ASHRAE EPIDEMIC TASK FORCE

BUILDING READINESS | Updated 5-17-2022

General Information

Epidemic Conditions in Place (ECiP)

Post-Epidemic Conditions in Place (P-ECiP)

Additional Information

Information in this document is provided as a service to the public. While every effort is made to provide accurate and reliable information, this is advisory, is provided for informational purposes only, and may represent only one person's view. They are not intended and should not be relied upon as official statements of ASHRAE.

General Information

Building Readiness Intent

The following Building Readiness information is meant to provide practical information and checklists for how your building should be operating and how to practically check its operation. Actual conditions at any specific building will vary, and the adjustments that should be made will depend on many factors such as local climate, complexity of systems involved and the use, occupancy and activities that occur in and around your building.

Building Readiness modes of operation for the building should include the following:

- Epidemic Operating Conditions in Place (ECiP)
    - Occupied- at pre-epidemic capacity
    - Occupied- at reduced capacity
    - Unoccupied temporarily, and
    - Operation during building closure for indefinite periods

- Post-Epidemic Conditions in Place (P-ECiP)
    - Prior to Occupying
    - Operational Considerations once Occupied

General Information

Building Readiness Intent Continued

Please keep in mind that the mode of the building (ECiP or P-ECiP) is a decision by the Owner that should consider the Federal, State, or Local Government or Health Department designation for the location of this building.

Also note, that the ASHRAE Epidemic Task Force has created a single page document for Core Recommendations for Reducing Airborne Infectious Aerosol Exposure that should be referenced to understand the intent behind all of the guidance.

General Information

Building Readiness Intent Continued

The Building Readiness Guide will provide some of the practical guidance on operating your building systems in these different modes. The suggested mode of operation during the Epidemic periods are detailed in the Buildings Guidance on the ASHRAE Covid-19 Website.

- Healthcare
- Residential Healthcare
- Residential
- Multifamily
- Commercial
- Schools & Universities
- Laboratory
- Assemblies of Faith
- Transportation

In addition, this document will cover specific recommendations from the Building Guidelines such as:

- System Analysis
- Ventilation
- Increased Filtration
- Flushing Calculations
- Energy recovery ventilation systems operation considerations
- Building exhaust air re-entrainment

This document assumes that the Owner and Facility Operators have completed their Epidemic Preparedness Plan and are ready to shut down, operate, and re-open their building. This can be done in either mode, ECiP or P-ECiP.

The following guide is to provide practical guidance for the Mechanical Systems for those scenarios.

Keep in mind, that for the P-ECiP mode, there are really two phases to consider; Prior to Occupying, and Operational Considerations once Occupied.

General Information

Building Readiness Team

The Building Readiness Team could include licensed and certified professionals and companies that can perform the analysis, testing, design, construction, control programming, balancing, commissioning, maintenance and operation services required to make the adjustments and achieve the performance included in these recommendations. The following are the typical service providers that may be required:

- **Commissioning Provider (CxP)** – engage a CxP that has a recognized certification from ASHRAE (BCxP), ACG (CxA), BCA (CCP), NEBB (BSC and RCx), or others. They should also have completed several Retro-Commissioning or New Building Commissioning projects in the building type in question.
- **Test and Balance Company (TAB)** – engage a TAB that has recognized certification from Associated Air Balance Council (AABC), National Balancing Council (NBC), National Environmental Balancing Bureau (NEBB) and Testing Adjusting and Balancing Bureau (TABB) or another certifying body. The TAB agent or service provider should have experience with the building type and systems being evaluated. These certifying bodies require a TAB company operator to have been trained and certified and requires the use of calibrated instruments.
- **Building Automation Systems (BAS) Company** – the Owner should engage the company currently providing service and support for the control system(s) that are installed in the building. If a new service provider is required, finding a local company that has experience working with and operating the building's existing control systems and preferably certified by the manufacturer to provide services for their equipment.
- **Contractors** – the Owner should engage, if necessary, the appropriate contractors to install or repair equipment or systems identified by the CxP, TAB, or BAS providers. This could include the following:
  - General Contractors (GC)
  - Mechanical Contractor (MC)
  - Electrical Contractor (EC)
  - Specialty contractors for fire alarm and smoke control systems and interfaces.
- **Architect and/or Engineer (AE)** – the Owner should engage a design team for any issues that might require permit drawings. It is preferred that the original Engineer or Architect of Record that was involved with the original construction or the latest renovation or addition to the facility be engaged if possible. Those professionals should be most familiar with the building's current operation.
- **Owner's Facility Staff** – the Owner should make sure that their facility staff are involved in the process. This allows for the information transfer on how systems might be altered to operate.

General Information

Building Readiness Plan

This is a document that should be created to document the mitigation strategies that the facility is going to utilize, whether temporary or permanent modifications, for the facility operators and occupants to understand the plan.

This should include the non-HVAC strategies as well as the HVAC mitigation strategies that are discussed in this document.

Non-HVAC strategies could include, but not be limited to, the following items:
- Building Occupancy Levels Allowed
- Face mask requirement or recommendation
- Social distancing between desks, breakrooms, conference rooms, elevator, etc.
- Directional flow for office space
- Personal hygiene
- Cleaning requirements

HVAC strategies could include, but not limited to, the following items:
- Increased Ventilation
- Improved Filtration
- Air cleaning devices (such as UVGI and other newer technologies)

It is crucial to note, that each HVAC system needs to be analyzed for the appropriate engineering controls to utilize to improve its potential to reduce virus transmission in the building.

Epidemic Conditions in Place

Systems Evaluation:

The Owner should consider evaluating their building systems to check that it is operating in proper order (per design conditions or current operational strategies), is capable of being modified to align with HVAC mitigation strategies, and to identify deficiencies that should be repaired. This could be viewed as tactical commissioning of the systems to determine risk areas for the building operating in epidemic conditions.

Systems evaluation should include the following steps:

1. Gather and review building and systems documentation, including but not limited to:
    a. Most recent design documents, specifically the HVAC and Plumbing Water systems construction documents
    b. Record documents (as-built, marked up drawings and specifications received from the Contractor at the conclusion of construction)
    c. Original, approved equipment and system submittal documents
    d. Systems manuals or turnover package
    e. Controls and Building Automation System (BAS) drawings and sequences of operation and initial system parameters
    f. Equipment control wiring diagrams and troubleshooting guidelines
    g. Service contracts and maintenance logs
    h. BAS Trend reports and alerts and notifications reports
    i. Most recent Testing, Adjusting and Balancing (TAB) reports
    j. Most recent Commissioning Reports (if available)

Epidemic Conditions in Place

Systems Evaluation Continued:

2. **Inspect equipment, systems and controls to determine where existing problems may exist.**
Start with components, then move to systems, finally move to the BAS and integrated, whole building operations.
Look for energy savings opportunities available based on por optimization from all systems.

For example:

a. **Components**
   i. Boilers
   ii. Chillers
   iii. Air Handling Units (including filter rating, filter installation for leakage, coil conditions and accessories used to control outdoor air flow)
   iv. Control Dampers (check they are functioning and that the positions seem correct)
   v. Control Valves
   vi. Control Sensors
   vii. Airflow Measuring Stations (AFMS)
   viii. Fan Coil Units
   ix. Grilles, registers and diffusers
   x. Variable speed drives
   xi. Variable Air Volume terminal units,
   xii. Water-to-water heat exchangers
   xiii. Water-to-refrigerant heat exchangers
   xiv. Water to air heat exchangers
   xv. Steam-to-water heat exchangers

b. **Systems**
   i. Chilled water systems
   ii. Hot water systems
   iii. Condenser water systems
   iv. Air handling systems (Air handling equipment and air distribution networks: supply ducts, return ducts, exhaust ducts)
   v. Steam distribution systems
   vi. Refrigerant systems

Epidemic Conditions in Place

Systems Evaluation Continued:

c. **Building Automation Systems (BAS) and Integrated Systems**

i. Graphic user interfaces
ii. Set Points (Temperature, Humidity, Airflow, CO2, etc)
iii. Schedules (Occupied and Unoccupied)
iv. Trend reports
v. Alarm, alert and notification logs
vi. Remote access capabilities
vii. Life safety system interfaces and interlocks
viii. Access control interfaces
ix. Smoke control system interfaces
x. Lighting control interfaces
xi. Electronic security system interfaces

Epidemic Conditions in Place

Systems Evaluation Continued:

3. The investigators should be considering the HVAC mitigation strategies to reduce the potential bio-burden in the building that could be implemented on the systems.

4. When checking calibration, use the guidance in ASHRAE Guideline 11-2018 -Field Testing of HVAC Control Components.

5. Prepare a deficiency log and issue work orders to in-house maintenance personnel and purchase orders to qualified service providers to correct any critical issue identified in steps 1 and 2 that would prevent the system(s) from functioning in accordance with the systems' original design intent or the building's current use, occupancy and activity.

6. Prepare a Building Readiness Plan that identifies the HVAC mitigation strategies for the systems. This should include a brief work order description for the in-house maintenance personnel and qualified service providers. This should detail modifications or additions to components, systems and controls necessary so that the recommendations included in this document
 may be implemented.

Epidemic Conditions in Place

Building Automation Systems (BAS)

Evaluate your BAS:

It is crucial for the Owner to understand the type of BAS they have in their building. HVAC controls range from simple single zone thermostats controlling a single HVAC unit's heating and cooling modes of operation, to complex BAS that integrate the controls from large building owners and owners with multiple large buildings in their portfolios, such as school districts, university campuses and large government installations and everything thing in between.

In addition, there are legacy HVAC systems and BAS that still use electric and pneumatic controls and time clocks that do not have modern, digital communications interfaces and therefore, do not allow building operators any insight into how their buildings are performing without being physically in the building or at the piece of HVAC equipment.

Epidemic Conditions in Place

Building Automation Systems (BAS) Continued

Remote Access:

If the building is equipped with a Building Automation System (BAS), it should have an existing method for remote access.

If the BAS does not have a method for remote access, the owner should coordinate with buildings the IT provider and BAS provider for secure remote access for the required users.

- Cybersecurity must be put at the forefront of this endeavor as to not open the BAS and other building networks to unauthorized access.
- If the BAS is not on its own Virtual Local Area Network (VLAN), consider segregating the building systems (BAS, Fire Alarm, Card Access, Cameras, etc.) into a VLAN to limit remote exposure to the buildings internal networks.
- Consider two step authentication as mandatory for remote access.
- Care should be taken in granting editing access to the BAS to knowledgeable, trained operators only.
- Set up user logging such that a virtual log of all changes are documented.

These remote systems range from the simple to complex communication capabilities.

- The simple could be dial up modems transmitting alerts and notifications to cell phones and/or email addresses.
- The more complex is a BAS system that is connected to local area networks that can be accessed via VPN connections.

Depending on that connection, there are variations to the amount of data access which can range from limited data to a fully web based, graphic user interfaces connected to a host of mobile devices such as smartphones, tablets and stationary PC workstations.

Epidemic Conditions in Place

Building Automation Systems (BAS) Continued

Prior to making any changes:

- Perform a full backup of all BAS software, databases, programs, graphics, trends, schedules, etc. and store off site either physically or in the cloud.
- Consider printing them physically or to a pdf so that values can easily be returned when the epidemic is over.
- Inspect or replace any batteries in building controllers such that databases are not lost during any extended power interruptions.
- If your building is not on a scheduled BAS inspection (either by third parties or self-performed) consider performing a preventative maintenance inspection of all systems to confirm proper operation prior to any changes being made. Consider retaining the services of an independent 3rd party commissioning service provider (CxP) to help you review the scope of work for any control system modifications and who can verify the systems are functioning as intended.
- Review the access requirements with all parties that the owner wants to have remote access during the unoccupied or modified mode of operation period.
- Determine the level of access and permissions each person with access should have, such as full access to make changes in set points, schedules and system programming, schedule overrides only, alerts and notification access only and view only access.
- Confirm with company IT departments what requirements may be in place to qualify, screen and approve people for remote access to control systems and company IT networks.
- Set each person up as a unique user having unique usernames and password and permission levels so that access and changes to the system can be monitored and documented.
- Have a trained and experienced operator go over the existing systems remote access features of the system and its interface with anyone who will be given remote access to the system.
- Review all alerts, notifications, event logs and system and control point trend reports prior to making any modifications and download those reports to create a baseline for comparing the effects of any changes that may be made in the future.

Epidemic Conditions in Place

Building Automation Systems (BAS) Continued

Prior to making any changes:

- If possible, walk the facility or facilities being controlled and managed by the BAS to become familiar with the location, size and scale of the control network.
- As minimum, review system graphics for all system types and buildings to become familiar with the system(s).
- Make note of any communication issues with components, sensors, controllers, buildings, etc. and develop a list of repairs that may need to be made before the system is placed in extended shut down, unoccupied or partial occupancy modes of operation.
- Review system graphics or text-based reports to determine if temperatures, humidity, CO2, airflows (supply, return, outside air, exhaust), damper positions, control valve positions, motor speeds and status are returning or reporting reasonable values.
- Use test instruments to verify any questionable information and to spot check a representative quantity of points. Start with verifying critical sensors, such as CO2 or airflow measuring stations.
- Collaborate with the building owner, building users and building operators and create a plan for modifications to sequences, set points and system operations.
- Note who was in attendance, what was discussed, and any decisions made and implemented.
- Obtain buy-in and approval from key stakeholders before making any changes.
- Repairs to systems involved in this response should be considered mandatory as any new sequences may not be able to be implemented via the BAS.

Epidemic Conditions in Place

Building Automation Systems (BAS) Continued

Making changes to accommodate epidemic responses:

- After determining what sequence of operation changes are appropriate, make small changes to the system at a time and monitor for a few days or through some varying weather conditions to make sure the system and building(s) is responding to the changes as expected.
    - Have the CxP or Control Contractor verify and document the effect of the changes through key trend reports and physical measurements or standalone data loggers.
- Keep good records and document all meetings, agreed to repairs, maintenance and changes with written communication.
- The team should consider making the changes to include an automated response such that you may return to the original sequences (or pre and post pandemic sequences) at the push of "virtual" button.
    - Care should be taken to limit access to the initiation of these automated sequences as they may have a large energy and comfort impact on your facility.
- Existing alarm parameters may need to be adjusted during these new sequences as the original "normal" conditions may not be able to be met.
- Confirm that this team follows the guidance for the facilities Systems Manual later in this document.

Epidemic Conditions in Place

Ventilation per Code / Design

ASHRAE is indicating that the building systems need to be evaluated to confirm that the building's HVAC systems are capable and operating to provide the code required or design levels of outdoor air when the building is occupied.

The intent is to operate the systems in this manner when the building is occupied.

Increasing outdoor air above code / design is considered a mitigation strategy to be evaluated.

Epidemic Conditions in Place

Increased Ventilation above Code

There is potential that building operators could increase their systems outdoor air ventilation to reduce the recirculation air back to the space. The guidance indicates that this should be done, if it is the selected mitigation strategy for this system, as much as the system and or space conditions will allow. It is very important that these overall building systems are evaluated by a qualified TAB firm, Cx provider or design professional to confirm that the modifications for pandemic safety do not create additional issues.

One major concern is the ability to maintain space conditions. Hot and humid climates could struggle to keep the space below acceptable temperature and relative humidity for comfort. Cold climates could struggle to keep the space above acceptable space temperature and relative humidity for comfort. It is important to note that research indicates that maintaining the space relative humidity between 40% and 60% decreases the bio-burden of infectious particles in the space and decreases the infectivity of many viruses in the air. The team should consider adjusting the space comfort setpoints to increase the system's ability to use more outside air.

Epidemic Conditions in Place

Increased Ventilation Continued:

The ability for a cooling coil to provide additional capacity was evaluated using a typical cooling coil at various percent of outside air. This evaluation shows the additional required cooling capacity and gpm required[1] if the same exact coil experiences the different entering air conditions while achieving constant leaving air conditions. The following shows the impact of increasing the percent of outside air:

Percent OA	EAT DB / WB (deg F – deg C)	CHW (GPM – L/S	Coil Pressure Drop (Ft H2O – kPa)	Total Capacity (MBH - kW)	Sensible Capacity (MBH - kW)
20	78.43 / 69.31 25.79 / 20.73	88.64 / 5.60	7.06 / 21.10	541.29 / 0.16	292.45 / 0.09
30	79.64 / 70.80 26.47/ 21.56	95.82 / 6.05	8.14 / 24.33	596.98 / 0.17	306.33 / 0.09
40	80.84 / 72.64 27.13 / 22.58	107.15 / 6.77	9.99 / 29.86	671.74 / 0.20	320.33 / 0.09
50	82.04 / 73.64 27.8 / 23.13	113.49 / 7.15	11.10 / 33.18	712.95 / 0.21	333.99 / 0.10
60	83.24 / 75.00 28.47 / 23.89	121.01 / 7.62	12.49 / 37.33	768.22 / 0.23	347.89 / 0.10
70	84.44 / 76.30 29.13 / 24.61	131.79 / 8.30	14.61 / 43.67	826.98 / 0.24	361.82 / 0.11
80	85.63 / 77.57 29.79 / 25.32	139.60 / 8.79	16.24 / 48.54	881.63 / 0.26	375.69 / 0.11
90	86.81 / 78.80 30.45 / 26.00	151.96 / 9.57	18.99 / 56.76	941.36 / 0.28	389.49 / 0.11

The unit was selected to be 10,000 cfm with a constant 44°F chilled water supply with a 12°F chilled water rise to make a consistent coil leaving air temperature of 52°F dry-bulb and 51.5°F wet-bulb. This assumes a return air condition of 76°F and 60% RH from the space. The outside conditions are the Orlando WB with MCDB which is 88 °F dry-bulb and 80 °F wet-bulb. The coil was locked in at an 8-row coil with 126 fins per foot that is 20.45 square feet of coil face area.

Epidemic Conditions in Place

Increased Ventilation Continued:

The ability for a heating coil using heating hot water was also evaluated for its ability to handle the added load for various percent of outside air. This evaluation shows the additional required heating capacity and gpm required if the same exact coil experiences the different entering air conditions while achieving constant leaving air conditions. This case was to use a pre-heat coil that conditions the outdoor air prior to it connecting to an air handling unit, so it is in essence a 100% outdoor air coil. This assumes the same 10,000 CFM total supply air from the AHU to understand the percent OA.

The following shows the impact of increasing the percent of outside air:

Percent OA	OA Flow (CFM – L/S)	Face Velocity (FPM – M/S)	Coil Air Pressure Drop (in wc - Pa)	HW Flow (GPM- L/S)	Coil Water Pressure Drop (Ft H2O - Pa)	Leaving Water Temp (deg F – deg C)	Sensible Capacity (MBH - kW)
20	2,000 / 944	500 / 2.54	0.12 / 29.89	5.85 / 0.370	0.05 / 149.45	142.18 / 61.21	110.62 / 32.41
25	2,500 / 1,180	625 / 3.175	0.178 / 44.34	8.89 / 0.562	0.11 / 328.80	148.91 / 64.95	138.27 / 40.51
30	3,000 / 1,416	750 / 3.81	0.244 / 60.78	14.12 / 0.892	0.27 / 807.05	156.52 / 69.18	165.93 / 48.62
35	3,500 / 1,652	875 / 4.445	0.318 / 79.21	23.93 / 1.512	0.74 / 2,211.91	163.85 / 73.25	193.58 / 56.71
40	4,000 / 1,888	1,000 / 5.08	0.399 / 99.39	48.05 / 3.034	4.42 / 13,211.7	170.81 / 77.12	221.24 / 64.8
45	4,500 / 2,124	[1]	[1]	[1]	[1]	[1]	[1]

[1] The software program would not select a coil at this air volume due to an excessive face velocity and increased gpm and tube velocity. The manufacturer does not recommend using this amount of outdoor air.

This coil is based on sizing it at 2,000 CFM for 20% OA of a 10,000 CFM AHU. The two-row coil was held at 14" long by 44" wide and 29" high. Fins are spaced at 80 per foot. The entering air was assumed to be near the ASHRAE 99.6% Heating conditions for Springfield, Illinois which is 4.3°F dry bulb and 2.2°F wet bulb. The selection use 4°F dry bulb with a target discharge of 55°F air to the AHU.

Epidemic Conditions in Place

Increased Ventilation Continued:

Another way to potentially increase the quantity of outside air is to clean the cooling coil to recapture lost heat transfer from fouling.

- Studies indicate that dirty coils reduce the capability for heat transfer.
- Please follow the appropriate maintenance procedures for coils.

Another concern for coils is the amount of glycol (ethylene or propylene) that is in the system to avoid freezing the liquid in the coil and pipes. Please make sure to look at that percentage to understand the impact it would have on a coil's performance. The tables above are based on 100% water without an additive. The following table, from www.RhomarWater.com, shows the impact of glycol:

Propylene or Ethylene Glycol % by Volume	Capacity Deration			
	Ethylene Glycol		Propylene Glycol	
	Factors	%	Factors	%
10	0.98	2	0.97	3
20	0.96	4	0.95	5
25	0.94	6	0.93	7
30	0.93	7	0.92	8
40	0.90	10	0.88	12
50	0.87	13	0.84	16
60	0.84	16	0.79	21

NOTE: Glycol deration factors will be affected by the altitude above 7,500 feet as well as fluid temperature.

Epidemic Conditions in Place

Increased Ventilation Control:

The assessment team determining how much more a coil can handle can see that increasing from 20% outside air to 90% outside air doubles the required chilled water, triples the coil pressure drop and requires just over twice the amount of cooling source from the chiller plant. And even with a large capacity heating plant where heating capacity might not be an issue the coil may be the limiting factor. The capacity of the plant and coils need to be evaluated.

There are other options to increase the outside air in an AHU as much as the building automation system (BAS) will allow based on space conditions. There are at least two approaches to modify a system to optimize the outside air without ignoring space comfort that is a twist on the dynamic supply air temperature reset strategy. This is assuming a typical variable air volume AHU serving multiple VAV boxes or as a single zone VAV unit. The outside air damper and return dampers could be linked or separate, but they work in opposite directions in any option presented.

Option 1: Increased OA based on Cooling Coil

If the cooling coil control valve is less than 90% AND the discharge air temperature (or space temperatures) are satisfied, OPEN the OAD [CLOSE the RAD] 3% every 15 minutes.

If the cooling coil control valve is greater than 90% OR the discharge air temperature (or space temperatures) is exceeded by 1-degree F, CLOSE the OAD [OPEN the RAD] 6% every 5 minutes.

Option 2: Increased OA based on Space Conditions

This option assumes that a coil leaving air temperature controls the CHW valve to maintain a constant setpoint.

If the space temperatures are satisfied and the relative humidity is less than 55%, OPEN the OAD [CLOSE the RAD] 3% every 15 minutes.

If the space temperatures are exceeded by 1-degree F OR the relative humidity is greater than 60%, CLOSE the OAD [OPEN the RAD] 6% every 5 minutes.

These options require different sensors to be installed in the unit to work properly. Either sequence would allow the unit to increase the outdoor air without exceeding the space comfort conditions. It is also important to note that demand-controlled ventilation, static pressure reset strategies and the typical supply air temperature reset strategies should be disabled.

Epidemic Conditions in Place

Building and Space Pressure:

Building and space pressurization is another important consideration.

Care should be taken when increasing outside air but keeping exhaust and relief air systems as designed. New problems can be created such as:

- Doors that will not close
- Excessive noise at entrance doors and between adjacent spaces
- Access / egress issues at common hallways or egress points (in extreme conditions)
- Reverse of the intended pressure required for a space

Excessive building pressurization can also affect vertical transportation systems and areas that are intended to be negatively pressurized, such as commercial kitchens, bathrooms, process areas and custodial areas.

It is very important that these overall building systems are evaluated by a qualified TAB firm, Cx provider or design professional to confirm that the modifications for pandemic safety do not create additional issues.

Epidemic Conditions in Place

Flushing Between Occupied Periods Strategy:

Flush the spaces between occupied periods for a duration sufficient to reduce concentration of airborne infectious particles by 95%. For a well-mixed space, this would require supplying 3 space volumes of equivalent outdoor air. Equivalent outdoor air includes the effect of filtration and air cleaners as detailed in the calculation methodology.

In lieu of calculating the equivalent outdoor air change rate, flushing between occupied periods for 2 hours should be sufficient for most systems meeting minimum ventilation standards.

For each mode, the control would be as follows:

- Occupied: bring in the code / design outdoor air per system.
- Flushing Between Occupied Periods Operate the systems in Occupied Mode for “x” hours between occupancy. Use the calculation to determine “x”.

Note: During extended unoccupied periods, natural inactivation, deposition, and infiltration alone may be sufficient to achieve the recommended equivalent outdoor air changes without HVAC system operation.

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Epidemic Conditions in Place

Flushing Air Changes Calculations for Well Mixed Spaces:

- The flushing process is intended to be for removing gases in a well-mixed space.
- It is good for removing VOC's, CO2, and any contaminant that approximate gases.
- While all gases can be assumed with good science to be evenly distributed in the space, particles may not. Airborne particles cannot be treated as gases and these particles follow relaxation theory and move on air currents, some unknown percentage of particles may go back to the return and likely do.
- The entire principles that this section is based on is delivering viral load particulate reduction to the space by diluting the clean air breathing zone.

Epidemic Conditions in Place

Flushing Air Changes Calculations for Well-Mixed Spaces

One air change = c / C_{0A} = $\exp^{-1}$ = 0.368

Three air changes = c / C_{0A} = $\exp^{-3}$ = 0.050

Five air changes: c / C_{0A} = exp(-5) = 0.010

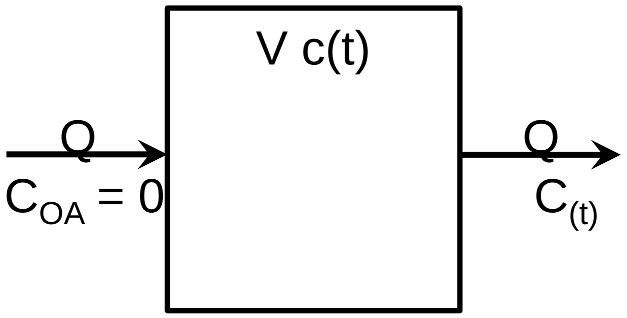
Therefore, three air changes result in the removal of 95% of the contaminants in the space for a well mixed system

Abbreviations and Assumptions:

- V = Volume
- Q_t = Total air flow
- c = space concentration
- C (t=0) = C_0
- C_{OA} = 0
- N = number of air changes
- ACH is outdoor airflow rate in air changes per hour
- t[h] = hours for flushing between occupied periods

Change of contaminant in space is equal to flow of contaminant in minus flow of contaminant out during a time interval dt

Flow in – Flow out



$$VdC = \left(QC_O - QC\right)dt$$

Outdoor air concentration is zero so

$$VdC = -QCdt$$

$$\frac{dC}{C} = -\frac{Q}{V}dt$$

$$\int_{C_0}^{C} \frac{dC}{C} = -\int_0^t \frac{Q}{V}dt$$

$$\ln\left(C\right) - \ln\left(C_O\right) = -\frac{Qt}{V}$$

$$\frac{C}{C_O} = \exp\left(-\frac{Qt}{V}\right) = \exp\left(-N\right)$$

Where N = number of air changes

Time for N air changes:

$$N = \frac{Qt}{V}$$

$$t = \frac{N}{Q/V}$$

$$t\left[h\right] = \frac{N}{ACH}$$

Where ACH is the outdoor air flow rate in air changes per hour (ACH)

Epidemic Conditions in Place

Equivalent Outdoor Air:

The equivalent outdoor air calculation indicates that the outdoor air can be calculated by using the combination of the actual outdoor air, impact of filtration or air cleaning technologies on recirculated air, and the impact of air cleaning technologies in the space.

This is using the principal of filters in series and the effectiveness at reducing particles. For items in series, the initial item would see the recirculated airflow to clean. The second item in the series would see the “cleaned” air from Item 1 and so the impact of Item 1 must be accounted for in Item 2.

> An example is, a unit with a filter at the return and a UVC single pass inactivation system after the cooling coil. This makes the filter Item 1 and the UVC Item 2, and so the air that is treated by UVC has already been treated by the filter. There is a cascading effect of each device in series that must be accounted for.

Let’s look at it via equations.

Epidemic Conditions in Place

Equivalent Outdoor Air Continued:

Assumptions:

Q_R is the recirculated air
ACH_e is the air changes of equivalent outdoor air
ACH_oa is the air changes of outdoor air
ACH_f is the equivalent outdoor air changes due to filtration (assumed new filters that are well installed)
ACH _e,c is the equivalent outdoor air changes due to the air cleaner after the effect of the filter

Q_R is the recirculated air
Q-e is the equivalent outdoor air flow rate
Q-e,f is the equivalent outdoor air flow rate from the filter
Q-e,f+c is the equivalent outdoor air flow rate from the air cleaner (after it went across the filter)
E_z = zone air distribution effectiveness (From Std 62.1 Table 6-4)
eta_f is the efficiency of filter
eta_c is the efficiency of the air cleaner
eta_T is the total efficiency of the series of devices

Epidemic Conditions in Place

Equivalent Outdoor Air Continued:

So, eta_T = 1 – (1-eta_f) * (1-eta_c), which allows us to state that

Q-e,f+c = Q-e,f + Q_e,c Q_R* [1-(1-eta_f)

OR

Q-R * [1-(1-eta_f)*(1-eta_c)] = Q_R * eta_f + Q_e,c

Re-arranged it results in the following equation:

Q_e,c = Q_R * (1-eta_f) * eta_c

The goal is to determine equivalent air changes, so revise the equation to be:

ACH_e = ACH_oa + ACH_f + ACH_e,c

Converting from Q to ACH is based on the fact that ACH = (CFM * 60) ÷ Volume

Then, you want to apply the impact of the Zone Air Distribution Effectiveness.

Epidemic Conditions in Place

Equivalent Outdoor Air Continued:

Then, you want to apply the impact of the Zone Air Distribution Effectiveness to include the impact that a space is not always well-mixed. ASRHAE Std 62.1 Table 6-4 [7] provides the E_z value for multiple systems that will be used to adjust the time to flush. The starting point is 1.0 and can be adjusted in the calculation tool.

Select the appropriate Ez for your system from this table from Standard 62.1:

Table 6-4 Zone Air Distribution Effectiveness

Air Distribution Configuration	E_z
Well-Mixed Air Distribution Systems	
Ceiling supply of cool air	1.0
Ceiling supply of warm air and floor return	1.0
Ceiling supply of warm air 15°F (8°C) or more above space temperature and ceiling return	0.8
Ceiling supply of warm air less than 15°F (8°C) above average space temperature where the supply air-jet velocity is less than 150 fpm (0.8 m/s) within 4.5 ft (1.4 m) of the floor and ceiling return	0.8
Ceiling supply of warm air less than 15°F (8°C) above average space temperature where the supply air-jet velocity is equal to or greater than 150 fpm (0.8 m/s) within 4.5 ft (1.4 m) of the floor and ceiling return	1.0
Floor supply of warm air and floor return	1.0
Floor supply of warm air and ceiling return	0.7
Makeup supply outlet located more than half the length of the space from the exhaust, return, or both	0.8
Makeup supply outlet located less than half the length of the space from the exhaust, return, or both	0.5
Stratified Air Distribution Systems (Section 6.2.1.2.1)	
Floor supply of cool air where the vertical throw is greater than or equal to 60 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) above the floor and ceiling return at a height less than or equal to 18 ft (5.5 m) above the floor	1.05
Floor supply of cool air where the vertical throw is less than or equal to 60 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) above the floor and ceiling return at a height less than or equal to 18 ft (5.5 m) above the floor	1.2
Floor supply of cool air where the vertical throw is less than or equal to 60 fpm (0.25 m/s) at a height of 4.5 ft (1.4 m) above the floor and ceiling return at a height greater than 18 ft (5.5 m) above the floor	1.5
Personalized Ventilation Systems (Section 6.2.1.2.2)	
Personalized air at a height of 4.5 ft (1.4 m) above the floor combined with ceiling supply of cool air and ceiling return	1.40
Personalized air at a height of 4.5 ft (1.4 m) above the floor combined with ceiling supply of warm air and ceiling return	1.40
Personalized air at a height of 4.5 ft (1.4 m) above the floor combined with a stratified air distribution system with nonaspirating floor supply devices and ceiling return	1.20
Personalized air at a height of 4.5 ft (1.4 m) above the floor combined with a stratified air distribution system with aspirating floor supply devices and ceiling return	1.50

Epidemic Conditions in Place

Equivalent Outdoor Air Continued: EXAMPLE

The following is an example on applying these concepts to a real system and space.

Example:

Keep in mind that this is to account for the devices being arranged in series and the equation would have to be modified to align with the arrangement of the systems engineering controls being applied to the recirculated air.

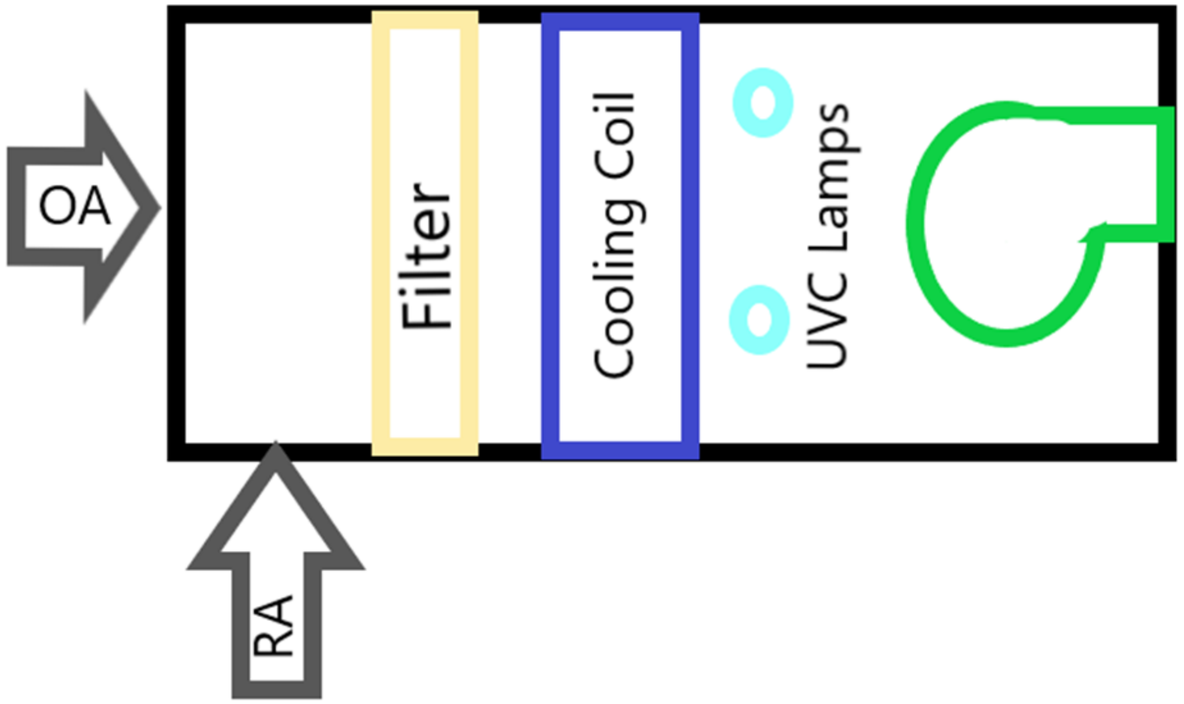
Also, only the recirculated airflow should receive credit for capture or inactivation of the virus by the filter and air cleaning technology. Outdoor should typically not be included as it is typically accepted to be clean of the virus.

Now, for an actual example that has MERV-10 filters (the equipment could not handle the MERV-13 filter target) and UVC after the cooling coil with an inactivation of 95%. Use the filter's Droplet Nuclei Efficiency as described in Filter Droplet Nuclei Efficiency.

Epidemic Conditions in Place

Equivalent Outdoor Air Continued: EXAMPLE

The school system AHU was a recirculating system supply air to 900 SF with 9-foot ceiling space from a variable air volume boxes with electric reheat. The VAV was set-up to supply 1,350 CFM Supply Air (SA) to the spaces resulting in 10.0 effective supply air (SA) air changes per hour (ACH). The unit is balanced to provide 400 CFM of outdoor air (OA), resulting in 2.96 effective ACH of OA. The unit would look something like this with resulting calculations:



ACH_oa = 2.96 ACH

ACH_f = (10-2.96) * 63.53% (MERV 10 Droplet Nuclei Efficiency) resulting in 4.47 ACH

ACH_e.c = (1 – eta_f) * eta_c * (ACH_SA – ACH_OA) = (1 - .63) * 0.95 * (10.0-2.96) = 2.444 ACH

ACH_e = 2.96 + 4.47 + 2.44 = 9.87 ACH

Epidemic Conditions in Place

Equivalent Outdoor Air Continued: EXAMPLE

Then the Zone Air Distribution Effectives will be applied when calculating the time. In this case, we have and overhead supply and return whose system is controlled to keep the heating air no more than 15 F (-9.44 C) above room temperature setpoint. This results in an Ex of 1.0.

Therefore, the time required to complete the 3 building volume changes with outdoor air equals:

Time = 3 / 9.8716 / 1 = 0.3 hours or 18.23 minutes.

This means that by doing the calculation, the flushing between occupied periods would only be set up for approximately 20 minutes instead of 120 minutes.

Epidemic Conditions in Place

Equivalent Outdoor Air: EXAMPLE

There is a calculator created to help use this method to determine the system's time to flush. This is set-up for the specific scenario of the filter and then UVC or In Room HEPA Fan Filter Unit in the space. If the arrangement is different, revise the calculation method to make sure the impact of Item 1 is incorporated before the treatment of Item 2.

[Equivalent Outdoor Air Calculator]

Purpose	This is using the ASHRAE Epidemic Task Force's Building Readiness Guide for determine the Equivalent Outdoor Air to be used for determining time required for flushing between occupied periods. The intent is to perform the calculation to reduce the flush time from the prescribed 2 hours without a calculation.	
Supporting Information		
	Building Readiness Guide	https://www.ashrae.org/file%20library/technical%20resources/covid-19/ashrae-building-readiness.pdf
	ASHRAE Guidance	https://www.ashrae.org/technical-resources/resources
Date	April 4, 2022	
Version	v1.2	
Link to File	https://docs.go	
IMPORTANT	This tool is inte contaminant re	
	Airborne trans	
	Universal mas	
	Read the DISC	
USE OF THIS TOOL	This Google S	
The user must understand the following about the		
Space area and ceiling height OR volume		
Filter MERV Rating		
UVC Inactivation percentage		
Supply air CFM or ACH		
Outdoor air CFM of ACH		
Portable Filter CADR		
If these terms are not clear, please reference the E		
You should only have to enter data in the cells wit		
This assumes an arrangement of the following unit		

Name of Space / AHU / Building	Units	MERV 13	MERV-8 and UVGI	MERV-8 and IR	MERV-11 and UVGI	Lecture - Max	Lecture - Min
Area	Sq Ft	900	900	900	900	780	780
Average Ceiling Height	Ft	9	9	9	9	11	11
Volume	Cu Ft	8100	8100	8100	8100	8580	8580
Total Supply Air	CFM	1350	1350	1350	1350	1920	480
Total Outdoor Air	CFM	337.5	337.5	337.5	337.5	460.8	480
Supply Air ACH	ACH	10.00	10.00	10.00	10.00	13.43	3.36
Outdoor Air ACH	ACH	2.50	2.50	2.50	2.50	3.22	3.36
Central AHU Filter MERV Rating	MERV	13	8	8	11	13	13
UVC Single Pass Inactivation	%	0.00%	80.00%	0.00%	80.00%	0.00%	0.00%
In Room Fan HEPA Filter	CADR	0	0	200	0	0	0
Number of In Room Fan HEPA Filters	Qty	0	0	2	0	1	0
Effective Air Changes Based on Technology							
ACH_OA	ACH	2.50	2.50	2.50	2.50	3.22	3.36
ACH_MERV filter in AHU	ACH	6.50	3.71	3.71	5.03	8.85	0.00
ACH_e,c	ACH	0.00	3.03	0.00	1.98	0.00	0.00
ACH_air cleaner	ACH	0.00	0.00	2.96	0.00	0.00	0.00
Sub-Total Effective ACH	ACH	9.00	9.24	9.17	9.51	12.07	3.36
Total Effective ACH_e		9.00	9.24	9.17	9.51	12.07	3.36
Time Required to achieve Target Air Changes	Target Air Changes	3	3	3	3	3	3
Minutes	Min	19.99	19.48	19.62	18.94	14.91	53.63
Hours	Hours	0.33	0.32	0.33	0.32	0.25	0.89

Epidemic Conditions in Place

Equivalent Outdoor Air: EXAMPLE

Some key items to note about this spreadsheet:

- This calculator allows adjustment of the virus distribution anticipated. The starting point is based on the information presented for Influenza A but could change as more research is made available for SARS-CoV-2.

- This calculator allows the specific filter that is in the facility to be input. There is information for filters that are used to determine the filter performance in the Filter Droplet Nuclei Efficiency section.

- This calculator allows you to select your Zone Air Distribution Effectiveness value based on the HVAC system installed. This helps adjust for spaces that may not be well mixed.

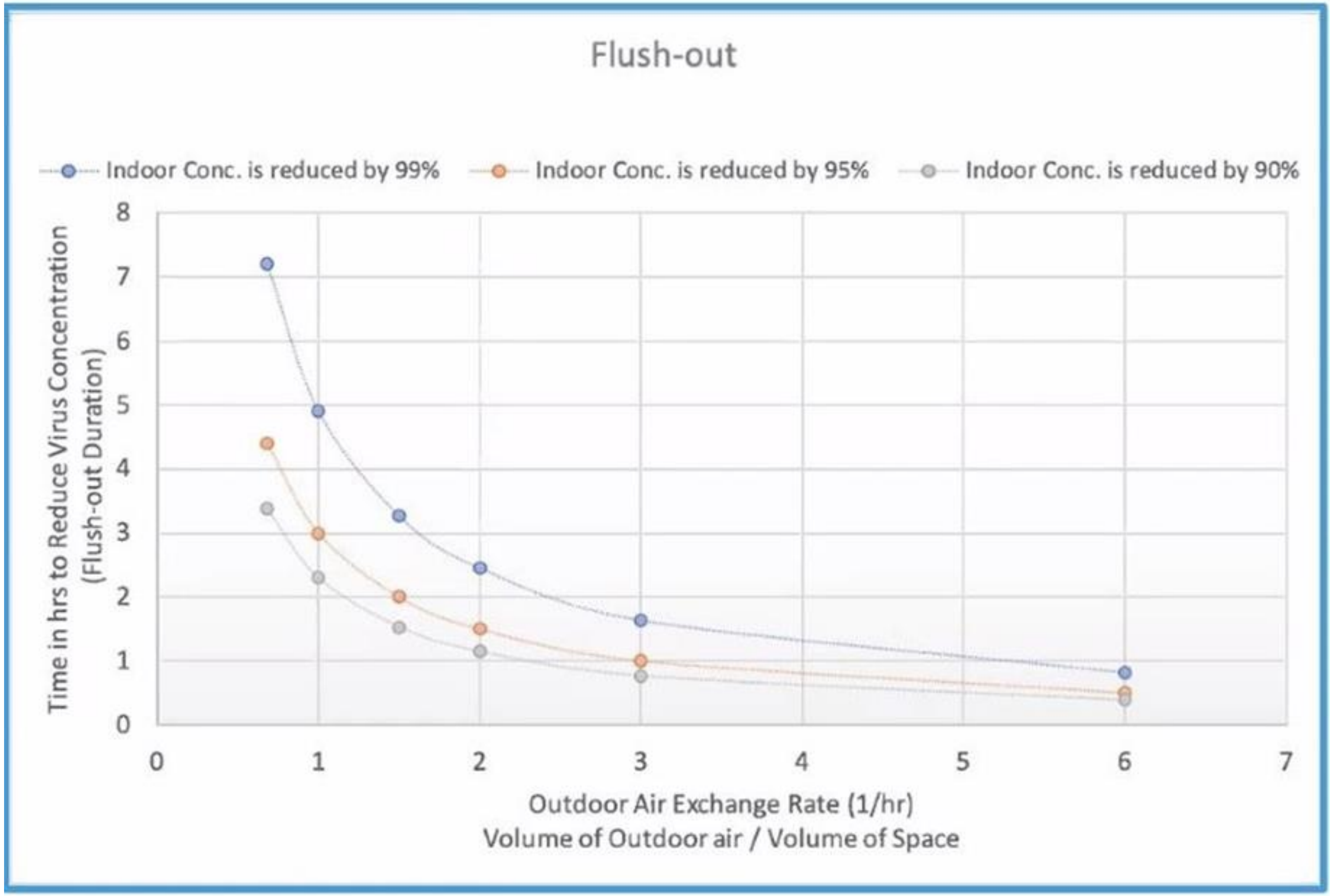
- The following impacts are not being addressed here that result in a more conservative time:

  - Deposition of particulate (PM2.5 is typically assumed to be about ½ air change of particle reduction)
  - Natural inactivation of the virus (https://www.dhs.gov/science-and-technology/sars-airborne-calculator with UV index set to 0)
    - Temperature of the space and or change of temperature.
    - Relative humidity of the space and or change of RH.
  - Infiltration

Epidemic Conditions in Place

Equivalent Outdoor Air

The following is a chart [8] that shows the time required to flush the building to three different contaminant removal goals (90%, 95%, or 99%) if you know your equivalent outdoor air changes per hour of your system.



Epidemic Conditions in Place

Upgrading & Improving Filtration:

Building owners are encouraged to improve the efficiency of the filters serving their HVAC systems within the guidance provided for most of the building types listed on the ASHRAE COVID-19 Preparedness Resources website. Mechanical filters are the most common types of filters found in HVAC systems. According to the ASHRAE Position Document on Filtration and Air Cleaning, the term used to describe mechanical filter efficiency is MERV which is an acronym for Minimum Efficiency Reporting Value (mechanical filter definition also include filters that have a static electrical charge applied to media prior to use). The MERV rating of a mechanical filter is determined by filter manufacturers in accordance with ASHRAE Standard 52.2 - Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size. Standard 52.2, table 12-1 lists filter MERV rating parameters for MERV 1 through MERV 16. The higher the MERV number the better the ability of a filter to remove particles from the air ranging in sizes from 0.3 micron diameter up to 10 microns in diameter at standard airflow conditions and face velocities specified in the test standard. A more detailed discussion of the various air filtration and disinfection technologies available may be found on the ASHRAE COVID-19 Preparedness Resources main page under the **Filtration/Disinfection** tab.

ASHRAE recommends that mechanical filter efficiency be at least MERV 13 and preferable MERV 14 or better to help mitigate the transmission of infectious aerosols. Many existing HVAC systems were designed and installed to operate using MERV 6 to MERV 8 filters. While MERV 13 and greater filters are better at removing particles in the 0.3 micron to 1 micron diameter size (the size of many virus particles) the higher efficiency does not come without a penalty. Higher efficiency filters may require greater air pressures to drive or force air through the filter. Care must be taken when increasing the filter efficiency in an HVAC system to verify that the capacity of the HVAC system is sufficient to accommodate the better filters without adversely affecting the system's ability to maintain the owner's required indoor temperature and humidity conditions and space pressure relationships.

Epidemic Conditions in Place

Filter Droplet Nuclei Efficiency / Particle Size Expectations

TARGET for the SARS-CoV-2 Virus is based on Influenza A Studies

The virus particle itself is very small, less than 0.14 micron. However, we know that it is sticky due to the lipid envelope as well as the sputum / saliva and therefor clumps with other particles making them larger. This is shown in the diagram below from the:

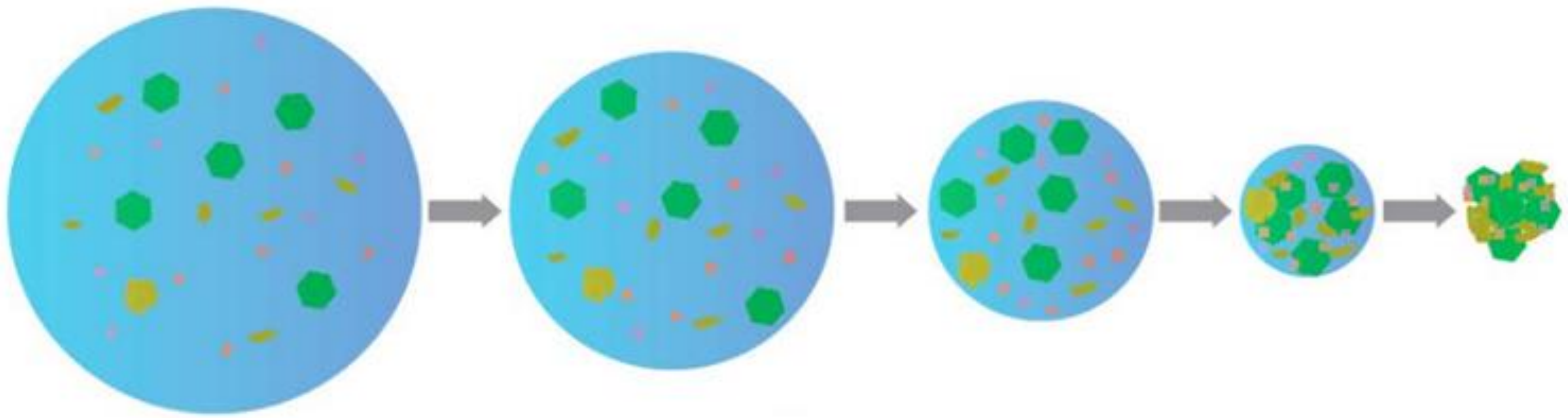


Figure 1. Evaporation of a liquid expelled *droplet* to a *droplet nucleus* (Image source: Verreault et al., 2008)

Azimi, Parham, and Brent Stephens. "HVAC filtration for controlling infectious airborne disease transmission in indoor environments: Predicting risk reductions and operational costs." *Building and environment* vol. 70 (2013): 150-160. doi:10.1016/j.buildenv.2013.08.025

Also, filters are rated at capture efficiency in three different ranges of particles [E1 is 0.3 to 1 um (micron), E2 is 1 to 3 um (micron), and E3 is 3 to 10 um (micron)].

Therefore, we must understand the range of virus sizes in the airstream to evaluate a filters overall performance in capturing the virus.

Epidemic Conditions in Place

Filter Droplet Nuclei Efficiency / Particle Size Expectations

Several research studies used quantitative polymerase chain reaction, or q-PCR to identify the presence of viruses or bacteria in expelled droplets and droplet and offered insights not only into what size aerosols exist after expulsion from the human body, but in what size-fractions are viruses or bacteria actually present and are thus of most concern for infectious disease transmission.

A study published by Dr. Brent Stephens on March 1, 2012 for The National Air Filtration Association (NAFA) Foundation titled “HVAC Filtration and the Wells-Riley approach to assessing risks for infectious airborne diseases” The following is an excerpt from that study:

> *These previous studies all confirm that aerosols generated during coughing by influenza patients and subsequently remaining suspended in indoor environments indeed contain the influenza virus and that much of that viral RNA is contained within particles in the respirable size range (i.e., <4 μm). However, whereas ~100% of the number of particles emitted during the aforementioned coughing and breathing studies were smaller than 4 μm in size, only 40-70% of the influenza virus RNA is typically detected on particles in this size range (Blachere et al., 2009; Lindsley et al., 2010; Lindsley et al., 2010a), suggesting that the virus content of aerosols may actually be skewed toward larger particles. A bias toward the presence of virus particles contained in larger particle size fractions also suggests that particle surface area or volume may be more appropriate for characterizing infectious aerosols, which is reasonable considering that a 5 μm particle would have a volume approximately 100 times greater than a 1 μm particle and thus likely store a greater amount of virus particles inside droplet nuclei. Although there is considerable uncertainty in all of these measurements and sample sizes remain limited, these studies provide important insight into what size of expelled and suspended particles actually contain virus particles.*

Epidemic Conditions in Place

Filter Droplet Nuclei Efficiency / Particle Size Expectations

Below is a summary Table published by Azimi and Stephens in 2013:

Table 2
Review of recent studies detecting influenza virus in size-resolved particulate matter samplers.

Source	Sampling environment	Sampling location(s)	Particle size distribution of influenza virus reported			Assumed distribution of influenza virus in modified ranges for use with ASHRAE Standard 52.2 (F_i)		
						0.3–1 μm	1–3 μm	3–10 μm
[51]	Urgent care clinic	Personal indoor	<1.7 μm 32%	1.7–4.9 μm 16%	>4.9 μm 52%	19%	20%	62%
		Stationary indoor (lower floor)	<1 μm 13%	1–4.1 μm 37%	>4.1 μm 50%	13%	24%	63%
		Stationary indoor (upper floor)	<1 μm 9%	1–4.1 μm 27%	>4.1 μm 64%	9%	17%	74%
[52]	Hospital emergency room	Combination of personal and stationary indoor	<1 μm 4%	1–4 μm 49%	>4 μm 47%	4%	33%	63%
[53]	Cough aerosol collection system	Personal cough airstream	<1 μm 42%	1–4 μm 23%	>4 μm 35%	42%	15%	43%
[54]	Health center, daycare center, and airplanes	Stationary indoor	<1 μm 36%	1–2.5 μm 28%	>2.5 μm 36%	36%	37%	27%
[55]	Patient room with breathing manikin	Combination of personal and stationary indoor	<1 μm 19.5%	1–4 μm 75.5%	>4 μm 5%	20%	50%	30%
Mean viral distribution across all studies						20%	29%	51%
Standard deviation						14%	12%	18%
Relative standard deviation						0.70	0.44	0.36

Epidemic Conditions in Place

Filter Droplet Nuclei Efficiency / Particle Size Expectations

The studies previously shown, for Influenza A, indicates a potential starting point of filter's effectiveness as an overall for this virus based on the following anticipated distribution in the three filter ranges.

Filter Ranges (Particle Size)	Anticipated Distribution of Virus
E1 (0.3 um to 1 um)	20%
E2 (1um to 3 um)	29%
E3 (3 um to 10 um)	51%

Epidemic Conditions in Place

Filter Droplet Nuclei Efficiency / Particle Size Expectations

There have been a few studies for SARS-CoV-2 viable virus particle distribution that have been peer reviewed. Unfortunately, there are a few items with these studies that are as follows:

- Studies are not consolidating the viable particle size in the same size ranges as ASHRAE Std 52.2
- Studies do not have the same particle size comparison (e.g., one looks at less than or greater than 5 micron and another looks at less than 1 micron, 1 to 4 micron, and greater than 4 micron).
- The results of the studies do not show the same results for specific sizes that overlap.

However, there is something that appears to be consensus amongst the papers [9, 10, 11], which is that most of the viable particles are less than 5 micron in size.

Based on this information, we are suggesting a starting point for anticipated distribution of virus to be per the table:

Filter Ranges (Particle Size)	Anticipated Distribution of Virus
E1 (0.3 um to 1 um)	30%
E2 (1um to 3 um)	30%
E3 (3 um to 10 um)	40%

NOTE: The most conservative approach for the distribution would be for the E1 range to 100% of the particles.

Epidemic Conditions in Place

Filter Droplet Nuclei Efficiency / Particle Size Expectations

Applying these distribution ranges to typical filters, we can determine their efficiency at capturing the virus if the efficiency at each range is known. That formula would be as follows"

Droplet Nuclei Efficiency = E1 Distribution of Virus x E1 Removal Efficiency + E2 Distribution of Virus x E2 Removal Efficiency + E3 Distribution of Virus x E3 Removal Efficiency

If the person doing this evaluation wants to use a very conservative approach, then perform the calculations with 100% of the particles in the E1 range since that is the lowest efficiency of the three ranges for all filters.

This guide looked at a lot of different filter efficiencies since their performance depends on the manufacturer, construction, and filter media.

The team used data from two sources:

- ASHRAE RP-1088 titled Coordinate and Analyze Interlaboratory Testing of Filters under ASHRAE Standard 52.2 to Determine the Adequacy of the Apparatus Qualification Tests dated May 12, 2005 completed by RTI International and actual filter performance data from personal projects.

- Actual filter performance data reported by multiple manufacturers on over 140 different filters.

Epidemic Conditions in Place

Filter Droplet Nuclei Efficiency / Particle Size Expectations

The filters were then grouped into each MERV rating and then the average of each range was calculated.

The following table shows the MERV rating and associated filter efficiency.

MERV Rating (Based on 52.2-2017)	E1 (%)	E2 (%)	E3 (%)
4	10.3	29.9	11.9
5	8.0	28.0	33.0
6	7.8	30.0	43.5
7	10.8	36.6	55.6
8	15.1	51.6	73.7
9	17.8	52.4	84.8
10	16.6	59.0	86.7
11	33.9	69.4	90.1
12	37.6	86.1	99.8
13	66.3	92.4	97.8
14	81.4	96.6	99.3
15	86.4	97.8	99.1
16	95.0	98.0	98.0

Epidemic Conditions in Place

Filter Droplet Nuclei Efficiency / Particle Size Expectations

Using the distribution of potential virus particles and the efficiency of the filter in each of the ranges, the following is the table of the Filter Droplet Nuclei Efficiency to be used in the equivalent outdoor air calculations.

MERV Rating (Based on 52.2-2017)	Filter Droplet Nuclei Efficiency
4	16%
5	24%
6	28%
7	36%
8	49%
9	54%
10	57%
11	67%
12	77%
13	86%
14	93%
15	94%
16	97%

The filter's Droplet Nuclei Efficiency can now be used to determine the equivalent outdoor air that it will generate when calculating the time to achieve the **Flushing Between Occupied Periods**. goal of 3 volume changes.

Epidemic Conditions in Place

Practical Approach to Increase MERV in an AHU:

The following are practical steps an owner can take to evaluate the maximum MERV rating and HVAC system can accommodate while maintaining acceptable system performance:

1. Consider retaining the services of a qualified design professional, a certified commissioning provider (CxP) or a certified testing, adjusting and balancing (TAB) service provider especially for larger, more complex HVAC systems or for systems serving critical buildings or spaces within buildings.
2. If available, gather the documents described above under the System Evaluation section of this document. One of the most valuable documents to have on hand for analyzing filter upgrades would be the original TAB report if the building configuration, use and occupancy has not changed since the building was originally constructed. Consider having readings taken to confirm the values in the TAB report.
3. Determine the manufacturer, size and thickness and MERV rating of the existing filters. For example, 20 inches by 20 inches square, 1-inch thick, MERV 8. Obtain the filter's operating characteristics, including the ASHRAE 52.2 test data, from the manufacturer or the manufacturer's website.
    a. The upgrade could be finalized here if there is a higher rated MERV filter that has the same or lower pressure drop than what is currently installed.
    b. However, analyzing the rest of the filter assembly can also identify issues with leakage that should be addressed.

Epidemic Conditions in Place

Practical Approach to Increase MERV in an AHU:

The following are practical steps an owner can take to evaluate the maximum MERV rating and HVAC system can accommodate while maintaining acceptable system performance:

4. Inspect the filter frames inside the air handling equipment where the filters are installed to determine the filters fit tight within the frames and seals around the perimeter of the frame to minimize any air leakage around the filters (often called bypass air). For most filter frames, it would be wise to add silicone sealant on the upstream and downstream side of the frame as it meets with the AHU wall.
    a. There are many studies that show the impact of filter bypass. The following table is for a modeling study that shows the impact of leakage and filter performance [5]:

Filter	1 mm gap, 2 bends	1 mm gap, 0 bends	10 mm gap, 2 bends	10 mm gap, 0 bends
MERV 6	6	6	5	<5
MERV 11	11	11	8	8
MERV 15	14	14	8	8

    b. This table is from the in situ study to verify the model of filter bypass impact on overall assembly MERV rating [6]:

MERV with No Bypass	Gap Size 6.4 mm	19 mm	32 mm
7	6[a]	6	6
11	10	8	8
14	12/13[b]	8	8

[a]Modeled value predicted no decline for U-shaped filter (i.e., MERV 7)
[a]Straight-through = MERV 12, U-shaped = MERV 13

    c. These two items show that making sure the filters are installed properly and that the fame and assembly are sealed has a major impact on the actual performance of filter assemblies.

Epidemic Conditions in Place

Practical Approach to Increase MERV in an AHU:

The following are practical steps an owner can take to evaluate the maximum MERV rating and HVAC system can accommodate while maintaining acceptable system performance:

5. With the existing filters installed in the system, have the TAB agent perform and document a complete static pressure and temperature profile of the unit prior to any filter upgrades. This should be done per ASHRAE Standard 111-2008 (RA 2017) - Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation and Air-Conditioning Systems guidance. If the existing filters are dirty, have the TAB agent develop the profile with dirty filters installed, then change to clean filters of the same type as existing and develop a second profile. The profile should also document fan and motor RPM and power supply voltage and amp draw at each condition (old dirty filters, old filter type clean and new filter upgrade).

6. Obtain the airflow pressure drop of the proposed increased filter efficiency (MERV 13 or higher) and determine the appropriate "dirty filter" setpoint for the new filters. Have the TAB firm insert materials, such as cardboard pieces, to block the existing filters to achieve the upgraded filter dirty setpoint.

7. Have the TAB company develop the unit profile. The profile should also document fan and motor RPM and power supply voltage and amp draw.

8. In addition, facility managers should consider training their filter changing staff by having an integrity test completed after the facility team has changed the filters in one of the typical AHUs. This integrity test would identify any gaps and issues with the installation that should be used on future filter change outs.

Epidemic Conditions in Place

Practical Approach to Increase MERV in an AHU Continued:

8. The team should determine if this is an acceptable temporary operating point for the AHU.
   a. The TAB agent should be able to calculate the changes in airflow caused by the change in filters and determine the percentage reduction in airflow. If the unit's airflow does not drop by more than 5% from the original TAB report airflow, unit discharge temperatures do not drop too low, or the airflow is less than the recommended CFM per ton to potentially cause coil freezing or suction pressure issues in DX equipment, then the filter upgrade may not require any further adjustments to the unit.
   b. If airflow drops to low and causes problems, then have the TAB agent evaluate the fan drive to determine if the fan motor speed may be increased for direct drive fans using variable speed drives or that a sheave change can be made to belt driven fans to get the fan back to its pre-filter change airflow without overloading motor and drive maximum amp ratings.
   c. If the new filter MERV rated filter pressure drop is too great to allow the unit to operate within 95% of the pre-filter change airflow, consider dropping to a lower MERV filter and repeat the process.
9. Once the appropriate new filter MERV level is determined, obtain a set of filters that can be inserted into this unit's filter frame. Change out the existing filters to the new filters and have the TAB agent develop unit profiles with the new filters installed. The TAB agent should be able to calculate the changes in airflow caused by the change in filters and determine the percentage reduction in airflow. If the unit's airflow does not drop by more than 5% from the original TAB report airflow, unit discharge temperatures do not drop too low, or the airflow is less than the recommended CFM per ton to potentially cause coil freezing or suction pressure issues in DX equipment then the filter upgrade may not require any further adjustments to the unit.
10. If it is still desired to upgrade the system to a higher efficiency MERV filtration rate, consider retaining a licensed design professional to size and select new fans and motors and/or new air handler to perform to pre-filter change performance criteria with the new filter upgrade pressure drop increase. Have the engineer consider increased static pressure loads on the unit with both clean and dirty filters.
11. If an increase in filter MERV level cannot be accommodated using the existing air handling equipment fans and motors, consider using in room HEPA filter units in high occupancy or high bioburden (such as the building entry) spaces.

Epidemic Conditions in Place

Calculation Approach to Increase MERV in an AHU:

The following provides a simple example of how this process might work in the field [2] using the fan laws:

- AHU is equipped with MERV 8 filters.
- Following ASHRAE recommendations, the filter system will be upgraded to MERV 14.
- Commercially available filter data, yields the following information:
  - MERV 8 clean at 0.25 in w.g. and considered dirty at 0.5 in w.g.
  - MERV 14 clean at 0.3 in wg and considered dirty at 1.0 in. w.g.
- The proposed AHU is 23,000 cfm with a supply fan array using variable frequency drives (VFD) controlled to duct static setpoint.
- The analysis will be on a per fan basis.

Epidemic Conditions in Place

Calculation Approach to Increase MERV in an AHU Continued:

Filter Level	Supply Airflow CFM	Fan RPM	Static Pressure Fan (in. w.g.)	Fan Brake Horsepower	Fan Motor NamePlate Horsepower
MERV 8	23,000	2,216	5.3 Dirty	5.36	7.5
MERV 14	23,000	2,395	5.8 Dirty	6.7	7.5

Discussion on the findings of the Calculated Approach:

1. Assuming the unit is under a constant discharge duct pressure control, a static pressure profile of the unit should show a nearly constant pressure in the supply plenum and a gradually increasing negative pressure in the mixing box, filter array and coils on the inlet side of the fan.
2. Energy saving strategies such as reducing the discharge pressure of the unit to serve the VAV box with the greatest air demand should and could still be employed and continued.
3. There is commercially available software that evaluates the costs of material and labor for filter change out intervals. Good testing instrumentation should be available to trend and chart (and if desired record) filter pressure drops.
4. This is only an example. There are potential issues in maintaining airflow at design by increasing fan speeds.
   a. Fan speed cannot be upgraded because of the limits of that fan construction class is an example. In this case, manufacturers data indicate that the fan maximum rpm is 3125. Check with the fan manufacturer.
   b. If changing the motor would necessitate an electrical system upgrade, this solution may be cost prohibitive. In this case the owner may choose to operate the system at a reduced air flow. Reduced airflow in this example would be approximately 22,200 cfm.
   c. Filter bypass is a potential problem. If possible, conduct a light test to determine if there are any major cracks needing closure.
   d. Cabinet negative pressure leakage is also a potential problem. Check with the manufacturer as they will be following AHRI standards.

Epidemic Conditions in Place

Energy Savings Considerations:

The health, safety and welfare of building occupants and maintenance personnel should always come first. This means that facility operators and maintenance personnel should focus on verifying that systems are functioning properly, and maintenance routines are kept as scheduled where possible during the event or crisis. However, for buildings that are experiencing temporary reduced occupancies and closures, the HVAC systems should be operated in their unoccupied modes using relaxed temperature and humidity set points to help reduce energy consumption and cost.

You might want to also consider checking your systems control strategies optimization. The typical building strategies are outlined in ASHRAE Guideline 36-2018 - High-Performance Sequences of Operation for HVAC Systems. While this document does not cover all of the systems, it does give some general guidance to recommended control strategies.

When buildings are scheduled for re-occupancy, guidance for re-starting systems is included in this document and on the ASHRAE Covid-19 Website.

Epidemic Conditions in Place

Exhaust Air Re-entrainment

Re-entrainment of contaminants from exhaust air can occur in all buildings. Re-entrainment can occur at any receptor (outside air intake, operable window, doors, etc.). It is important to note that this is not a major concern for buildings that are not intentionally having COVID-19 positive people in the building or spaces. For re-entrainment of the virus to be an issue, there must be someone present in the building shedding, have it captured by the HVAC system, and be exhausted and then re-entrained through the outside air and re-introduced elsewhere. There is a very low percentage of being the transmission route for a building, but warrants being checked.

Please refer to the Exhaust Re-entrainment Guide for information on the different field investigations:

Level 0 - Observation for Re-entrainment Risk Assessment
Level 1 - Semi-Qualitative Re-entrainment Risk Assessment
Level 2 - Experimental Re-entrainment Risk Assessment
Level 3 - Qualitative based on known emissions Re-entrainment Risk Assessment
Level 4 - Expert Re-entrainment Risk Assessment

Epidemic Conditions in Place

Energy Recovery Ventilation (ERV) Systems Operation Considerations

The Building Readiness Team worked with Technical Committee (TC) 5.5 Air-to-Air Energy Recovery to create guidance on how to evaluate if the ERV is well-designed and well-maintained systems that are currently installed in the buildings. Those recommendations are covered in depth in The Practical Guidance for Epidemic Operation of Energy Recovery Ventilation Systems.

The following are critical excerpts of that document that can be applied to ERV systems.

Epidemic Conditions in Place

Energy Recovery Ventilation (ERV) Systems Operation Considerations

Many building HVAC systems include Energy Recovery Ventilation (ERV) systems, either stand-alone or integrated with Air-Handling Units (AHUs) or Dedicated Outdoor Air Systems (DOAS). Their purpose is to (1) facilitate or provide outside air ventilation and (2) to reduce the energy use and system capacity required to condition that outside air to comfort conditions.

HVAC Systems and Equipment ASHRAE Handbook Chapter 26 “Air-to-Air Energy Recovery Equipment” describe the various types of ERVs. It is important to note that this document is focused on ERV units with exhaust and supply ducts co-located in the same cabinet. These are typically rotary wheel and fixed-plate heat or energy exchangers, but occasionally heat pipes and thermosiphon heat exchangers are used in co-located ducts in the same cabinet. Any ERV within co-located ducts and equipment casings has potential for some leakage between airstreams. The coil energy recovery (runaround) loops, heat pipes and thermosiphon heat exchangers when built to provide distance, or a physical separation (an air gap) between the two airstreams, are not.

Epidemic Conditions in Place

Energy Recovery Ventilation (ERV) Systems Operation Considerations Continued

Leakage from the exhaust airstream to the supply airstream, if it occurs within the energy exchanger portion of the ventilation system, is referred to as Exhaust Air Transfer (EAT) (T-6). The rate of EAT being passed into the Supply Airflow is called the Exhaust Air Transfer Rate (EATR) (T-5).

In many HVAC systems air from the space also is deliberately Recirculated (T-10) into the supply airstream to the space so that the required heating and cooling can be provided.

Finally, air exhausted from the building can be pulled back into the outside air intakes through Re-entrainment (T-11).

Re-entrainment in an ERV is a specific case of a much larger issue affecting all HVAC systems.

Re-entrainment is discussed in the previous section above in this document.

Epidemic Conditions in Place

Energy Recovery Ventilation (ERV) Systems Operation Considerations Continued

When HVAC systems include recirculation, the recirculated portion of the systems' entire airflow is typically responsible for the reintroduction of more contaminated air from the space than is EAT in the ERV or from re-entrainment.

Some ERV units or sections are designed to allow for as much as 5% or 10% EATR. This is within ventilation standard allowances and is the most energy-efficient for some spaces and building types.

ERV systems for other spaces and building types such as healthcare facilities are designed to minimize EATR to negligible levels. When well-maintained and properly operated, the EAT may be similar to or an order of magnitude less than the re-entrainment amount.

Epidemic Conditions in Place

Energy Recovery Ventilation (ERV) Systems Operation Considerations Continued

Well-designed and well-maintained air-to-air energy recovery systems should remain operating in residences, commercial buildings and medical facilities during the COVID-19 pandemic.

This is because maintaining at least normal outside air ventilation rates, with proper temperature and humidity conditioning of the inside space, is important for maintaining health and combatting infectious aerosols.

Dilution of contaminants, including infectious aerosols, by outdoor air ventilation is an integral IAQ strategy in ASHRAE Standard 62.1. A properly designed system also includes filtration in many forms, along with proper building pressurization controls.

When it is known or expected that an infectious outbreak has or will occur in a building, the ERV systems should be inspected for proper operation and condition and be evaluated for possible contribution of bioburden to the building's supply air.

Epidemic Conditions in Place

Energy Recovery Ventilation (ERV) Systems Operation Considerations Continued

The term “well-designed” in the context of this document means:

- The supply and exhaust fan(s) are located correctly for pressure control at the exchanger,
- the ERV is sized for an appropriate velocity and pressure drop, and
- that appropriate seals or purges have been specified (or exist) for the application.

The term “well-maintained” assumes that the well-designed ERV device was:

- installed and set-up,
- tested and balanced correctly during the construction phase, and
- has received manufacturer’s maintenance requirements.

There is much more guidance in Chapter 26 Air-to-Air Energy Recovery Equipment of the ASHRAE Handbook.

In addition, TC-5.5 has produced practical advice for inspection here.

Epidemic Conditions in Place

Energy Recovery Ventilation (ERV) Systems Operation Considerations Continued

In a pandemic environment, it must be recognized that even if the units and systems are designed properly, they must have been constructed and maintained properly to confirm they are not allowing excess transfer of exhaust air to supply air.

It is also possible that the facility was not designed with pandemic conditions in mind.

The facility maintenance team should do a check of their systems, in accordance to the manufacturer's guidance. That should include consulting the original engineer of record, a Commissioning Provider and a Test and Balance (TAB) agent, if needed, to determine the ERV device is functioning properly based on the current situation and needs.

Epidemic Conditions in Place

Energy Recovery Ventilation (ERV) Systems Operation Considerations Continued

Changing system settings and sequences of operation without a good understanding of the effects on system operation could result in unintended consequences. These could include reduced outdoor air ventilation rates or the loss of control of indoor humidity conditions, both which could increase the potential, may themselves favor the spread of viruses.

When competent system operators are available, and the ERV has been deemed to be well-maintained, the most appropriate adjustment generally would be to continue operation of the ERV component appropriate to climate conditions and to potentially increase outside air ventilation rates.

Increasing ventilation rates is consistent with the ASHRAE Position Document – Infectious Aerosols and recommendations from REHVA.

Epidemic Conditions in Place

Energy Recovery Ventilation (ERV) Systems Operation Considerations Continued

Systems using Heat Pipes, Run-around loops and Thermosiphon exchangers with air gaps

When these systems are built with the supply and exhaust sides separated by a physical distance/air gap between the two airstreams, systems using coil energy recovery (runaround) loops, heat pipes, and thermosiphon heat exchangers will not have Exhaust Air Transfer into the supply airflow. They should be inspected to confirm that:

1. airflows are being maintained at design levels
2. filters are in good condition
3. fluid flow rates are per design
4. refrigerant charges are correct

Epidemic Conditions in Place

Energy Recovery Ventilation (ERV) Systems Operation Considerations Continued

Remediation of Systems with ERV Exchangers

If further inspection, than what is detailed herein, of the ventilation system is necessary, additional considerations should be added to the assessment.

Epidemic Conditions in Place

ERV Systems Design Considerations

The energy-recovery wheel or plate exchanger is a sub-component of the overall system and any analysis should be made based upon the total system configuration.

The following types will be discussed:

- Systems with Intentional Recirculation
- Systems with 100% Outside Air (No Recirculation)

Epidemic Conditions in Place

ERV Systems with Intentional Recirculation

If the ERV exchanger is installed in a system where the outdoor air portion of the total system airflow is being processed through the ERV, but a portion of the return air is being recirculated back to the space as shown in Figure 1 (as are most conventional packaged systems) then turning off the wheel would do little to improve the supply air quality since the EATR associated with the wheel could be small compared to the recirculation rate.

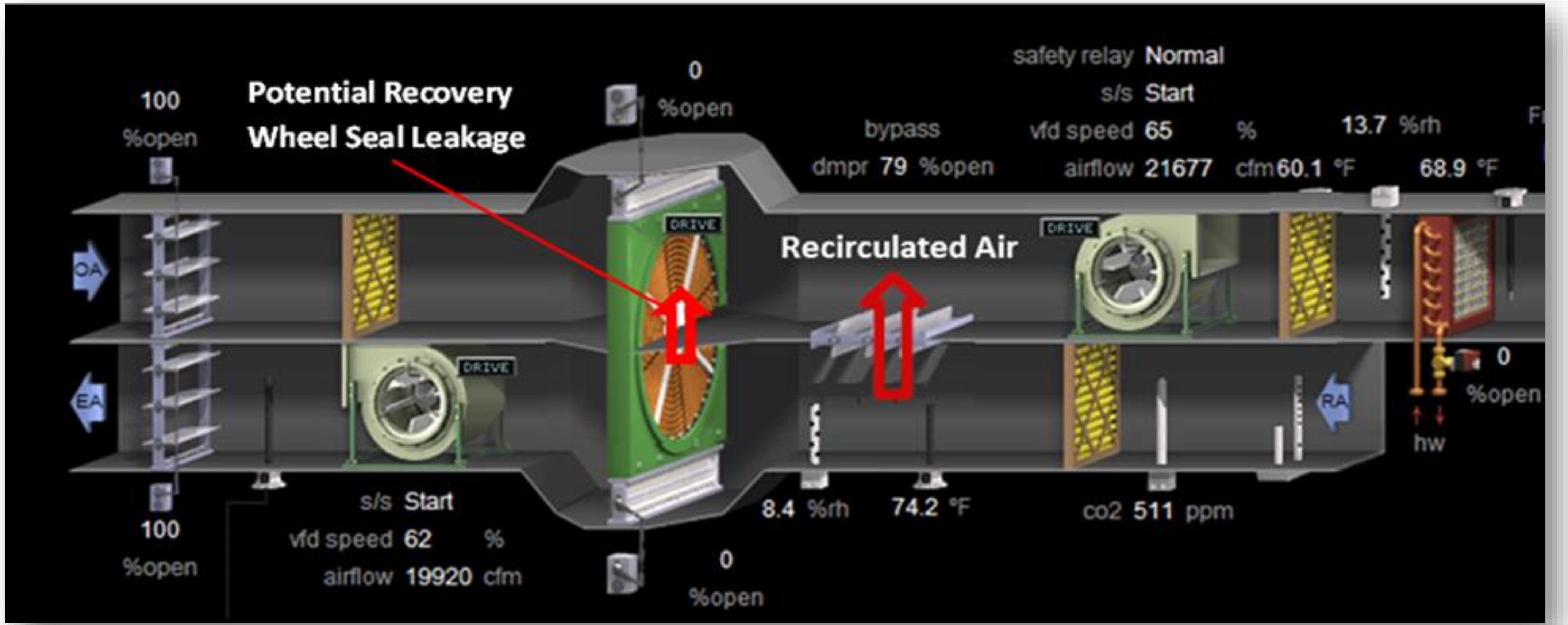


Figure 1 AHU Configuration with Recirculated Air and Energy Recovery Wheel Heat Exchanger

Epidemic Conditions in Place

ERV Systems with Intentional Recirculation Continued

However, if the unit has the capacity and capability such that the return air dampers can be closed and the system can be operated as a 100% outdoor air unit, this mode of operation might be preferred when pandemic concerns exist.

To accomplish this, the supply and return outside air ventilation rates should be increased, the recirculation damper closed, and the system balanced so that static pressures are correct for the exchanger type.

See the following section for a discussion of static pressures.

Epidemic Conditions in Place

ERV Systems with 100% Outside Air (No Recirculation)

If the recovery wheel is installed in a system that is processing 100% outdoor air (no intentional recirculation of return air) then the system re-entrainment and the exchanger EAT following system operational parameters should be considered to establish and assess any relative source of cross-contamination associated with the energy recovery wheel in the system.

Whether there is EAT at an ERV is strongly determined by the fan positioning in the energy recovery unit or HVAC system.

If the static pressure in the supply side of an exchanger is at least 0.5 inches water column (often abbreviated 0.5” or 0.5 in. H2O) greater than the static pressure in the return side air entering the energy recovery wheel, then any seal leakage will move from the clean to the dirty airstream and any carry-over will be insignificant.

Under these pressures, energy wheels equipped with a properly installed purge section have an EATR less than 1% and in some cases approaching zero. This can be substantially less than the re-entrainment previously discussed.

Epidemic Conditions in Place

ERV Systems with 100% Outside Air (No Recirculation) Continued

Exhaust Air Transfer can occur in ERV units or HVAC systems using plate exchangers as well. In most cases the Exhaust Air Transfer rates are lower, and the driving forces are confined to the static pressure differentials between the compartments adjacent to the exchanger.

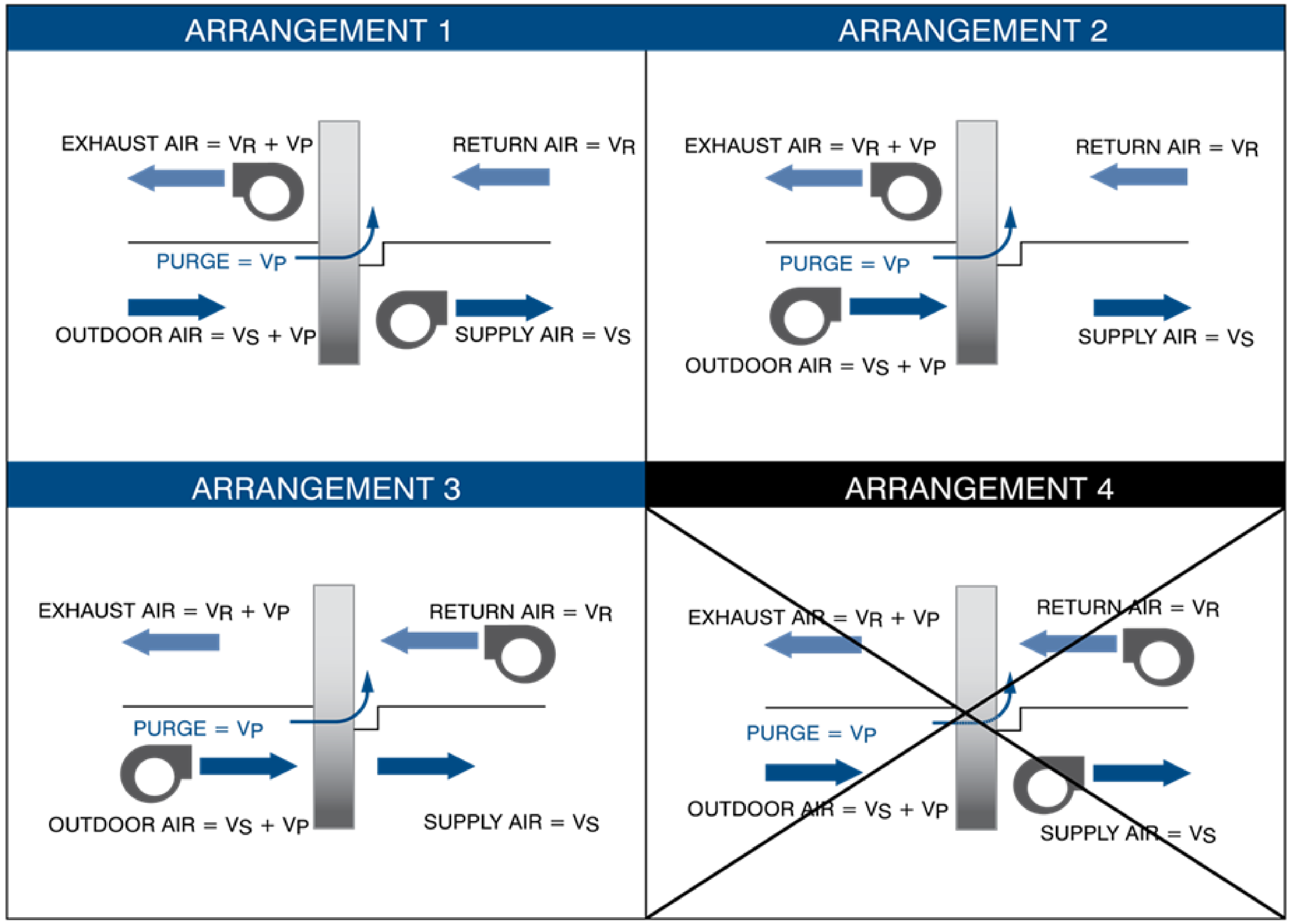


Figure 2 Fan arrangements for energy recovery exchangers

Epidemic Conditions in Place

ERV Systems with 100% Outside Air (No Recirculation) Continued

Figure 2 shows the potential fan configurations used for energy recovery or DOAS systems.

Fan positioning: **Arrangement 4 should not be used** since the seal leakage will always go from the dirty to the clean airstream and the purge section will not function in this manner. Exhaust Air Transfer ratio in excess of 10% will be typical.

Almost all energy recovery systems installed will employ either Arrangement 1 or Arrangement 2, and both can be effective in limiting Exhaust Air Transfer provided that a proper minimum pressure differential exists between the return and supply airstreams.

If a system uses Arrangement 2, and if, for wheels, a purge section is in place and the wheel is rotating in the proper direction (discussed later) then it is almost certain that leakage will move from clean to dirty and the purge section will function well with air carry-over being generally less than 1%, and therefore there is no need to measure to confirm system pressures except in the most critical applications. Arrangement 2 works well for plate exchangers as well.

Epidemic Conditions in Place

ERV Systems with 100% Outside Air (No Recirculation) Continued

If a system uses arrangement 1 or 3 shown in Figure 2, the static pressures at the inlets and outlets of the exchanger can be significantly impacted by the location of the supply fan being either before (blow through) or after (draw through) filters, coils and other components.

The pressure drops or rises caused by other components in the system including filters, ducts and coils can affect the pressure differential between the supply and exhaust sides of an energy wheel significantly.

Epidemic Conditions in Place

ERV Systems with 100% Outside Air (No Recirculation) Continued

The direction of leakage at the exchanger cannot be predicted without an understanding of the static pressures at the exchanger, but general trends, particularly with stand-alone ERV units, are as follows:

Rooftop units: these are typically ducted only at the exhaust air inlet and supply air outlet of the unit, so static pressure at the exchanger entering exhaust airflow is usually lower than at the entering supply airflow, therefore leakage is from outside air to exhaust air;

Indoor units: these are typically ducted at both inlet and outlet:

- When pressure drop between the unit and the building's inlet and outlet grilles are low compared to those on the other side of the unit, leakage at the exchanger again tends to be from supply to exhaust, resulting in no or low EATR.
- When pressure drop between the unit and the building's inlet and outlet grilles are high compared to those on the other side of the unit, leakage at the exchanger tends to be from exhaust to supply, and Exhaust Air Transfer occurs.

Epidemic Conditions in Place

ERV Systems with 100% Outside Air (No Recirculation) Continued

The above discussion is not intended as a substitute for inspection and validation that the ERV exchanger or unit is operating effectively, but as a guide to understanding the behavior of these systems and the mechanisms by which air from the building return and exhaust systems can be reintroduced to its supply air, intentionally or unintentionally.

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of All Types and Systems

This section provides the first steps in field inspection of ALL units or systems with ERV exchangers. It is assumed that the maintenance personnel is wearing the appropriate PPE for this process.

With system documentation in-hand, if possible:

1. Clean the unit with a vacuum to facilitate inspection. It may be helpful to remove filters in order to inspect the exchanger(s).
2. Clean the exchanger surface as recommended by the manufacturer, or simply clean the exchanger with a vacuum and soft brush (use a HEPA vac if possible, and always if the unit is inside a building).
   - NOTE: Some exchangers can be washed, others cannot. Confirm with the heat exchanger manufacturer that the cleaning and disinfection solutions proposed to be used are compatible with the heat exchanger's frame and heat exchange media.
3. Check for gross leak paths between compartments that might result from age or deterioration. Check inside the cabinet to see if light is coming in thru fastener holes or seams.

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of All Types and Systems Continued

This section provides the first steps in field inspection of ALL units or systems with ERV exchangers. It is assumed that the maintenance personnel is wearing the appropriate PPE for this process.

With system documentation in-hand, if possible:

4. Verify that seals exist on cabinet/casing access doors and that they are in good condition to prevent air from bypassing the exchanger between the access door and the wheel’s structural frame.
5. Check that the bypass and other damper are operating properly, not jammed, and that the damper seals are in good condition.
6. Determine the general layout of the system and identify the four compartments adjacent to the energy recovery exchanger, referring to Figure 6 for the standard designations. Also identify any bypasses between compartments.
7. Check filters: dirty filters affect airflow and pressure differentials.
8. Verify the outdoor air path is not obstructed (e.g. by clogged intake screen or louvers).

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Energy Wheels

For a person not very familiar with the energy recovery wheel device here are the very first steps to take when inspecting for proper operation.

Armed with the building systems documentation perform the following:

- Inspection with System Turned Off
- Inspection with System Operating
- Evaluation for Leakage

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Energy Wheels Continued

Inspection with System Turned Off

1. **Is the wheel clean?** This can affect both flow and leakage. A dirty wheel will change the operating characteristics of the fan system.
2. **Is there visible damage or areas of wear such as loose media, damaged media or degraded structural integrity?** These will affect the operation of the wheel and system.
3. **Are the seals set properly?** The two most common types of seals are contact/non-contact seals and you would have to refer to the original manufacturer to determine the proper setting. Seals should be inspected for wear. Older wheels that rely on seals that are in contact with the wheel surface may have seals that are worn or damaged.
4. **Is the wheel equipped with a purge?**

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Energy Wheels Continued

Inspection with System Turned Off

Purge sections a difficult item to provide guidance for as 90% of the purges are fixed. End users should be able to contact the wheel manufacturer using a fixed purge, and with the measured purge pressure, be given an estimate on the EATR.

Coupled with operating flows/pressures that aren't equivalent to the scheduled values, little can be done aside to changing system operational characteristics to match the scheduled values or providing a new purge to match the buildings operational characteristics.

Static pressure is the value that is most often inconsistent with the scheduled values.

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Energy Wheels Continued

Inspection with System Operating

With the system running and any wheel bypasses closed, confirm and record the following information:

1. **Is the wheel turning?** Many projects rely on the building management system or some other indicator, but the only sure way is to visually inspect. This should also include a determination that the wheel rotation direction is correct. To confirm proper rotation, a spot on the wheel should rotate from the return/exhaust airstream into the supply/outdoor airstream.
2. **Is the wheel rotating at the correct speed (RPM)?** An incorrect factory speed can be attributed to a replacement motor/pulley combination being used or an improperly programmed VFD. (Note: since Exhaust Air Transfer is lower at reduced wheel rotation speeds, it is most important that actual wheel rotation speed not be higher than the designed speed).

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Energy Wheels Continued

<u>Inspection with System Operating</u>

With the system running and any wheel bypasses closed, confirm and record the following information:

3. **Is the wheel turning in the correct direction?** When the wheel is equipped with a purge section, the wheel must rotate in a specific direction, see Figure 3.

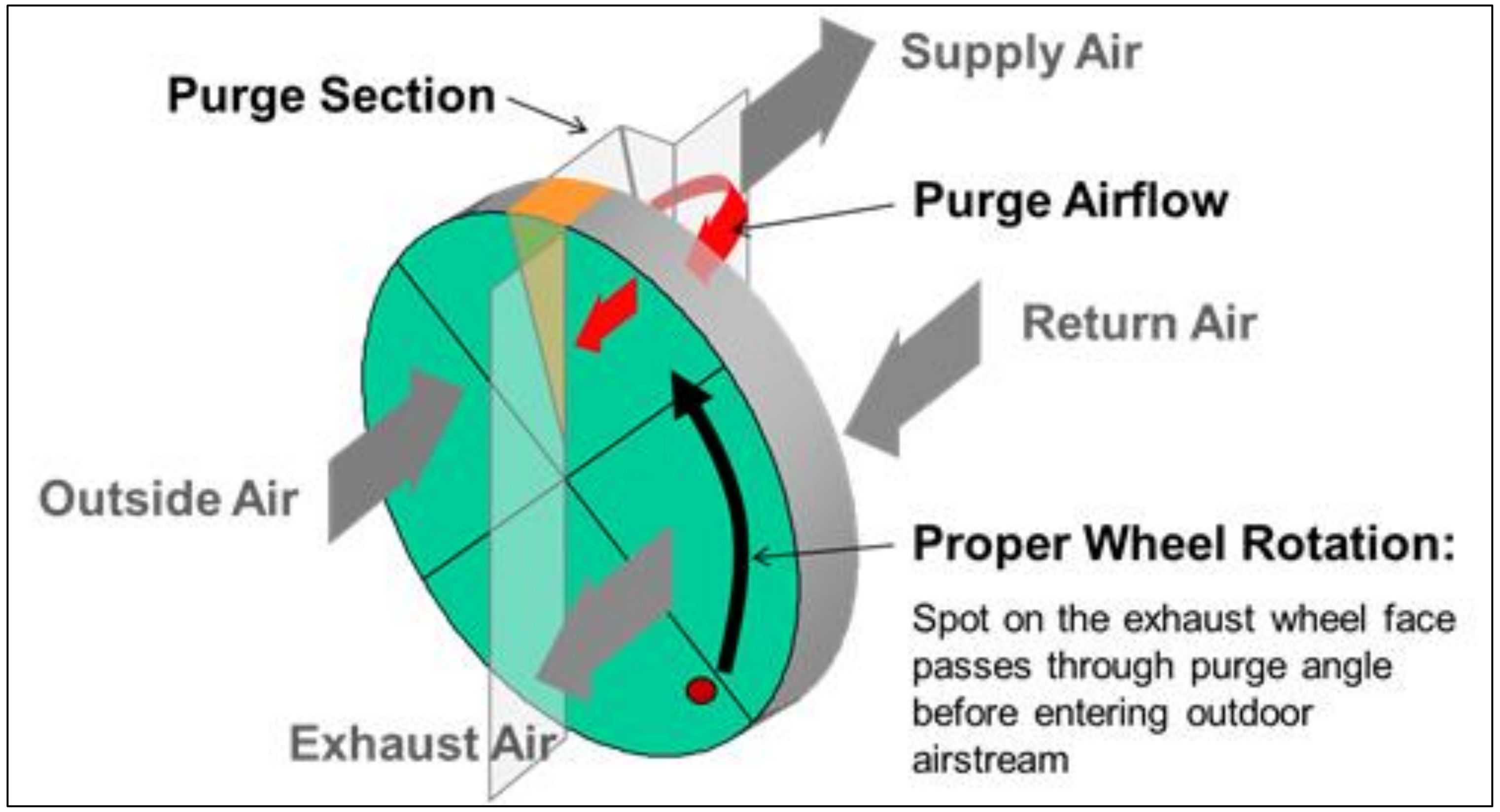


Figure 3 Illustration of the purge section and correct rotation direction for purge operation

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Energy Wheels Continued

Inspection with System Operating

With the system running and any wheel bypasses closed, confirm and record the following information:

4. With the ERV system operating normally with all bypass(es) closed, measure and record the static pressures in each of the four compartments around the exchanger. If the ERV has more than one operating mode, repeat this process. Figure 4 shows the items necessary to determine this information.

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Energy Wheels Continued

<u>Inspection with System Operating</u>

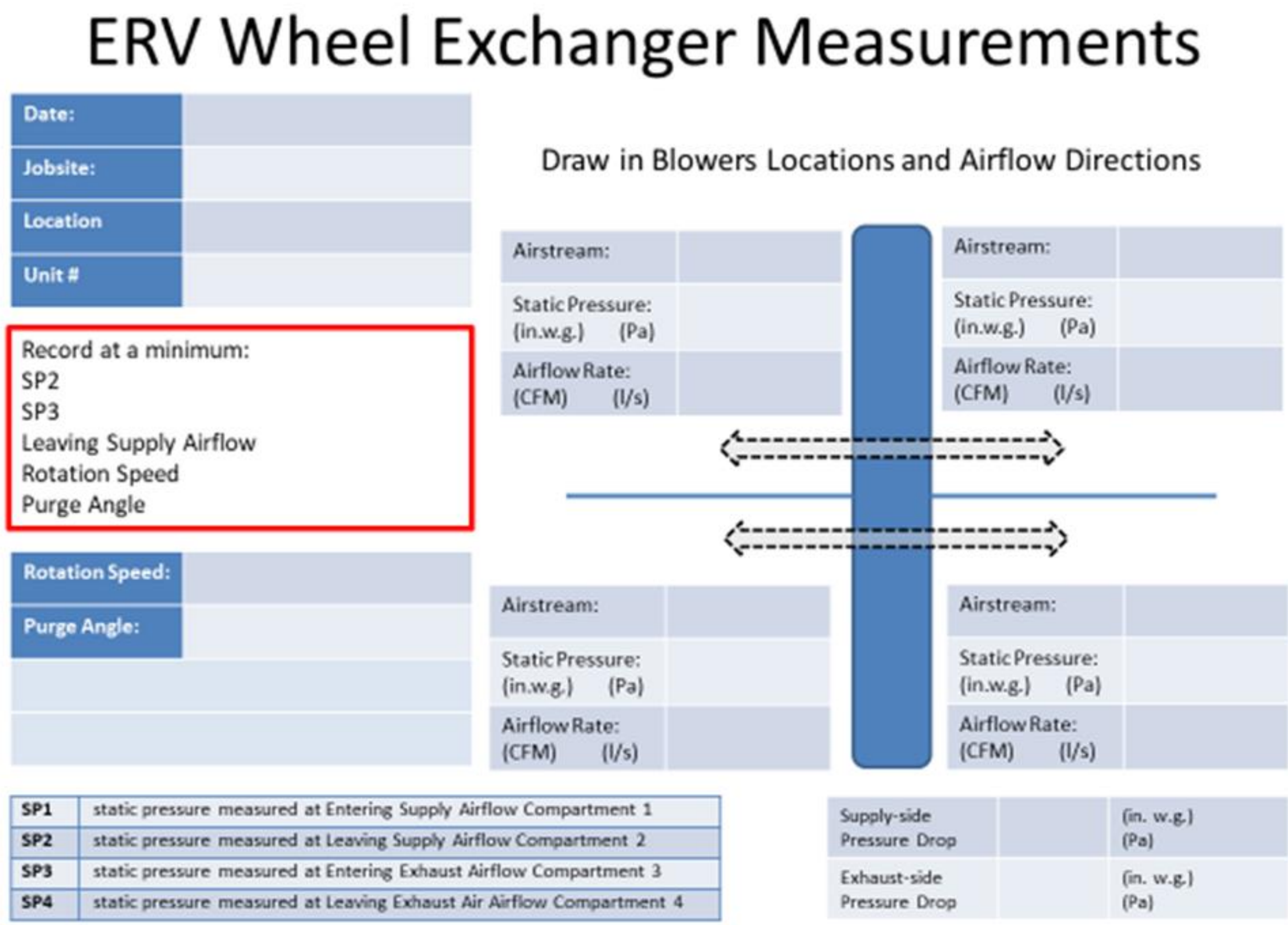


Figure 4 Field Recording Sheet for ERV Exchanger Operating Parameters

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Energy Wheels Continued

<u>Inspection with System Operating:</u>

Record the following items:

SP1	Record static pressure measured at Entering Supply Airflow Compartment 1
SP2	Record static pressure measured at Leaving Supply Airflow Compartment 2
SP3	Record static pressure measured at Entering Exhaust Airflow Compartment 3
SP4	Record static pressure measured at Exhaust Air Outlet Compartment 4

Table 1 Static Pressure Designations at Compartments adjacent to Exchanger

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Energy Wheels Continued

Evaluation for Leakage

1. Leaving Supply static pressure (P2) should be at least 0.5 in. w.g. greater than the entering return airstream static pressure (P3) measured near the wheel surfaces. This means there is a positive static pressure differential.

2. Positive pressure differential means the pressure at the supply outlet (P1) of the wheel is higher than the exhaust inlet of the wheel.

   As shown in Figure 5, this causes seal leakage in the desired direction: from supply air to return to be exhausted.

3. Pressure differential as-installed is frequently different from the original pressure differential calculated during design, refer to the original commissioning report, if available, that identified the as-installed initial pressure differential.

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Energy Wheels Continued

Evaluation for Leakage

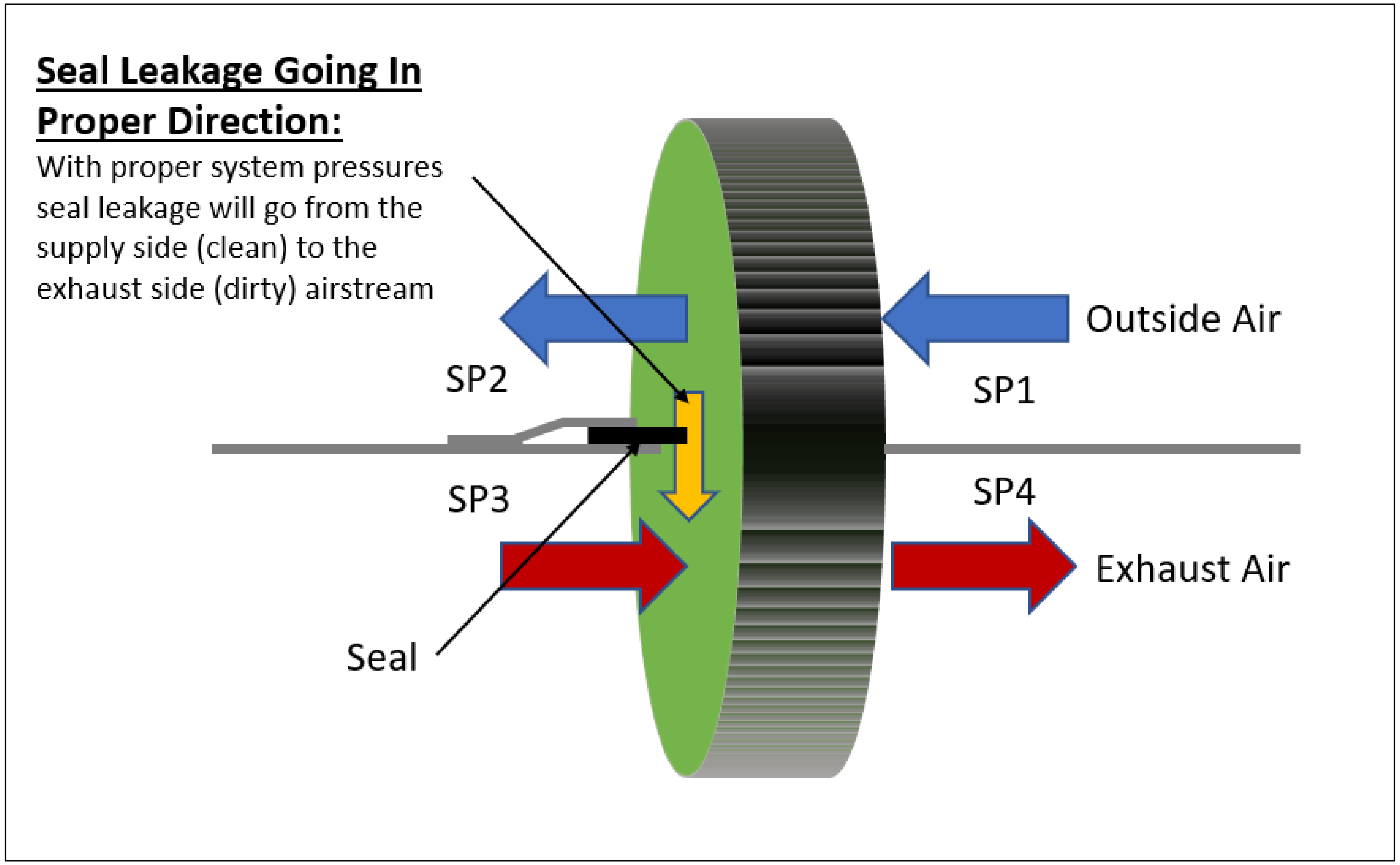


Figure 5 Supply static pressure should be higher than exhaust static pressure

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Energy Wheels Continued

Evaluation for Leakage

4. If there is a driving force for exhaust air transfer to the supply (P2 greater than P1), ask the ERV manufacturer for an EATR prediction. Provide the manufacturer the following information, at minimum: SP1, SP2, SP3, Rotation Speed, Purge Angle (if one is used) and Leaving Supply Airflow Volume.

5. Request the estimated exhaust air transfer as a volume rate (e.g. in CFM) at the specific operating condition.

6. To determine the Leaving Supply Airflow Volume, measure it directly if possible.

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Plates (or Heat Pipes with co-located ducts)

For a person not very familiar with the heat plate device here are the very first steps to take when inspecting for proper operation.

Armed with the building systems documentation perform the following:

- Inspection with System Turned Off
- Inspection with System Operating
- Evaluation for Leakage

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Plates Continued
(or Heat Pipes with co-located ducts)

Inspection with System Turned Off

1. Clean the exchanger surface as recommended by the manufacturer, or simply clean the exchanger with a vacuum and soft brush (use a HEPA vac if possible, and always if the unit is inside a building). Some exchangers can be washed, others cannot.

2. Check the exchanger for any splits that connect adjacent compartments, shrinkage or broken seals around the framing.

3. Determine the general layout of the system and identify the four compartments adjacent to the energy recovery exchanger. Also identify any bypasses between compartments.

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Plates Continued (or Heat Pipes with co-located ducts)

Inspection with System Operating

1. With the ERV system operating normally with all bypass(es) closed, measure and record the static pressures in each of the four compartments around the exchanger. If the ERV has more than one operating mode, repeat this process.

   Refer to Table 1 Static Pressure Designations at Compartments adjacent to Exchanger for a key to the static pressure designations. See also Figure 4 Field Recording Sheet for ERV Exchanger Operating Parameters.

   Note: The original wheel design may have required bypass dampers to be partially open to allow for a certain amount of air to bypass the wheel all the time. If that is the case, the bypass dampers should be set to the position established by the original TAB agent when the unit was originally TAB'd.

2. For each operating mode, measure or estimate the airflow rate in at least the ERV Exhaust inlet and the ERV Supply outlet.

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Plates Continued (or Heat Pipes with co-located ducts)

Evaluation for Leakage

1. SP1 should be higher than SP2. If not, there is no outdoor air flow, compartments are misidentified, or outdoor airflow is backwards.

2. SP3 should be higher than SP4. If not, there is no exhaust air flow, compartments are misidentified, or exhaust airflow is backwards.

3. If SP3 is greater than SP1 or SP2, there is a driving force for exhaust air transfer into the supply.

4. If SP4 is greater than SP1 or SP2, there is a driving force for exhaust air transfer into the supply.

5. If SP1 is a negative pressure, check again that the outside air path is not obstructed. After cleaning or replacing filters measure the pressures again.

Epidemic Conditions in Place

ERV Systems: On-Site Inspection of Plates Continued (or Heat Pipes with co-located ducts)

Evaluation for Leakage

6. If there is a driving force for exhaust air transfer to the supply (condition 3 or 4 above), ask the ERV manufacturer for an EATR prediction. Provide at minimum: SP1, SP2, SP3, Rotation Speed, Purge Angle (if one is used) and Leaving Supply Airflow Volume.

7. Request the estimated exhaust air transfer as a volume rate (e.g. in CFM) at the specific operating condition.

8. To determine the Leaving Supply Airflow Volume, measure it directly if possible.

NOTE: Some manufacturers of plate exchanger units provide charts which correlate pressure differences between the inlet and outlet compartments to the flow rate. Describe the condition of the exchanger to the manufacturer and ask whether these charts remain valid.

Epidemic Conditions in Place

UVGI SYSTEMS

There is a lot of ASHRAE (and others) guidance on ultraviolet (UV) technology for the built environment.

Please refer to some of the documentation to determine the best application for your building or systems:

- Filtration and Disinfection Guidance on the ASHRAE COVID-19 site
- Chapters in ASHRAE Handbook
  - 2019 Applications - Chapter 62: ULTRAVIOLET AIR AND SURFACE TREATMENT
  - 2016 Systems and Equipment - Chapter 17: ULTRAVIOLET LAMP SYSTEMS
- ASHRAE Journal article: Ultraviolet Germicidal Irradiation - Current Best Practices (2008, Martin et al)
- For upper room systems – NIOSH guidelines (2009)

Epidemic Conditions in Place

Bipolar Ionization and other Emerging Technologies

ASHRAE consulted with CDC regarding the use of Bipolar Ionization and other emerging technologies and received the following guidance:

"CDC does not provide recommendations for, or against, any manufacturer or manufacturer's product.

While bi-polar ionization has been around for decades, the technology has matured and many of the earlier potential safety concerns are reportedly now resolved. If you are considering the acquisition of bi-polar ionization equipment, you will want to be sure that the equipment meets UL 2998 standard certification (Environmental Claim Validation Procedure (ECVP) for Zero Ozone Emissions from Air Cleaners) which is intended to validate that no harmful levels of ozone are produced.

Relative to many other air cleaning or disinfection technologies, needlepoint bi-polar ionization has a less-documented track record in regard to cleaning/disinfecting large and fast volumes of moving air within heating, ventilation, and air conditioning (HVAC) systems. This is not to imply that the technology doesn't work as advertised, only that in the absence of an established body of evidence reflecting proven efficacy under as-used conditions, the technology is still considered by many to be an "emerging technology".

<u>As with all emerging technologies</u>, consumers are encouraged to exercise caution and to do their homework. Consumers should research the technology, attempting to match any specific claims against the consumer's intended use. Consumers should request efficacy performance data that quantitively demonstrates a clear protective benefit under conditions consistent with those for which the consumer is intending to apply the technology. Preferably, the documented performance data under as-used conditions should be available from multiple sources, some of which should be independent, third party sources."

Epidemic Conditions in Place

Domestic Water & Plumbing Systems

Building owners and operators should review the following industry guidance related to building shutdowns and re-opening:

- Centers for Disease Control and Prevention (CDC) - Guidance for Reopening Buildings After Prolonged Shutdown or Reduced Operation:
- American Water Works Association (AWWA) - Shutoffs and Return to Service Guidance
- US Environmental Protection Agency - Information on Maintaining or Restoring Water Quality in Buildings with Low or No Use
- ASHRAE Standard 188-2018: Legionellosis: Risk Management for Building Water Systems
- Guideline 12-2020 - Managing the Risk of Legionellosis Associated with Building Water Systems
- Departments of Health – Building owners and operators should be aware of information provided by their state or local Departments of Health
- Water Utility Providers – Building owners and operators should coordinate with water utility providers.
- Authorities Having Jurisdiction - Building owners and operators should coordinate with local authorities having jurisdiction for policies adopted for low or no use building occupancy and re-commissioning water systems.
- Purdue University Considerations for Large Building Water Quality after Extended Stagnation

Epidemic Conditions in Place

Domestic Water & Plumbing Systems Continued

Building owners and operators should review existing water management plan or program documents. If this document is not available, develop a water management program for your water system and all devices that use water.

Guidance to help with this process is available from CDC and others.

In general, fresh water should be drawn into building water systems and stagnant water flushed out before they are reopened.

Epidemic Conditions in Place

Domestic Water Systems Continued

Keep water above 140°F to avoid microbial incursion. Do not let it drop below 120°F. Refer to Figure 1 from [ASHRAE Guideline 12-2020]():

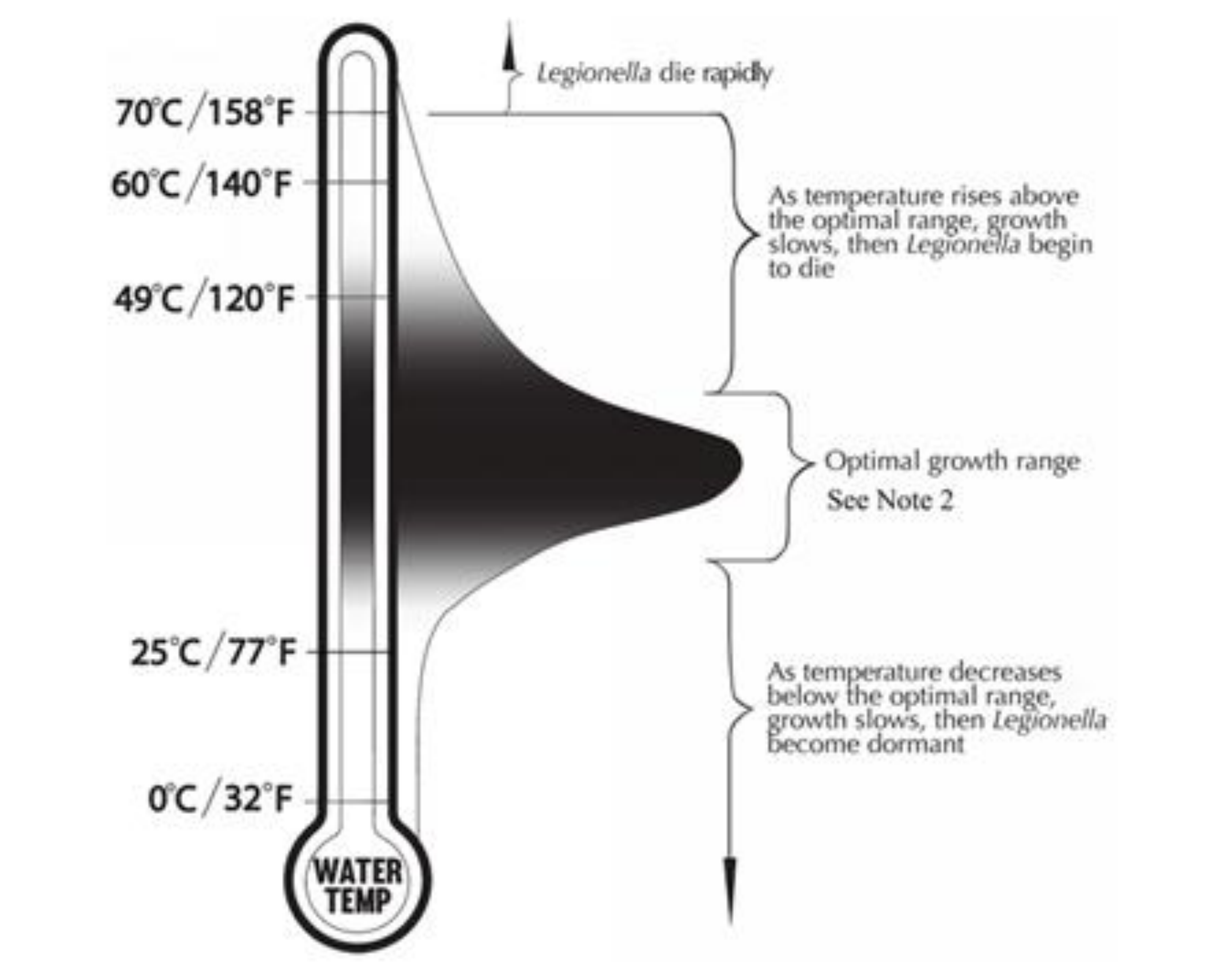


Figure 1 Temperature effects on survival and growth of *Legionella* in laboratory conditions.

Epidemic Conditions in Place Maintenance Checks

For equipment within a building that is not identified within this response, we recommend referring to the following documents for additional guidance:

- ASHRAE Standard 180-2018: Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems.
- ASHRAE Standard 188-2018: Legionellosis: Risk Management for Building Water Systems
- ASHRAE Guideline 12-2020: Managing the Risk of Legionellosis Associated with Building Water Systems

Epidemic Conditions in Place Maintenance Checks

General Recommendations:

- ❑ Notify Tenants of exact dates and times the building will be setback.
- ❑ Check remote or offsite access connections to the Computerized Maintenance Management
- ❑ System (CMMS), Building Management System (BMS), and Building Automation System (BAS) to make sure they are functioning properly and can be logged into, if any.
- ❑ Assign personnel rotation for weekly onsite rounds, provide a schedule for the rounds and trades.
- ❑ Set up a log for tracking all adjustments and trends to identify deviations from the program.
- ❑ Verify all the modes modified are working daily.

Epidemic Conditions in Place Maintenance Checks

Heating, Ventilating & Air-Conditioning

Where semi-annual / annual scheduled maintenance on the equipment can be performed safely, do not defer this maintenance cycle. Where worker safety could be at risk, consider deferment of semi-annual / annual maintenance on the equipment up to 60 days.

The following are recommended as minimum verification/checks to be performed:

Boilers (Monthly):

- ❑ For systems with Steam Boilers, develop a schedule that provides minimum supervision on-site.
- ❑ Perform chemical testing of system water. Verify water treatment target levels are being maintained.
- ❑ For systems using fuel oil
- ❑ Check fuel pump for proper operation.
- ❑ Inspect fuel filter; clean and verify proper operation.
- ❑ For systems using natural gas
- ❑ Check gas pressure, gas valve operation, and combustion fan operation.
- ❑ Check for evidence of leakage of fuel supply, heat transfer fluid, and flue gas.
- ❑ Verify proper operation of safety devices per manufacturer's recommendations.

Chillers (Monthly):

- ❑ Perform chemical testing of system water. Verify water treatment target levels are being maintained.
- ❑ Check control system and devices for evidence of improper operation.
- ❑ Check variable-frequency drives for proper operation.

Epidemic Conditions in Place Maintenance Checks

Heating, Ventilating & Air-Conditioning Continued:

Air Cooled Chillers:

- ❑ Check refrigerant system for evidence of leaks
- ❑ Check/clean fan blades and fan housing
- ❑ Check/clean for fin damage
- ❑ Check for proper fluid flow and for fluid leaks

Water Cooled Chillers:

- ❑ Check refrigerant system for evidence of leaks
- ❑ Check for proper fluid flow and for fluid leaks
- ❑ Check compressor oil level and/or pressure on refrigerant systems having oil level and/or pressure measurement means

Cooling Towers and Evaporative-Cooled Devices (Monthly):

- ❑ Perform chemical testing of system water. Verify water treatment target levels are being maintained.
- ❑ Check chemical injector device for proper operation
- ❑ Check conductivity and other sensors for proper readings
- ❑ Check water system ultraviolet lamp, replace bulbs as needed (if applicable)
- ❑ Check control system and devices for evidence of improper operation
- ❑ Check variable-frequency drive for proper operation
- ❑ Check for proper fluid flow and for fluid leaks
- ❑ Check for proper damper operation
- ❑ Inspect pumps and associated electrical components for leaks and normal operation

Epidemic Conditions in Place Maintenance Checks

Heating, Ventilating & Air-Conditioning Continued:

Steam Distribution Systems (Monthly):

- ❑ Perform chemical testing of system condensate and feed water
- ❑ Check piping for leaks
- ❑ Check steam traps and condensate return units for proper operation
- ❑ Check safety devices per manufacturer's recommendations

HVAC Water Distribution Systems (Monthly):

- ❑ Perform chemical testing of system water. Verify water treatment target levels are being maintained.
- ❑ Check for proper fluid flow and for fluid leaks. If necessary, vent air from system high points and verify backflow preventers and pressure regulating valves on makeup water lines are functioning properly.
- ❑ Check expansion tanks and bladder type compression tanks have not become waterlogged

Pumps:

- ❑ Inspect pumps and associated electrical components for proper operation
- ❑ Check variable-frequency drive for proper operation
- ❑ Check control system and devices for evidence of improper operation

Air Handling Units (Monthly):

- ❑ Check for particulate accumulation on filters, replace filter as needed
- ❑ Check ultraviolet lamp, replace bulbs as needed (if applicable)
- ❑ Check P-trap
- ❑ Check control system and devices for evidence of improper operation
- ❑ Check variable-frequency drive for proper operation

Epidemic Conditions in Place Maintenance Checks

Heating, Ventilating & Air-Conditioning Continued:

Roof Top Units (Monthly):

- ❑ Check for particulate accumulation on outside air intake screens and filters, replace filter as needed
- ❑ Check ultraviolet lamp, replace bulbs as needed (if applicable)
- ❑ Check P-trap
- ❑ Check control system and devices for evidence of improper operation
- ❑ Check variable-frequency drive for proper operation
- ❑ Check refrigerant system for leaks
- ❑ Check for evidence of leaks on gas heat section heat-exchanger surfaces
- ❑ Check variable-frequency drives. For fans with belt drives, inspect belts and adjust, as necessary

Water-Source Heat Pumps (Monthly):

- ❑ Check for particulate accumulation on filters, replace filter as needed
- ❑ Check P-trap
- ❑ Check control system and devices for evidence of improper operation

Epidemic Conditions in Place Maintenance Checks

Plumbing Systems

Follow recommended operations as outlined in the Building's Legionella Management Plan. In absence of this plan, the following are minimum recommendations.

- ❑ Water features and fountains - shutdown per manufacturer's instructions and drain.

Plumbing Rounds (Weekly):

- ❑ Flush piping systems through drinking fountains, lavatories, urinals, water closets and sinks to prevent stagnation
- ❑ Verify wet floor sinks and drains remain wet
- ❑ Check for proper fluid flow and for fluid leaks
- ❑ Inspect booster pumps system for proper operation
- ❑ Inspect Domestic Hot Water heater for production of hot water at 140°F
- ❑ Inspect pumps and associated electrical components for proper operation
- ❑ Check the recirculation system for proper flow and for fluid leaks
- ❑ Inspection of secondary disinfection system for proper operation (if applicable)

Epidemic Conditions in Place Maintenance Checks

Electrical Systems:

- ☐ Disconnect all non-essential appliances wherever possible from power outlets. Coordinate with building tenants or departments.
- ☐ Turn off lights, keep the emergency and egress lighting energized.

Special Systems:

- ❑ Inspect fire alarm master panels and other life safety equipment with battery backup power supplies are functioning. (Weekly)
- ❑ Inspect the battery backup power supplies for IT and IOT devices and mission critical systems. (Weekly by IT personnel)
- ❑ Run emergency or backup generators, test transfer of power, per manufacturer's recommendations. (Monthly)

Shut Down a Building Temporarily

General Recommendations:

1. Notify relevant people of the need to shut down or partially occupy the building. Include exact dates and times the building will be shut down.

2. Backups and Data Protection–Backup all necessary computer data, e.g. building control systems and servers to local and/or cloud-based backup services and media.

   a. If there are tenants that need to use the building during lockdown, they should refer to the Commercial Building Guide on ashrae.org/COVID19 site under the "**Buildings**" section, as the building may not be able to be shut down.

3. Check important remote or offsite access connections to the Building Management System and Building Automation System (BMS includes more than the HVAC controls in the BAS) to make sure they are functioning properly and can be logged into, if any. For example, remote observation via the security and access platforms, such as security cameras, locks, alarms and more can help monitor the building for emergencies remotely.

4. Operators should confirm that they have electronic copies of their building plans, past test and balance reports, operation and maintenance (O&M) manuals, systems manual and other pertinent information to operate the building.

5. If someone does visit the building to check, they could also be tasked with watering any of the plants.

Shut Down a Building Temporarily

Heating, Ventilating & Air-Conditioning

1. **In buildings equipped with a Building Automation Systems (BAS):**
   a. It is not recommended to completely shut off HVAC systems in a building that is being temporarily shut down or unoccupied for an undetermined amount of time during an emergency.
   b. Operate or place the HVAC systems in the Unoccupied Mode using the BAS. For example, if the system is normally controlled to a 70°F heating with 40% RH and 75°F cooling setpoint at about 55% RH when the building is occupied, then having the limits in heating at set back to 65°F, 40% RH and cooling limits up to (80°F, 60% RH) is reasonable. If the limits are exceeded while in the Unoccupied Mode, the systems should be enabled and allowed to operate, with the OA dampers at minimum and exhaust fans off, until the space returns the Unoccupied Setpoint conditions. The intent is to maintain the building within a reasonable range of temperature and humidity conditions to help avoid developing poor indoor conditions while reducing energy consumption during the shutdown.
   c. If occupants are going to be allowed to use the building on a partial or limited basis during a shutdown, it may be desirable to program an override into the BAS to allow the systems to be returned to normal Occupied modes of operations for temporary length of time, such as for two hours. After the override period expires, the system should automatically return to the Unoccupied setpoints.
   d. Check if all the setbacks and setup modes are working.

2. **A building without a BAS may require more set-up time to have the building be shuttered and may require more direct monitoring on site during the shutdown.**
   a. Recommend that the HVAC systems should not be completely shut down in any building where the building is being unoccupied for any length of time if the intent is to re-occupy the building in the future.
   b. In addition, we do not recommend extreme setbacks for heating thermostat setpoints or extreme setup for cooling thermostat setpoints. The intent is to set the individual controls on the equipment to do the following–maintain a cooling space setpoint of 80°F and less than 60% RH in cooling and 65°F and minimum 40% RH in heating.
   c. Any outside air dampers should be set to their minimum position for building pressure. The exhaust fans other than those in restrooms and critical applications should be turned off.
      i. If the OA dampers are closed, all exhaust fans shall be turned off.
   d. Monitoring the building regularly to confirm that no unexpected consequences are occurring such as condensation, moisture or fungal growth on HVAC system components or building surfaces and finishes.

Shut Down a Building Temporarily

Heating, Ventilating & Air-Conditioning Continued:

3. **Boilers and distributed hot water:**
    a. If the building has more than one boiler, reduce the number of operating boilers to bare minimum needed. If the building is going to be offline for more than 60 days, dry storage is recommended via desiccants or inert gas blanketing. If using inert gas, follow OSHA safety protocols.
    b. For boilers less than 300 hp, a heat source (light bulb) with a fan may be enough. Warm wet storage is acceptable; oxygen scavenger residuals in the boiler should be 500% of normal (i.e. if you normally run 20 to 40 ppm of sodium sulfite, maintain 100-200 ppm during mothball period).
    c. Maintain 400-600 ppm P-alkalinity during wet storage.
    d. Boilers should fire and circulate once per week for a minimum of 1 hour.
    e. **Cold wet storage is discouraged!** Equipment could suffer significant corrosion damage.
    f. If the boilers are offline, drain all deaerators, feed water tanks, surge/condensate receivers, superheaters and economizers. If you cannot drain them, make sure they are fully flooded, and oxygen scavenger levels are at 500% of normal.
    g. If steam lines are idle, make sure all steam traps and condensate receivers are empty. Be prepared to dump condensate for several days upon restart due to flash rusting developing on the interior surfaces of the lines.

4. **Cooling towers, chillers and chilled water distribution piping:**
    a. Many facilities have a water risk management plan such as an ANSI/ASHRAE Standard 188-2018, Legionellosis: Risk Management for Building Water Systems, to provide guidance and protocols to minimize the risk of water borne pathogens, such as *legionella pneumophila* in their utility water systems. If you have a plan and it addresses shut down and restarts of this magnitude, follow it. If you do not have a plan:
        i. Keeping systems running keeps the equipment in the best shape. Set the BAS to unoccupied temperature and humidity setbacks and monitor and adjust to preserve IAQ and building elements.
        ii. With all mechanical systems, if you do not use it, nature takes it back. If you are taking chilled water systems down for an extended period, completely drain the cooling towers, chillers, heat exchangers and associated piping. Leaving the system with stagnant water can result in severe corrosion, biofouling and contribute to transmission of Legionnaires' disease. Be prepared for rust and biological incursions when bringing branch lines back into service. Do a complete system flush to restore design water parameters and clean strainers throughout. Consider adding side stream filtration.
        iii. Try to maintain circulation in main chilled water loops, the larger the loop the greater the importance.
        iv. If operating at reduced capacities for extended duration, for HVAC hydronic loops, increase the frequency of testing and adjusting of biological control regimen by your water treatment provider.

Shut Down a Building Temporarily

Domestic Water & Plumbing Systems:

1. Building owners and operators should coordinate with local authorities having jurisdiction, state or local Departments of Health and water utility providers for policies adopted and recommended best practices for low or no occupancy situations.

2. Review existing water management plan or program documents and execute steps for system shutdown. If this document is not available, develop a water management program for your water system and all devices that use water. Guidance to help with this process is available from CDC and others.

3. Many water risk management plans provide guidance and protocols to minimize the risk of waterborne pathogens such as legionella pneumophila in their utility water systems.

4. Regularly turn on the water and run the drinking fountains, lavatories, urinals, water closets and sinks. Do this once a week or as needed to maintain a minimum disinfectant residual and avoid issues with stagnant water.

5. Make sure all plumbing P and U-traps are wet (filled with water) and check them routinely during the unoccupied times.

Shut Down a Building Temporarily

Domestic Water & Plumbing Systems Continued:

6. Water features should be shut down and properly drained , including ice machines, coffee makers or other devices with water reservoirs. This should be part of the water risk management plan.

7. Consider shutting down and draining water heaters.

8. If water heaters continue to operate, confirm water heaters are properly maintained, the temperature is correctly set, and water is circulating.

   Keep water above 140°F to avoid microbial incursion. Do not let it drop below 120°F. Refer to Figure 1 from ASHRAE Guideline 12-2020.

Shut Down a Building Temporarily

Domestic Water & Plumbing Systems Continued:

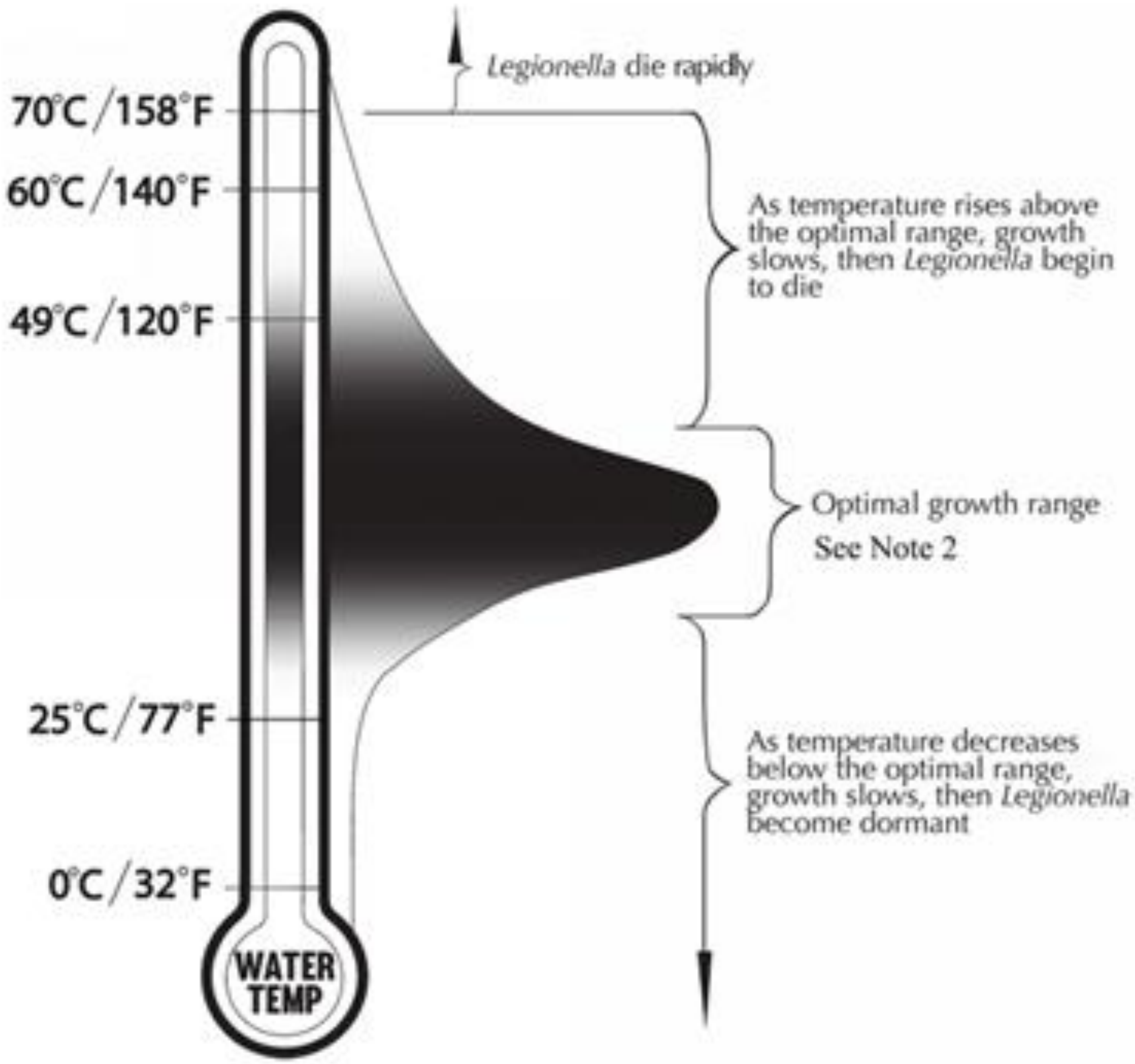


Figure 1 Temperature effects on survival and growth of *Legionella* in laboratory conditions.

Shut Down a Building Temporarily

Electrical Systems:

1. Unplug or disconnect non-essential appliances wherever possible– unplug any and all appliances that don’t need to stay powered on to avoid “Vampire or Phantom Appliances”.

These including but are not limited to:

- Computers
- Routers
- Modems
- Televisions
- Printers
- Chargers
- Microwaves
- Vending machines (remove food that may spoil before disconnecting vending machines that store food and perishables)
- Things that turn on with a remote control

2. It is important to work with your IT department because some computers and monitors will need to remain powered on to facilitate remote desktop functions for remote working employees.

Shut Down a Building Temporarily

Special Systems:

1. Check on fire alarms and other equipment with battery backup power supplies. Consider having an electrical technician come and check that everything is working properly.

2. Check on the battery backup power supplies for IT and IOT devices, especially the ones that are mission critical. These items include but are not limited to servers, BAS, communication systems, lighting control systems and security systems.

3. If the building is equipped with an emergency or backup generator, arrange to have it tested regularly as required by codes, local jurisdictions and the manufacturer’s recommendations.

ECiP - Systems Manual

A Systems Manual should already be in place for normal operations which is a system-focused composite document that includes the design and construction documentation, facility guide and operation manual, maintenance information, training information, commissioning process records and additional information of use to the Owner during occupancy and operations. If there is not an existing Systems Manual, refer to [ASHRAE Guideline 1.4-2019: Preparing Systems Manuals for Facilities] for guidance to build that document.

While the Systems Manual should include all modes of operation, it is unlikely that it would include a mode for Epidemic Conditions in Place. During an Epidemic, the Systems Manual should be updated to include special operations and considerations such as:

1. Indicate which systems will remain online without alterations.
2. Indicate which systems will remain online with alterations.
    a. Detail special provisions
    b. Detail revised sequences of operations
    c. Include any BAS checks to make sure the proper mode is engaged
3. Indicate which systems will be de-energized
    a. If these include water systems, indicate how those will get water flow occasionally to avoid growth issues
4. Outline daily activities and documentation that might be different than the normal facilities checks. Include updated data logs and forms as needed.

Just as a normal Systems Manual might be used in the training of the operations and facility staff and occupants before and during normal operations, the updated Systems Manual that includes the Epidemic Conditions in Place Mode should also be used to train operations and facility staff and occupants. This training should be done prior to switching to Epidemic Conditions in Place Mode for the facility and during the event.

Re-opening During Epidemic Conditions in Place

1. There are many buildings that are re-occupying prior to the Epidemic or Pandemic being fully over for your locale.

2. Please refer to the “P-EciP: Prior to Occupancy” section of this document.

Post-Epidemic Conditions in Place (P-ECiP)

There are actions that should be done prior to occupying a building that has been unoccupied or shut down during the epidemic versus the continued operation after it has been made ready for occupancy. This document splits those into:

Prior to Occupying

Operational Considerations once Occupied

The following items should be done based on a Safety Benefit analysis for your system, building, occupancy and climate. These are general suggested actions that need to be applied to your specific systems in your specific building.

P-ECiP: Prior to Occupying

Re-starting a Building

The intent of re-starting a building is for when the work-remote orders are retracted, and the threat of exposure is greatly reduced. Those are listed below for many systems in the building. If you are restarting a building still at a high-level threat of exposure, please review following information in the "**Buildings**" section on the ashrae.org/COVID19 site.

- Commercial Building Guide
- Schools
- Healthcare
- Transportation

P-ECiP: Prior to Occupying

General recommendations

1. Prior to starting the building, operators may want to create a strategic plan that includes the following:
   a. Create measures to make occupants feel safer
   b. Confirm supply chain for critical items, such as filters, as confirmed for delivery
   c. Review contractual agreements with tenants with regards to building support
   d. Establish a communication protocol with tenants and include key contacts
   e. Prepare and provide training for tenants on safety measures

It is important to note, that if you are opening when PPE requirements are still in place, the Occupancy Guides should be referenced as they deal with functioning buildings during the epidemic.

2. Notify relevant people - include exact dates and times that the building will be reopened.

3. Follow all local, state and federal executive orders, statutes, regulations, guidelines, restrictions and limitations on use, occupancy and separation until they have been officially relaxed or lifted.

4. Follow CDC advice regarding PPE

5. Follow OSHA Guidelines

P-ECiP: Prior to Occupying

General recommendations continued:

6. Confirm that custodial scope includes proper cleaning procedures built from EPA, OSHA and CDC guidance on approved products and methods:
    a. Disinfect high-touch areas of HVAC and other building service systems e.g. on/off switches, thermostats
7. Review the BAS programming to adjust the systems to align with the accepted requirements in the Operational Considerations once Occupied Section.
8. Install signage to encourage tenants to use a revolving door, if any, rather than opening swing doors in the lobby area.
9. Review all procedures to consider the addition of “touchless” interactions where applicable. As an example, auto-flush valves are considered “touchless”.
10. Engage a qualified Commissioning Provider (CxP), TAB firm, and/or BAS contractor to verify sensor calibration for demand-based ventilation instrumentation, airflow measurement instrumentation and temperature control instrumentation.
11. Engage a mechanical service company, if not already under contract, to inspect and assess the operational capabilities of all mechanical refrigeration equipment (i.e. chillers and DX cooling equipment), water heaters, steam boilers, pumps and associated specialties (i.e. expansion tanks, deaerators, traps, PRVs, mixing stations, etc.).
12. Consider future renovations, to be included in the capital budget, to incorporate some of the strategies to mitigate transmission of viruses as indicated in the Occupancy Guides at ashrae.org/covid19.

P-ECiP: Prior to Occupying

Heating Ventilating & Air Conditioning:

1. ASHRAE recommends that all building owners and service professionals follow the requirements of ASHRAE Standard 180-2018 "Standard Practice for the Inspection and Maintenance of Commercial HVAC Systems which has tables to show the typical maintenance on equipment that has been in operation
2. Consider PPE when maintaining ventilation materials, including filters and condensate. Consult additional guidance before duct cleaning.
3. Confirm occupancy schedule with building tenants and review programmed operation schedule in BAS and/or HVAC components (i.e. unitary controls). Modify as needed to fit the current occupancy schedules and ventilation requirements.
4. Open outside air intake dampers to their maximum, 100% preferred, four hours minimum, before the reoccupation. The maximum position the outside air dampers may be opened will depend on the time of year, local climate, the temperature and humidity of the outside air and the capability of the HVAC equipment to condition the outside air so that the system is able to maintain acceptable indoor temperature and humidity. When operating in this "flush out" mode, monitor the system continuously to make sure that unexpected or unacceptable conditions inside do not develop.
5. In buildings with operable windows, if the outside air temperature and humidity are moderate, consider opening all windows for two hours minimum before the reoccupation.
6. Operate the HVAC systems in Occupied mode for at least 24 hours after completing the previous steps. Trend temperature control and ventilation parameters through the BAS. If this capability is not available, request a qualified Commissioning Provider or TAB firm install monitoring equipment or measure systems to verify proper temperature and ventilation control. Be advised that equipment may be operating below design capacity, but sequencing and temperature control should function correctly.
   – Check to see that space temperature and relative humidity levels are being controlled to the acceptable setpoints.
7. Verify Occupied / Unoccupied sequencing after measurement and verification of Occupied parameters is complete.
8. Check the status of any heat recovery wheels in the systems for leakage and cross-contamination. Consider deactivating these wheels until a service technician checks the operation and condition.
9. Consult with the CxP, BAS contractor, TAB firm or Design firm to identify any areas of concern or anomalies in the monitored or measured data and compile a list of issues to be addressed to meet minimum occupancy ventilation requirements and occupant comfort / operational temperature setpoints.

P-ECiP: Prior to Occupying

Airside Systems:

1. Check to see that the fans have turned on, and that air is moving in and out of the building.

2. Check to make sure the dampers (outside and return) are working properly as this helps control the fresh air to the building. If the building increased its outside air (OA) during the epidemic, rebalancing the dampers may be required to achieve design air flows.

3. Check overall building pressure to make sure it is positive. Do the same for any critical interior spaces.

4. Check that the filters are still in acceptable condition. Facility staff should wear PPE, assuming the system may have been contaminated prior to shut down or upon restarting.

5. Operators should consider increasing the level of filtration in the Air Handling Units (AHUs) for one or two replacement cycles upon opening the building. Make sure the air handling systems and fans can overcome the additional pressure drop of the new filters and still maintain air flow at acceptable levels. Refer to the Filtration Guidance.

If higher efficiency filtration is not available, portable units in the high-traffic areas may be used for a few months.

P-ECiP: Prior to Occupying

Cooling systems:

1. Check the refrigerant pressures to make sure the system is adequately charged.
2. Check the water quality in the systems and add chemicals as needed.
3. Check coil leaving air temperatures to make sure the systems are providing dehumidification.
4. Check the water levels and make-up water source for cooling towers to confirm they are available.
5. Check pump operation and that water is flowing.

Heating System:

1. Check the fuel source to make sure it is on and available. Old fuel oil may need to be replaced.
2. Confirm that the flues and make-up air paths are open prior to engaging boilers.
3. Check that the coil actuators are controlling to temperature, or that heating elements are turned on at the disconnect.
4. If the boiler system(s) were shut down, follow state boiler codes and the manufacturer's written instructions for starting up, and bring hot water and steam heating systems and plants back online.

P-ECiP: Prior to Occupying

Building Automation System:

1. Check that the devices and sensors are within an acceptable calibration for controlling space comfort and ventilation. Use the guidance in ASHRAE Guideline 11-2018 -Field Testing of HVAC Control Components.

2. Check that the alarms are set up and their communication path is correct (it is notifying the right person).

3. Consider an update to the programming that would incorporate HVAC strategies to reduce virus transmission prior to future events. Automate the control sequences applied as “Epidemic Mode” operations that can be manually selected by the operator with one stroke.

   – Refer to Occupancy Guides for suggested HVAC strategies to employ when operating the building in an epidemic.

P-ECiP: Prior to Occupying

Building Automation System:

4. Reset and ventilation control strategies to increase outside air back to normal. This means to re-engage demand-controlled ventilation and potentially eliminate the **Flushing Between Occupied Periods**.

5. Filters should be replaced, at the normal interval, back to the previous MERV level. It makes financial sense to wait until the currently installed filter pressure drop indicates it needs to be changed. Refer to filter modification notes to determine required adjustments to the system to achieve initial operating conditions.

6. Make sure your toilet exhaust fans are now set to turn off in unoccupied mode if that is how it was previously operated.

P-ECiP: Prior to Occupying

Domestic Water & Plumbing Systems:

Building owners and operators should coordinate with local authorities having jurisdiction, state or local Departments of Health and water utility providers for policies adopted and recommended best practices prior to building occupancy.

Review existing water management plan or program documents and execute steps for system start-up. If this document is not available, develop a water management program for your water system and all devices that use water. Guidance to help with this process is available from CDC and others.

Utilize the following steps:

P-ECiP: Prior to Occupying

Domestic Water & Plumbing Systems Continued:

1. In general, fresh water should be drawn into building water systems and stagnant water flushed out before they are reopened.

2. Maintenance staff should wear epidemic-level PPE when maintaining any sewage ejectors and lift stations until those systems are sterilized.

3. Confirm your water heater is properly maintained and the temperature is correctly set.

   Keep water above 140°F to avoid microbial incursion. Do not let it drop below 120°F. Refer to Figure 1 from ASHRAE Guideline 12-2020:

P-ECiP: Prior to Occupying

Domestic Water & Plumbing Systems Continued:

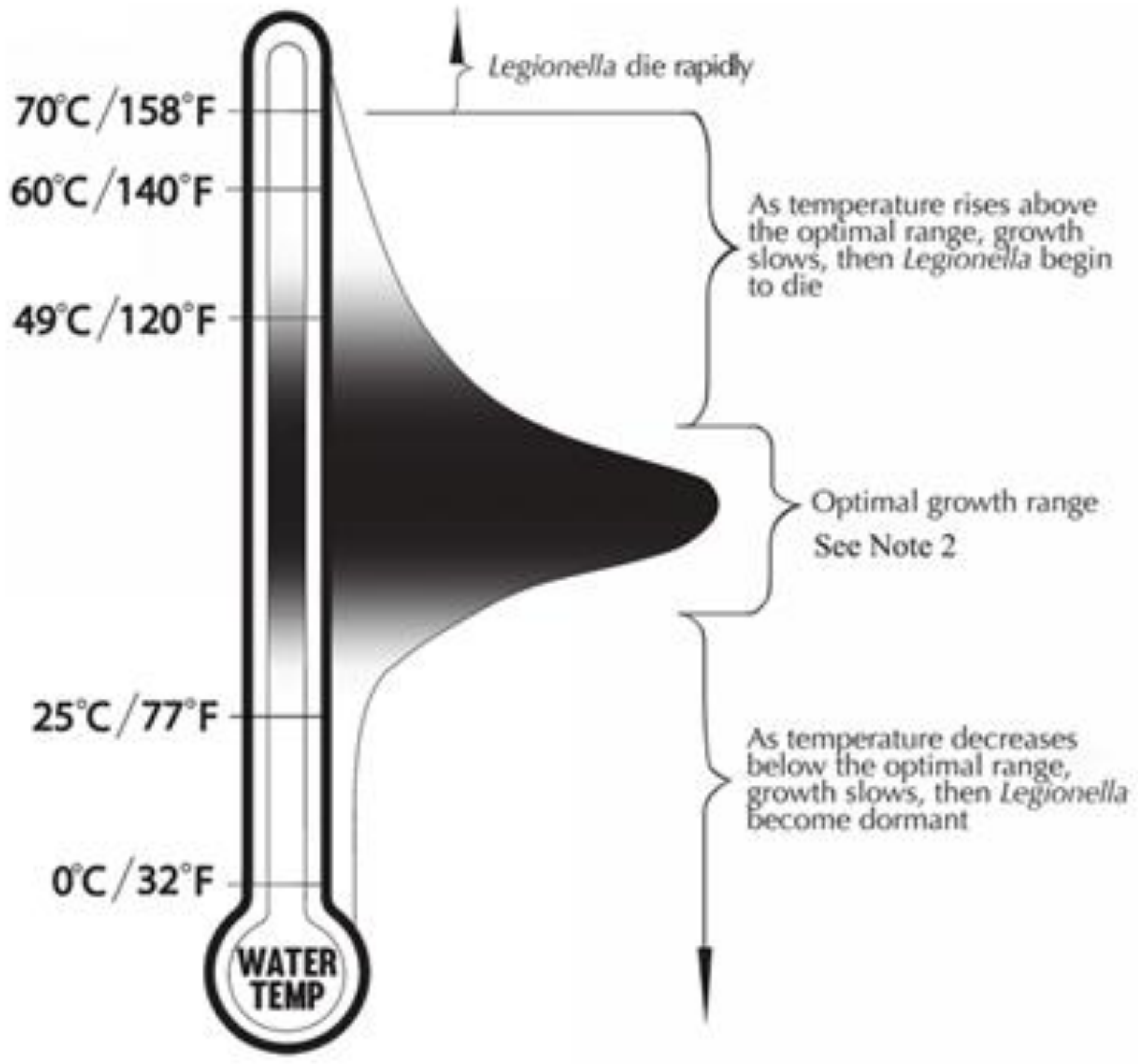


Figure 1 Temperature effects on survival and growth of *Legionella* in laboratory conditions.

P-ECiP: Prior to Occupying

Domestic Water & Plumbing Systems Continued:

4. Flush your water system:

   If applicable, flush water distribution system mains to maintain water quality delivered to buildings. Coordinate with local water utility provider as needed to confirm water residual disinfectant levels are maintained. Coordinate with local water utility provider and authorities having jurisdiction to complete other testing in water mains such as free chlorine, lead, Heterotrophic Plate Count (HPC) or Legionella Pneumophila.

   Flush building cold water loops through all points of use, including all water-using appliances like ice machines, humidifiers and dishwashers. Flushing may occur in segments or by zone. Confirm a minimum disinfectant residual is achieved before usage. Coordinate with local water utility provider and authorities having jurisdiction to complete other testing in building water systems such as free chlorine, lead, Heterotrophic Plate Count (HPC) or Legionella Pneumophila. Discolored water can be a sign of more complex issues and should be investigated.

P-ECiP: Prior to Occupying

Domestic Water & Plumbing Systems Continued:

5. Evaluate water filtration for systems and individual devices to determine if replacement is needed.
6. Make sure all P and U-traps on plumbing drains are wet.
7. Clean all decorative water features, such as fountains.
8. Confirm hot tubs/spas are safe for use.
9. Confirm cooling towers are clean and well-maintained.
10. Confirm safety equipment including fire sprinkler systems, eye wash stations, and safety showers are clean and well-maintained.

P-ECiP: Prior to Occupying

Electrical Systems:

Plug in all appliances that were unplugged to avoid phantom electrical loads, including but not limited to:

a. Computers
b. Routers
c. Modems
d. Televisions
e. Printers
f. Chargers
g. Microwaves
h. Things that turn on with a remote control

P-ECiP: Prior to Occupying

Special Systems:

1. Check on fire alarms and other equipment with battery backup power supplies. Consider having an electrical technician come and check that everything is working properly.

2. Have fire protection sprinkler systems, fire alarm systems, emergency lighting systems and other life-safety systems inspected by local authorities having jurisdiction (AHJs), if required by state and local statutes and ordinances, and by contract service professionals who routinely maintain these systems.

3. Check on the battery backup power supplies for Information Technology (IT) and Internet of Things (IOT) devices, especially the ones that are mission critical. That would include servers, building automation systems (BAS), communication systems, lighting control systems and security systems.

4. If the building is equipped with an emergency or backup generator, arrange to have it tested as required by codes, local jurisdictions and the manufacturer’s recommendations.

P-ECiP: Operational Considerations once Occupied

The intent is to return your building to the new normal mode of operation for your facility, but what is the new normal? There are questions the facility needs to address as it modifies its systems.

In general, use the Building Readiness Plan to re-open your building. In addition, continue to follow the CDC advice regarding PPE and OSHA Guidelines for workspaces.

Next, let's capitalize on some of the lessons learned, which may adjust your new normal, that the facility has experienced with the recent COVID Pandemic by exploring the following questions:

P-ECiP: Operational Considerations once Occupied

Did your maintenance program have any scheduled preventive maintenance periods missed because the building was unoccupied?

- This would include any monthly, quarterly, semi-annual or annual inspections and service.

If the answer is yes, then get these back on schedule without putting the current and upcoming maintenance at risk.

- Current and upcoming maintenance should continue as scheduled.
- Prioritize the missed maintenance items, starting with any annual maintenance missed, for the longest period since the last annual inspection and maintenance.
- Move to the semi-annual then the quarterly.
- Start scheduling these missed service intervals on equipment over the next month to catch up.
- With the quarterly inspections, if you are a month or less to the next quarterly inspection it might make sense to just skip the missed inspection cycle.

If the answer is no, continue with the current maintenance cycle as scheduled.

P-ECiP: Operational Considerations once Occupied

Did you have issues acquiring parts or consumable maintenance materials during the pandemic period?

If the answer is yes, consider generating a stock backlog of commonly used parts or consumables. Of course, one needs to always pay attention to this by using the stock and restoring the backlog as items are used to keep items with shorter shelf life current. This can be a challenge at some locations, as space is a true premium.

If the answer is no, continue with the current program, but think forward. Is there anything in your stock that would be a problem if you could not acquire it in another event?

P-ECiP: Operational Considerations once Occupied

Were you able to continue daily or weekly rounds at the building during the shut down?

If the answer is yes, review the notes from the rounds. If issues were identified start scheduling maintenance repairs to address any issues such as filters, leaking flanges, loose belts or sticking flush valves.

If the answer is no, consider going through your facility with diligence to confirm that all systems have returned to normal operations. Here is a list of easy low hanging fruit to look for, but certainly not all encompassing:

- Look closely at consumables, have any dried out and require replacement or refilling?
- Are all the filters still in the filter rack and not sucked in?
- Any visible leaks on the piping or plumbing fixtures?
- Do the batteries need to be changed in any paper towel dispensers?
- Are the sensors in the systems reading and reporting correctly?

P-ECiP: Operational Considerations once Occupied

Were there systems that were not able to be put into a setback mode?

If the answer is yes, look at these systems individually and determine a plan for the next long-term pandemic. Ask these questions:

- What prevented the setback mode from happening?
- Can the system be upgraded to have a setback mode?
- How do we implement the upgrade?

If the building is manual operations and not computerized, consider a control upgrade to the system. This could be a large undertaking so prioritize by system criticality. Remember some systems control setbacks just might not make sense.

If the answer is no, continue with the current program.

P-ECiP: Operational Considerations once Occupied

Do the building mechanical systems have reset and ventilation control strategies to increase outside air back to normal?

If the answer is <u>yes</u>, consider adding a schedule for times where the building can be automatically flushed with fresh air in addition to the demand-controlled ventilation increase.

If the answer is <u>no</u>, consider adding this to the next air handler replacement.

P-ECiP: Operational Considerations once Occupied

Are there other lessons learned that need to be addressed within the building from this experience?

Have a round table with the staff maintaining the facility, pull from their thoughts and experiences. Create a master list of the headaches and the problems that were found. Use these to help develop the new capital plan or program for the facility.

P-ECiP: Ventilation

Post-Epidemic Conditions in Place, the ventilation should be returned to normal quantity and duration prior to the epidemic.

Refer to ventilation modification notes to determine required adjustments to the system to achieve initial operating conditions.

P-ECiP: Filtration

Post-Epidemic Conditions in Place, the filtration can be returned to normal quantity and duration prior to the epidemic.

Prior to returning systems to their normal state, final measurements and data should be recorded for future use.

- Total airflow and static pressure should be recorded at a minimum, as well as filter status (clean, dirty, other).
- If temporary brackets or other modifications were made to accommodate larger or different style filters during the epidemic, a determination should be made whether or not to keep the modifications in place for possible future use, or if it needs to be removed or changed back in order to return the system to former operations.
- Any left-over filtration not used during the epidemic should be documented and stored for future use, as well as any removed modifications or materials used for modifications.

If owners/operators find that their facility operations were not reduced or hindered by the modifications or increased filtration (higher MERV rating), some facilities may opt to keep the increased filtration in place or shift to a new filtration efficiency. Whether systems are returned fully to pre-epidemic operations, returned to slightly better MERV rating than pre-epidemic operations, or kept in place, final long-term operation should be documented for record purposes (airflow, static pressures, amperages).

P-ECiP: Building Maintenance Program

Review your existing maintenance program:

- Are there systems within the program that need to be put at a higher priority than pre-pandemic conditions?
- Are there systems or equipment that have more issues than per-pandemic conditions?
- If you are only doing annual or semi-annual inspections and maintenance, is it worth considering adding a more frequent maintenance interval?

We would suggest that each piece of equipment and each system be evaluated individually taking into account what the system serves within the building. Depending on the building, some systems may take a higher priority because of the area of service.

P-ECiP: Building Maintenance Program

For those who have determined that a more robust maintenance program is required for the HVAC or Plumbing systems, some good resources include:

- ASHRAE Standard 180-2018: Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems
- ASHRAE Standard 188-2018: Legionellosis: Risk Management for Building Water Systems
- Guideline 12-2020 -- Managing the Risk of Legionellosis Associated with Building Water Systems

For electrical system programs, refer to the NFPA 70B Recommended Practice for Electrical Equipment Maintenance.

P-ECiP: Systems Manual

As stated above in the Epidemic Conditions in Place, a Systems Manual should be revised to include this new mode of operation for the facility. During an epidemic, there may be altered sequences of operations, as well as data logging information and operations for record keeping. When the epidemic is over and occupants begin to return to the workplace in a more normal capacity, systems will likely be returned to, or near, previous operations.

When returning systems to normal operations, operations staff should review the Occupied and Unoccupied Modes in normal operation to confirm that the document is current. There should be documentation kept of the change over, any anomalies encountered, as well as operational data recorded moving forward, when switching between modes.

The post-change over review should be performed so that any updates that need to be made can be made and put into action.

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TC-5.5 Committee

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