on manufacturer instructions, the maintenance requirements and frequencies provided in Section 9.2.2, and any changes made to the system for infection risk management mode (IRMM) as opposed to normal mode of operation (which is how the system is operating when it is not in IRMM). The BRP shall also include a zone-level ventilation matrix that specifies the V_{ECAi} target for each risk mitigation mode. If V_{ECAi} is to be provided by standalone systems (e.g., in-room air filters), then the BRP must also include O&M schedules for all such systems.

b. The non-engineering controls section shall include any requirements for allowed changes in building occupancy levels ($P_{z,IRMM}$), personal protection equipment use, social distancing, and cleaning. The BRP shall include any testing or safety documents required by this standard.

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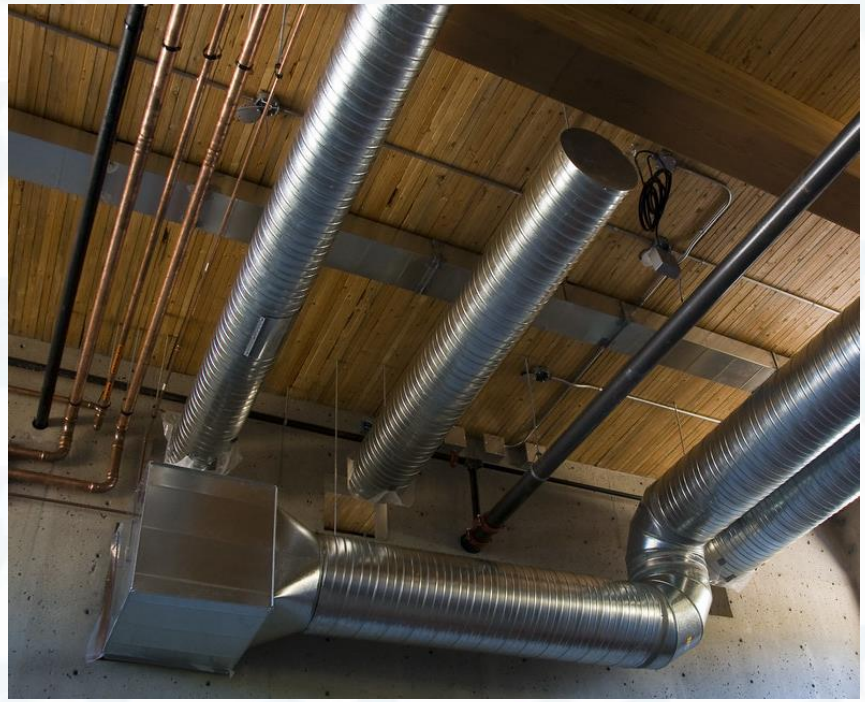
Assessment Planning and Implementation
Building Readiness Plan (BRP)

1. Data Gathering
2. Site Observations
3. Occupied Space Inventory & Categorisation
4. Equipment Inventory
5. Multi-Family Transfer Air & Pressurisation
6. Potential Separation Areas



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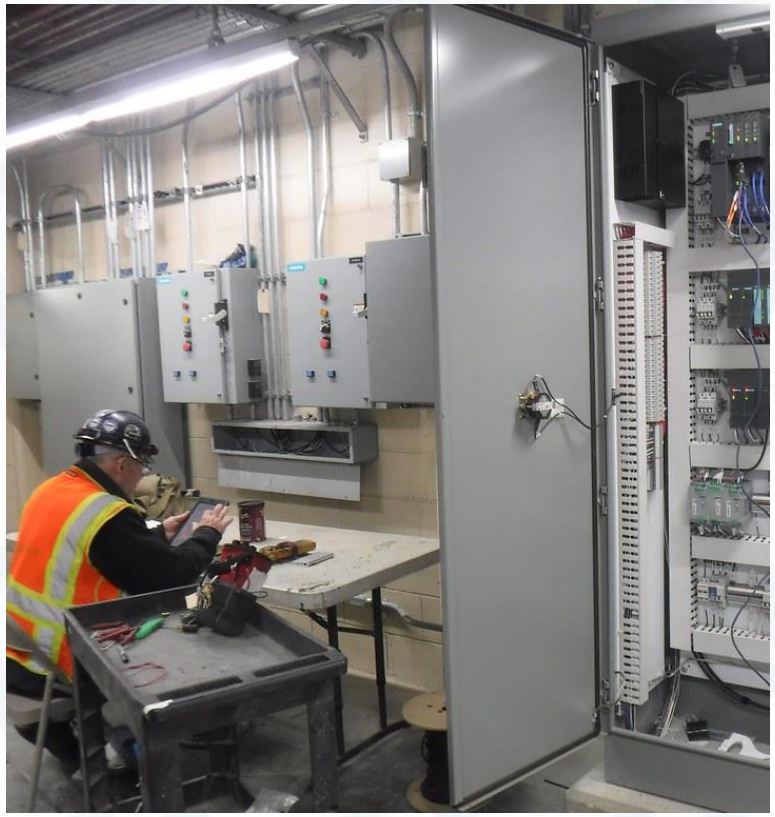
Assessment Planning and Implementation
Building Readiness Plan (BRP)

7 Ventilation system compliance with ASHRAE 62.1, 62.2, or 170

8 OA, supply and return flows identified or measured (TAB, audit)

9 Calculate minimum OA required; fix (note on issues log if deficient)

10 Assess ERVs



11 Verify controls provide OA continuously when occupied; deactivate DCV or use minimum DCV for calculations

12 Document filtration size, quantity, MERV rating, pressure drop, gaps influencing quality of installation

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Assessment Planning and Implementation
Building Readiness Plan (BRP)

13 Exhaust operation verified; pressure differential qual or quant

14 Assess need for calibration control sensors for air delivery

15 Document control strategies & sequences of operations if additional engineering controls will influence operation

16 Assess existing engineering controls per section 6 and 7

17 Evaluate existing systems for contribution to V_{ECAi}

18 Fix deficiencies, determine target, and select controls

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Assessment Planning and Implementation
Building Readiness Plan (BRP)

19 Use minimum flows in calcs for DCV and VAV

20 All modifications to be commissioned with functional performance tests as per ASHRAE 230 + normal mode and *IRMM* occupied and unoccupied

21 Alternative to FPT – use Normative Appendix C – test >10% of all space types, plus two randomly selected duplicates

22 Light check on filter bank include in commissioning

23 Establish an issues log & systems manual equipment, functions, sequence

24 Document everything above in BRP

Assessment Planning and Implementation
Building Readiness Plan (BRP)

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Minimum Maintenance Frequencies [as per 62.1 Table 8.1]

Quarterly

- filter pressure drop
- Outdoor air controls
- Proper damper operation
- UVGI
- In-room, duct, and UV air cleaners

Monthly

- P traps in rooms serving as plenums
- Visual inspection of outdoor air intake louvers, screens
- Proper operation of natural ventilation opening controls
- UVGI
- Verify air cleaners location and operation as per BRP

Annually

- Air filter fit; housing seal integrity

Every 2 years or every 3 years

- Sensors for OA, DCV, CO_2 (every 2 years)
- Total quantity of OA when in minimum OA mode (every 3 years)

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Summary ASHRAE Standard 241-2023

- ASHRAE Standard 241-2023 provides a comprehensive framework for managing infection control
- Invocation of IRMM is for owner/occupier or cognisant authority
- Multiple modes can be employed to achieve targets *including reducing occupancy*
- Calculated V_{ECAi} are based on reduction to acceptable risk level, equalised across spaces with 1 hour occupancy, after modelling known infection factors with a Monte Carlo approach
- Very feasible to implement but will require extensive assessment of current status and significant planning

PREZANT ENVIRONMENTAL

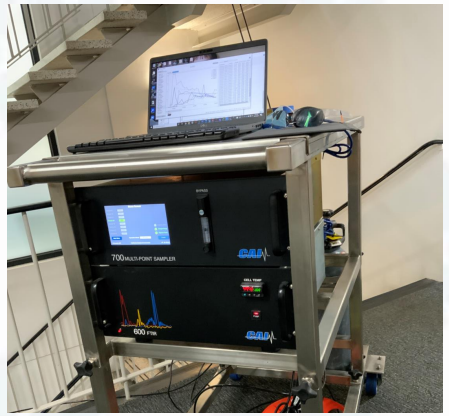
Ventilation Considerations for Infection Control in Health Care

1. Ventilation Can & Does Impact Airborne Transmission of Disease

2. Ventilation is firstly about controlling airflow via pressure management

3. Ventilation is secondarily about diluting or removing infective aerosols

4. ASHRAE offers a structured approach with ASHRAE 241-2023 including health care



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