ASHRAE Epidemic Task Force
Laboratory Subcommittee
Guidance Document

Introduction

SARS-CoV-2 virus, and other similar pathogens, may spread through various transmission routes, including direct or indirect contact with contaminated surfaces and exposure to respiratory droplets. While not initially considered, more data are becoming available that indicates that the potential for exposure from aerosolized particles must also be addressed. Both the World Health Organization (WHO) and the Center for Disease Control (CDC) have now made public statements recognizing the potential for airborne transmission. This has led to ASHRAE developing the formal position [(https://www.ashrae.org/technical-resources/ashrae-statement-regarding-transmission-of-sars-cov-2)](https://www.ashrae.org/technical-resources/ashrae-statement-regarding-transmission-of-sars-cov-2):

Transmission of SARS-CoV-2 through the air is sufficiently likely that airborne exposure to the virus should be controlled. Changes to building operations, including the operation of heating ventilation, and air conditioning systems, can reduce airborne exposures.

Initially, the laboratory environment was considered low risk for aerosol transmission because these facilities are already designed with the safety of occupants as a key performance indictor; typically through the use of 100% outside air (i.e., no recirculation) supply systems, higher air change rates, and exhaust systems designed to minimize re-entrainment of contaminated air. However, these same systems provide unique operating conditions that require distinct mitigation strategies to minimize the risk of transmission of aerosolized particles. Several recommended mitigation strategies that may be prudent for other building types should not be employed in a lab environment because they may adversely impact the air flow patterns within the lab and/or the performance of existing containment devices.

Therefore, the objective of this document is to address the mitigation strategies that are unique to the laboratory environment and to define those strategies that may be applicable to non-lab environments that should not be implemented within a laboratory or to its HVAC systems.

Before implementing changes to any of the systems within the laboratory, consult with professionals such as a Professional Engineer (refer to Building Readiness Team, https://www.ashrae.org/technical-resources/building-readiness#team, for more team members) to evaluate the effects the changes will have on the overall system. While the recommendations stated here are designed to make the laboratory safer, they cannot guarantee the safety of the occupants as the virus is spread from person-to-person and can linger in the air and/or on surfaces.

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Definition of a Laboratory

The definition of what is or is not a laboratory is subject broad interpretation. As such, ASHRAE Technical Committee 9.10 (TC9.10), in conjunction with the American Industrial Hygiene Association (AIHA) and the Division of Chemical Health and Safety of the American Chemical Society (ACS) has developed a document titled "Classification of Laboratory Ventilation Design Level". This document classifies five levels of laboratory ventilation design levels (LVDL-0 through LVDL-4) based on the types and quantities of hazardous material that may be used within the facility and the potential for airborne generation of these materials.

For the purpose of this document, the term "laboratory" refers to the following types of facilities, which typically have single-pass airflow (i.e., the supply of 100% outside air):

- Teaching or research laboratories supporting the management of exposures to airborne chemicals generated during laboratory scale activities.
- Applications where hazardous chemicals are used on a nonproduction basis, as defined by the Occupational Safety and Health Administration (OSHA).
- Biological laboratories, operating at levels BSL-2 through BSL-3+.
- Vivaria operating at levels ABSL-2 through ABSL-3+.

For the purpose of this document, precision and/or specialty laboratory spaces such as laser laboratories for physics, atomic molecular optics, etc. or other laboratory spaces which utilize recirculation air as part of their strategy for environmental control are excluded. For direction on the operation of these facilities consult the ASHRAE Commercial Guideline (https://www.ashrae.org/technical-resources/commercial).

This document does not provide guidance specific to the direct handling of SARS-CoV-2 virus samples in a laboratory environment. ASHRAE defers to the Center for Disease Control (CDC), the National Institutes for Health (NIH), and Health Canada for such guidance.

Guidance for the Operation of Existing Labs

General

ASHRAE guidance for many facilities is to consider increasing both the ventilation rates during occupied hours and/or increase the percentage of outside air. In the laboratory environment the HVAC systems are already equipped to provide 100% outside air, so they already meet this portion of the ASHREA guidance. Furthermore, based on environmental condition requirements, supply air is typically heated and humidified in the winter and cooled and dehumidified in the summer. As such, there is typically no opportunity to increase the percentage of outside air, and it is generally recommended that air change rates are not increased above design levels. Considering laboratory HVAC systems are already primarily designed to control the spread of contaminants, it is anticipated there will be few HVAC system adjustments needed to mitigate the spread of SARS-CoV-2 virus, as long as the system was properly designed and is currently operating at these design levels. Therefore, the primary recommendation is that existing HVAC system air flows, sequence of operation and pressure relationships should be verified.

Existing laboratories are typically designed as the following:

- ventilation dominant,
- hood dominant, or
- thermally dominant.

Ventilation dominant labs have the maximum supply airflow rate designed based on a minimum ventilation rate which is greater than the cooling/heating load airflow or hood make-up airflow. **Hood dominant labs** have the maximum supply airflow based on the required airflow to meet the airflow demands of the fume hoods and other containment devices located within the lab. **Thermally dominant labs** have the maximum supply airflow based on their cooling/heating loads. Hood dominant and thermally dominant labs, when designed with variable volume systems, may switch between any of the three types depending on hoods in use or space cooling/heating loads. Most control systems automatically prevent a system from going below the ventilation minimum supply flow rate programmed into the system.

Arbitrarily increasing the ventilation rate in a laboratory can have undesired consequences. Ventilation rates in laboratories are typically higher than normal office spaces to begin with. Increased rates have the potential to disrupt airflow patterns in the space and the ability of

source capture devices (fume hoods, snorkels, etc.) from properly containing or capturing the contaminants they are designed to capture. A CFD model or evaluation by a professional engineer familiar with laboratory systems should be consulted before modifying airflow rates from the original design levels.

Ventilation Demand Driven Laboratories

Laboratories are typically designed to operate in the range of 4 -12 air changes per hour of outdoor air. Because laboratory HVAC systems have 100% outdoor air and provide a relatively clean air environment for conducting experiments and research, increasing the air change rates above the original design is probably unnecessary. When a lab space includes an unoccupied ventilation mode or is equipped with a demand control ventilation system, occupancy sensors, or room scheduling, a risk analysis should be performed to determine if the reduced air change rates should be increased to the desired air exchange rates.

Increasing air changes per hour can enhance overall dilution of contaminants but may not achieve well-mixed conditions with uniform concentration in the entire space. Local airflow patterns determine the non-uniformity of concentrations and, hence, resulting exposure risk.

Fume Hood Driven Ventilation Demand

The total flow through a laboratory containing a variable-air-volume fume hood can vary depending on the operating mode. Exhaust flow through the fume hood can modulate from low flow with the sash closed to a much higher flow when the sash is open. The air change rate within the lab will vary in proportion to the flow through the fume hood and can be as much as 3 or 4 times greater when the sash is open versus closed. It is critical that the air supply and exhaust flow are coupled and modulate their flow in tandem to maintain the appropriate lab pressurization. Adjusting either the air supply or exhaust flow rates can adversely impact the performance of the fume hood, reducing its capture efficiency.

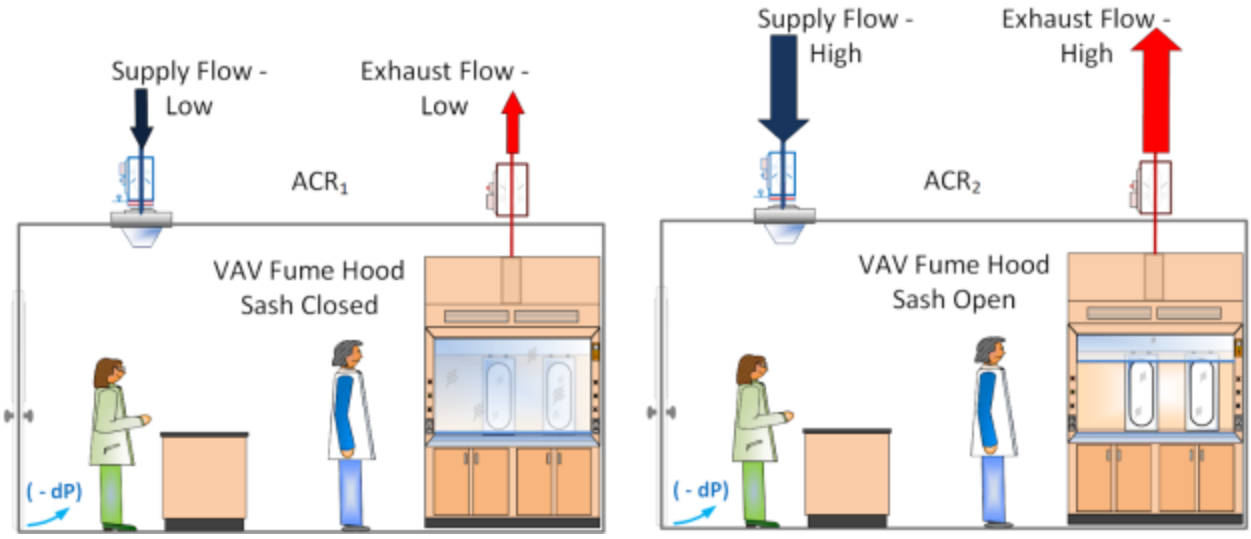

Figure 1. Variable volume ventilation in a fume hood dominated laboratory

(Figure Courtesy of 3Flow)

Thermally Driven Ventilation Demand

The primary objective of laboratory ventilation systems is to provide a safe and comfortable environment to personnel. The heat load within a laboratory may not be significantly greater than for a typical commercial building. It is usually defined by solar gain on the façade, occupants, lighting, and equipment loads. What is unique about laboratories is that the high ventilation rates may provide excess cooling depending upon the balance between the heat loads and the ventilation rates and supply air temperatures. If this imbalance would cause room temperatures below design conditions, re-heat is added in the supply ducts to increase the supply air temperatures to the labs. If the imbalance would cause the room temperatures to be above design conditions, or necessitate excess ventilation to meet the cooling load, additional cooling can be provided through local cooling coils, fan coil units, chilled beams, or other terminal cooling devices. In either situation, increasing ventilation rates within the laboratory can impact the room temperatures, increasing or decreasing them beyond acceptable levels and potentially causing condensation on cooler surfaces.

Ventilation Effectiveness

Often high airflow rates or air-change-rates per hour (ACH) are specified to cover the risk of chemical exposure in laboratory spaces. Although high supply airflow rates can reduce the overall concentration of contaminants, it may not ensure acceptable concentration levels everywhere in the occupied zone. Importantly, locations of high concentration, especially those

in the breathing zone of occupants, can pose potentially higher exposure risk. Ideally the clean supply air should sweep the contaminants from the breathing zone without significant recirculation and stagnation which can promote high concentration levels. At the same time, the clean air should not escape or short-circuit the space without collection and removal of contaminants from the breathing zone. Since air takes the path of least resistance the effectiveness of ventilation can depend on several factors related to the design and operation of laboratory ventilation systems.

The following principles can help improve ventilation effectiveness:

- Increase the number and size of exhaust grilles and/or exhaust outlets in a space.
- Place exhaust outlets away from the occupied zone to avoid stagnation of contaminants.
- Minimize turbulence of the supply air in the occupied breathing zone by appropriate selection of ACH and supply diffusers.
- Promote “single pass” sweep layout for HVAC designs.

The impact of each of these principles can be optimized by performing Computational Fluid Dynamics (CFD) simulations to evaluate the ventilation effectiveness of the of supply and exhaust systems. Arbitrarily increasing the ventilation rates within the entire lab and/or within individual zones, can adversely impact the ventilation efficiency of the system, increasing the potential for contaminated air within the breathing zone.

Demand Control Ventilation Systems

Demand control ventilation (DCV) systems utilized in the laboratory environment are often equipped with sensor groups that are designed to detect TVOCs and particulates, in addition to the CO_2 sensors commonly used in commercial applications. When the measured concentrations from all sensors are below defined trigger levels, the ventilation system operates at a minimum flow rate. If any of the measured parameters exceed the trigger level, the laboratory ventilation system will increase ventilation to a purge condition. While the particle counters used with the laboratory DVC systems cannot specifically detect the presence of the SARS-CoV-2 virus, some DCV systems can detect particles within the size range of human exhaled aerosols and droplets (typically considered to be in the range of 0.3µm to 3.µm when aerosolized and 5µm to 10µm as a droplet). The increase in ventilation due to the particulate threshold being exceeded in a DCV system could possibly provide additional benefit by diluting a potential Covid event. Although, the minimum ventilation rates of these systems, as well as

the minimum ventilation rates of labs that do not use Lab DCV can be increased, it should not normally be warranted for most situations and facilities.

Transfer Air

In most lab HVAC systems, the only source of air into the lab is the outside air drawn by the air handler. In some systems part of the air delivered to the lab is drawn from other occupied spaces, such as neighboring offices and conference rooms. This transfer air may come through the air handling system, driven by fans, or it may come through designed transfer grills or transfer ducts, drawn by the pressure difference between the spaces. Or this may occur by mechanical methods. Either way, bringing air from other spaces into the lab raises the possibility of contamination. If the lab ventilation source includes air transferred from other spaces, an engineer and a safety professional should assess the risk and consider measures to reduce it.

In the case of air transferred through the air handling system, it may be practical to add filters to reduce the risk. In the case of air driven by space pressure, filtration is probably not practical. It may be necessary to close the transfer path and adjust powered supply and exhaust flow rates accordingly.

Filtration

Additional filtration is typically not needed in laboratory air handling units since these units are already designed to provide 100% outside air. In addition, MERV 13 or 14 filters are commonly provided in these units to meet programmatic requirements to remove particles from outside. Where air handling units do include recirculated air from areas outside the laboratory, it is recommended the air handling unit filtration efficiency is increased to a minimum of MERV 13 or 14 where possible and that the filters are inspected to ensure that they are properly sealed to reduce bypass air.

Air handling units that serve adjoining non-laboratory spaces where some or all of the supply air is designed to infiltrate into the laboratory, should be equipped with MERV13 or 14 filters, unless they are also supplied with 100% outside air and meet the laboratory's programmatic requirements for filtration.

In-room HEPA units

In-room HEPA filter units should be avoided in laboratory spaces as they can significantly affect airflow patterns. Disruption of airflow patterns can affect the ability of source capture devices (such as hoods and snorkels) from providing proper containment of potential contaminants.

Furthermore, these portable filtration devices may create additional internal recirculation of the laboratory air; increasing the risk of exposure to any contaminants within the laboratory.

Air Cleaners

Overview

Electronic Air Cleaning is a unique and evolving technology within the larger air cleaning industry. Some Electronic Air Cleaning Technologies are stated to reduce and/or remove particle mass, VOC's, odors, molds and other IAQ contaminants within the breathing zone. Furthermore, some of the technologies have been reported to neutralize viruses and bacteria like SARS-CoV-2 that causes COVID-19. ASHRAE's general guidance on air cleaner types and their use is provided at: https://www.ashrae.org/technical-resources/filtration-disinfection.

Electronic Cleaning in a Lab Environment

The building owner or end user should fully understand the unique capabilities of the air cleaning technology that they are to be considering to implement in order to assure it will not impact the scientific activities in which they are involved. The cleaning and sanitizing capabilities may be detrimental to the experiments being performed. This would be specifically significant in a biological research lab where killing or neutralizing a specimen might not be desired. The other concern from a scientific perspective is understanding how the technology does its air cleaning so that introduction of ions, hydroxyl radicals, titanium oxides or other reactive species in the air impacts the science being performed.

Since the majority of laboratories use a high percentage of outside air, the air cleaning technologies will generally require higher concentrations of ions, etc. which needs to be taken into consideration. It is also likely improbable that a portable air cleaning device of any type would be effective in a lab space with a high outside air percentage. It might be more appropriate to consider electronic air cleaning systems in support spaces that are adjacent to the labs because of the benefits they can offer for IAQ. If the lab support spaces are not served by the lab HVAC systems, then a central electronic air cleaning system would likely be the most appropriate and most cost effective. But certainly, the technologies can be adaptable to HVAC terminal units or branch duct systems where the HVAC systems serve both the labs and the support spaces.

Humidification

Consider maintaining the space relative humidity between 40% and 60% RH. Optimal relative humidity levels for the purpose of infection control continue to be an area of research. ASHRAE Standard 55 provides guidance on temperature and humidity ranges for human comfort, and

not necessarily the prevention of disease transmission. Laboratories typically have temperature and humidity requirements that are not only for human comfort but also for maintaining consistency in experiments and or processes.

Specific to laboratories, relative humidity thresholds should be closely coordinated with the specific programmatic and research requirements to ensure that space relative humidity is maintained within optimal levels for the research and/or laboratory equipment.

Spaces with relative humidity below 40% RH have been shown to:

- Reduce healthy immune system function (respiratory epithelium, skin, etc.);
- Increase transmission of some airborne viruses and droplets (COVID-19 still being studied);
- Increase survival rate of pathogens; and
- Decrease effectiveness of hand hygiene and surface cleaning because of surface recontamination or too-quick drying of disinfectants.

When reactivating a dormant humidification system, verify proper operation and that high supply air relative humidity sensors are included. Watch interior spaces to confirm no condensation is occurring, which would permit mold and moisture issues.

Additional information on the importance of relative humidity control can be found at:

Climate-Informed HVAC Increases in Relative Humidity May Fight Pandemic Viruses; and

ASHRAE Tech Hour: Optimize occupant health, building energy performance, and revenue through indoor air hydration

Energy Recovery

Refer to the Practical Guidance for Epidemic Operation of Energy Recovery Ventilation Systems, authored by ASHRAE TC5.5, including specific Notes on Medical Facilities, to determine if energy recovery devices should remain operational for your facility.

Controls

Consult the Building Automation Systems section of ASHRAE's Building Readiness Guide. (https://www.ashrae.org/technical-resources/building-readiness#epidemic) Some major points in the guide are presented in the following paragraphs.

Evaluate the current state of the BAS. Know what you have and what it does. Consider your needs for remote access to the system. You might need to update or enhance that aspect of the BAS. If so, carefully consider the type of access needed for each user and cybersecurity. Engage a BAS service contractor and your IT department in this process.

Before changing any aspect of the system, back it all up and make a record of what you have. The Building Readiness guide elaborates on this point. This step may include testing or recommissioning selected aspects of the system. Automated tests may be cost effective.

Operational aspects of a laboratory BAS most likely to warrant changes include:

- Schedules for operating equipment and for use of the space
- Air flow rates for terminals serving specific spaces
- Capability to sense presence of occupants

In many cases, the selected changes should be made by a BAS service contractor at the direction of an owner or HVAC engineer.

Diffusers

Depending on the type, diffusers utilized in a space can either produce laminar flow that helps sweep the air from the diffuser to the exhaust grilles or they can induce air into the supply air stream and recirculate air throughout the space. The mixing of air dilutes contaminants to a lower level. Unfortunately, this will also spread aerosols from one person to another. If it becomes known that a person in the space was infected with Covid-19, then all surfaces including the diffusers should be disinfected.

Chilled Beams and Fan Coil Units

As an energy conservation measure, chilled beams and/or fan coil units may be included in laboratory spaces having high sensible cooling loads which would otherwise require additional supply air from the laboratory air handling system to meet the space temperature setpoint. The inclusion of chilled beams and/or fan coils units as supplemental cooling devices in laboratories

requires further consideration/review during a pandemic as each of these terminal devices results in the recirculation of some room air within the laboratory which would otherwise not exist.

Fan Coil Units

Unlike the primary laboratory air handling and exhaust systems, fan coil units recirculate a portion of the total volume of air within the laboratory space. Similar to other recirculating systems found in non-laboratory spaces, this could result in the spread of airborne disease(s) such as SARS-CoV-2 throughout the space from an infected occupant to other occupants.

Similar to other recirculating systems in non-laboratory spaces, recommendations such as improving filtration, the addition of single pass UV inactivation, etc. should be evaluated for supplemental fan coils units provided in laboratories.

Often supplemental fan coil units found in laboratories are small and it may not be practical or feasible to enhance them without physical replacement. Thus, consideration for disabling of fan coil units should be provided if doing so would not adversely affect the laboratory environment.

Chilled Beams

There are two (2) types of chilled beams that may be provided in a laboratory space to provide additional sensible cooling - active and passive.

Passive chilled beams utilize natural convection to provide sensible cooling and thus do not directly impact airflow within a space; therefore, they should be able to operate as normal.

Unlike passive chilled beams, active chilled beams utilize the induction of room air to provide sensible cooling. Active chilled beams mix air from within the space with primary air from the laboratory air handling system and therefore provide some level of recirculation. While the volume of primary (ventilation) air provided to an active chilled beam may be able to be increased.

If it becomes known that a person in the space was infected with Covid-19, then all surfaces including cooling coils, nozzles, fans, etc., as well as interior surfaces exposed to the airstream of the chilled beam and/or fan coil should be disinfected.

Separation Barriers

Providing separation barriers to reduce the need for 6 ft separation between people in the laboratory may seem like a good idea, however, it can disrupt the airflow and dilution patterns of the airflow in the space. Therefore, installation of barriers is not recommended within a laboratory, particularly on the bench top or near containment devices.

Space pressurization

Space pressurization is a ventilation technology applied to control migration of air between areas in a building. This tool for limiting exposure to air contaminants is applied in many circumstances with a known location of contamination and known locations of people to protect. The idea is to arrange air movement from the “clean” area and toward the “dirty” area.

If the air contaminant is infectious effluent from unidentified sick workers, pressurization is not an effective tool because the “clean” area and the “dirty” area are not known.

Nevertheless, facility operators are advised to confirm or correct pressurization relationships in laboratories and surrounding spaces. Air moving between spaces, whether intended or not, could spread pathogens and disease. It is much better to find deficiencies while inspecting or recommissioning a space, than when investigating an outbreak.

Space pressure monitors can continuously monitor the laboratory differential pressure. This helps the facility staff maintain the intended air movement, and record that it has been maintained. When selecting a space pressure monitor, consider the accuracy and low differential pressure being read along with maintenance.

Laboratory Exhaust Systems

Laboratory exhaust systems that service potentially contaminated laboratory room air, fume hood exhaust, bio-safety cabinet exhaust, chemical storage cabinets, and/or vivarium spaces, are commonly designed to avoid adverse re-entrainment of these potential contaminants into nearby air intakes, or adversely expose individuals within the near vicinity of the exhaust system. To meet the requirements for these systems, the allowable downwind dilutions are typically on the order of 1:100 to 1:3000, or greater. This provides much greater protection (i.e., dilution) than the standard guidance of employing at least MERV 13 air filters in a recirculated air stream.

Therefore, if the laboratory exhaust system was designed and is operating properly, the risk of adverse exposure to the SARS-CoV-2 virus due to re-entrainment of the laboratory exhaust system is minimal.

For non-laboratory exhaust systems, such as areas serving ASHRAE Standard 62.1 Class 2 or Class 3 office and/or auxiliary spaces, the ASHRAE Building Readiness Guidance (https://www.ashrae.org/technical-resources/building-readiness#increasedvent) includes an Exhaust Re-Entrainment Guide (https://www.ashrae.org/file%20library/technical%20resources/covid-19/exhaust-re-entrainment-guide.pdf) that can used to help evaluate whether or not re-entrainment for any non-contaminated exhaust systems are a potential risk for creating adverse exposure to the SARS-CoV-2 virus.

Summary Checklists

- Verify existing system operations are consistent with the design of the system and are operating properly.
- Verify energy wheels are operating properly with minimal (less than 0.05%) exhaust air transfer.
- Evaluate continued use of DCV systems.
- Verify operation and adjustments of seals on energy recovery wheels.
- Do not add separation barriers between workspaces unless airflow pattern analysis is performed.
- Do not add portable HEPA filtration units to lab spaces if they will disrupt airflow patterns and capture of hoods.
- Have a professional engineer evaluate proposed changes to the system to avoid unintended consequences (i.e.: upgrading filters, but existing fans cannot handle additional static pressure to maintain airflow).
- Confirm that outside intakes do not draw in contaminated air due to re-entrainment from neighboring exhaust sources.
- Check the HVAC system's ability to include one or more of the following while maintaining the proper space pressure relationships:
  - Additional outdoor air;
  - Additional filtration (for recirculated spaces only); and/or
  - Air cleaning technology (for recirculated spaces only).

Critical Control System (BAS) Checks

- Confirm relationships between mechanical equipment, control equipment and spaces served.
- Report failed and disabled points.
- Consider recalibrating sensors: air flow, space temperature, space humidity.
- Consider adding humidity sensors in spaces that don't have them.
- Inventory and review schedules for equipment and spaces.
- Run diagnostics to find faults – confirm air flow range, confirm control to setpoint.
- Consider enabling ventilation alarms (smart alarms, fdd or some other name).
- Develop a strategy and practice spelling out who gets alarm data and how they respond.
- Report ventilation parameters for each space.

- Report normal operating parameters for each exposure control device.
- Confirm expected operation of each exposure control device.
- Review plan for space pressurization (magnitude and direction).
- Review monitoring of space pressurization.
- Consider adding space pressurization monitors.
- Confirm space pressurization physically.
- Plan regular confirmation of pressurization.
- Test occupancy sensors in rooms that use them to set ventilation rates.
- Consider high-resolution occupancy sensors to monitor effectiveness of spacing policy.

Ventilation System Checks

Supply Air Handler Units

- Damper operation (dampers are opening and closing without binding).
- Filters are of the proper MERV rating and installed properly with minimum bypass between filters.
- Coils are clean, drain pans are draining properly.
- Fans are functioning properly, and belts are tight.
- Humidifiers are functioning properly.
- Energy recovery is functioning properly with little or no cross contamination.
- Control valves are functioning (valves open and close completely).
- Airflow measurement stations are reading correctly, if not clean and recalibrate if needed.
- Temperature, humidity, and pressure sensors are reading correctly, if not clean, calibrate or replace.
- Verify control functions are controlling properly.
- Fan responding to system pressure changes.
- Cooling and heating valves responding to changes in temperature.
- Humidifier responding to changes in relative humidity.
- Dehumidification mode is functioning.

Room Level Ventilation Controls

- Dampers or air valves operation (dampers are opening and closing without binding).
- Air flow measurement stations are reading correctly, if not clean, calibrate, or replace as necessary.

- Control valves are functioning (valves open and close completely).
- Temperature, humidity, and pressure sensors are reading correctly, if not clean, calibrate or replace.
- Verify Hood monitors/controllers are functioning properly.
- Verify control functions are controlling properly.
- System properly responds to hoods opening and closing.
- Cooling dampers or valves and heating valves responding to changes in temperature.
- Verify room pressure relationships are maintained as hoods are opened and closed and as the system responds to temperature cooling demands.

Exhaust Fans

- Damper operation (dampers are opening and closing without binding).
- Filters are of the proper MERV rating and installed properly with minimum bypass between filters, if applicable for energy recovery.
- Fans (VFDs) and dampers are responding to changes in duct static pressure.
- Energy recovery is functioning properly with little or no cross contamination.
- Control valves are functioning (valves open and close completely).
- Pressure, sensors are reading correctly, if not clean, calibrate or replace.
- Airflow measurement stations are reading correctly, if not clean and recalibrate if needed.
- Damper operation (dampers are opening and closing without binding).
- Validate current ventilation rates meets basis of design requirements.
- Check for leakage, or corrosion that could lead to leakage, in the exhaust ducts and within the exhaust fans.

Risk Assessment

Aerosolized Pathogen Risk Assessment Tool for Indoor Environments (APRATIE)

The purpose of the APRATIE is to help evaluate occupied spaces within a building to determine the relative risk of exposure to aerosolized pathogens and transmission of infection. The tool considers risk of transmission as a function of various risk factors that include type and number of occupants, size of the space, proximity and duration of the occupants, the type of HVAC system serving the space and the operation of the HVAC systems.

The diagram in Figure 2. depicts a system where people occupy different types of communal air spaces from offices, conferences rooms and laboratories. The quantity and quality of the air is based on the design and operation of the airflow systems. Labs typically have one-pass air systems where some portion of the air in the space is not recirculated by the HVAC system.

Potentially infectious aerosols can be generated and dispersed within a space when an infected person exhales, sneezes, or coughs. The larger aerosol droplets may settle on nearby surfaces whereas smaller aerosols (i.e. < 10 μm) may be transported within the space via the motive force of the exhalation as well as conveyance by the internal airflow patterns. The volume of the space and quantity of the airflow may help with dilution, but the airflow patterns and degree of turbulent mixing can increase potential for occupant exposure and surface contamination. The objective would be to limit spread from the source and minimize migration throughout the space. Optimizing work practices such as wearing masks within the space may help reduce risk by reducing the generation and spread of contaminants from the source. Enhancing operation of the airflow systems may enhance capture, dilution, and removal before reaching an appreciable dose.

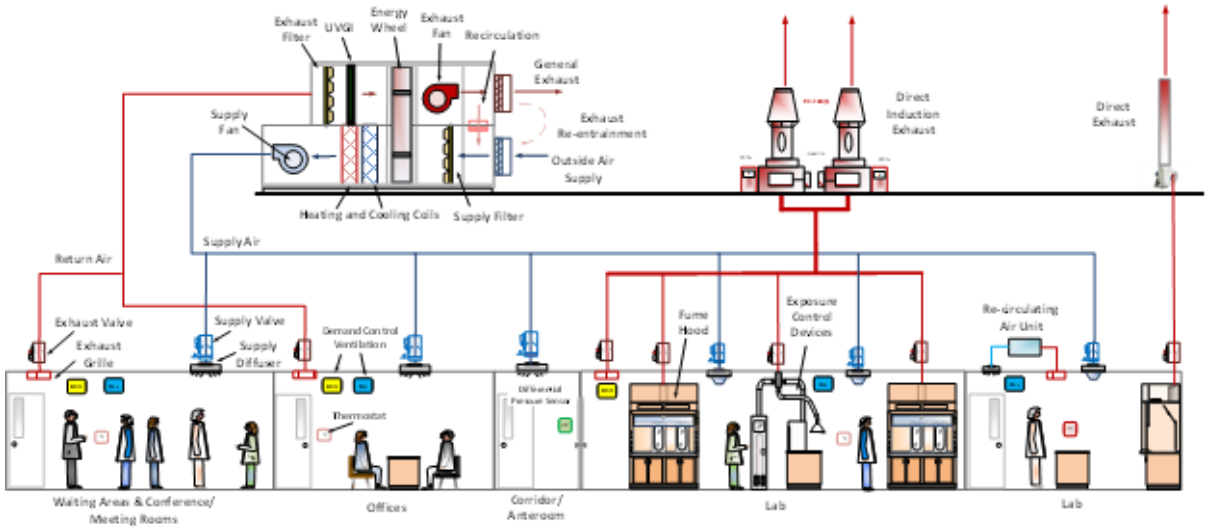

Figure 2. Diagram of Airflow Systems serving different types of Indoor Environments

(Figure Courtesy of 3Flow)

Based on the rating and weighting of the factors, risk is assigned using a numerical value of 0 to 4 where 0 indicates negligible risk and 4 indicates the highest level of risk.

Attempts to minimize risk should focus on limiting generation through use of masks, social distancing to reduce near-field exposure and maximizing ventilation effectiveness. A ventilation system designed to simultaneously dilute, capture and remove airborne contaminants as found in most well designed and properly functioning labs will minimize exposure dose and help mitigate risk of infection and adverse health effects. Ventilation effectiveness can be evaluated for any space through application of relatively simple air tracer tests or through use of more sophisticated methods such as computational fluid dynamic modeling. Labs or any space with less than optimal ventilation effectiveness can be upgraded or modified to reduce risk to as low as reasonably achievable.

Additional information and guidance on conducting an APIRAT based risk assessment will be available in an upcoming version of ASHRAE's ETF Building Readiness Guideline.

Guidance for the Design of Future Labs

The performance of the ventilation system will likely become an increasingly important facet in the design of future laboratory facilities. It will be advantageous for these systems to provide an increased level of isolation that minimizes the transfer of air between individuals within the laboratory.

During the early stages of pandemic, it was believed the COVID-19 disease was primarily spread by the SARS-CoV-2 coronavirus present in the large droplets which were generated by coughing and sneezing of an infected person. Social distancing was advised to keep the 6 ft distance between individuals to avoid contact with these large particles which were assumed to primarily fall within this distance due to gravitational pull.

While the role of aerosols in spreading the COVID-19 disease was still uncertain on July 6 2020, a group of 239 scientists appealed to WHO in an open letter that "**beyond any reasonable doubt** that viruses are released during exhalation, talking, and coughing in micro-droplets small enough to **remain aloft in air** and pose a risk of exposure at distances beyond 1 to 2 m from an infected individual". (Morawska and Milton, 2020)

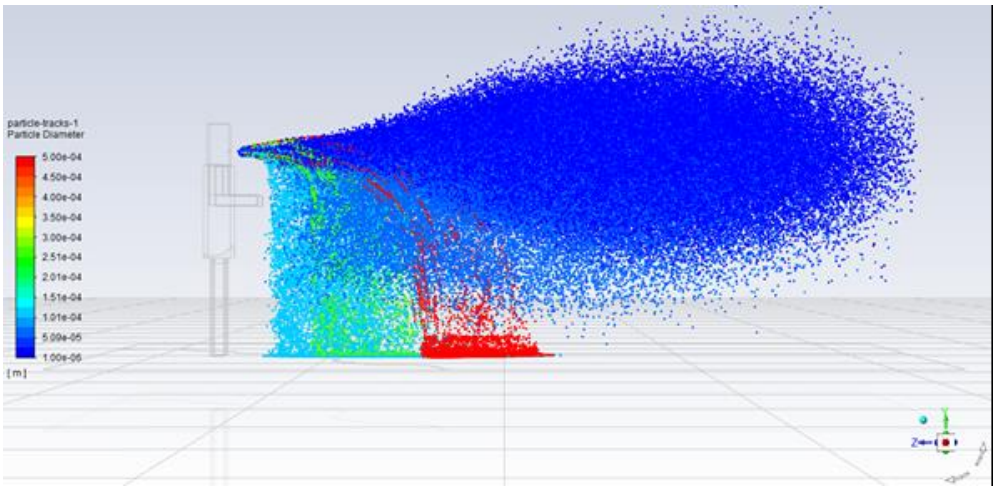

Figure 3. CFD analysis of airflow path of aerosol indicates that large droplets settle due to gravity near the source while small aerosol particles travel beyond the recommended 6 feet social distancing.

(CFD analysis courtesy of AnSight LLC, Ann Arbor, MI)

There was a COVID-19 infection incident that occurred in late January 2020 in the restaurant located in Guangzhou province of China. Studies of the infection spread in this restaurant indicated the spread was consistent with a spread pattern representative of exhaled virus-laden

aerosols without close contact or fomite contact. It was also concluded that the droplet transmission was prompted by air-conditioned ventilation and the lack of outdoor air. One of the key factors for the spread of the virus within the restaurant was the direction of the airflow. (Li Y. et.al. 2020).

Therefore, to avoid adverse risk of infection spread within the laboratory environment, future lab spaces should address the potential for cross-contamination due to local air flow currents. Proper placement of supply diffusers, exhaust vents, laboratory furniture and containment devices can help reduce the presence of contaminants within the breathing zone throughout the occupied portion of the laboratory. In areas where cross-contamination cannot be avoided, such as in front of fume hoods when they are used as the primarily exhaust for the laboratory, additional measures may be necessary to protect the occupants.

Minimizing Cross Contamination

Ventilation effectiveness typically evaluates the ability of the ventilation system to provide a uniform distribution of airflow and temperature within a room. However, in the laboratory environment, the design of the ventilation system should also address the effectiveness of the system at minimizing the time-based exposure (dose) potential of airborne contaminants within the breathing zone. The primary sources of the contaminants are typically considered liquid spills or gaseous emissions which may occur outside of containment devices. However, these same techniques can be used to design laboratory ventilation systems to minimize the exposure of airborne virus particles, as well.

Air is the primary carrier of heat, moisture, and contaminants in and around laboratory buildings. Airflow patterns play an important role in determining the air velocities, air temperatures, and concentration of contaminants which subsequently determine thermal comfort of occupants and indoor air quality in laboratories. However, there are no easy means available to visualize airflow patterns. The flow path of air and the resulting flow path of contaminants can depend on several inter-related factors including the supply airflow rate or air changes per hour (ACH); in the case of ventilation dominated laboratories the contaminant generation rates and their location and type of contaminants; location, number, and type of supply diffusers; number and locations of exhaust grilles and returns; in the case of cooling load dominated laboratories the location and strength of various heat sources; in the case of fume hood dominated ventilation the location and size of fume hoods; and finally the arrangement of furniture and other airflow obstructions.

Real time measurements of all the parameters that affect the performance of laboratory ventilation effectiveness including the airflow patterns and the resulting flow path of

contaminants is not feasible, if not impossible. In such situations Computational Fluid Dynamics (CFD) analysis provides a sound scientific alternative. CFD analyses, if performed properly with adequate expertise, can predict airflow patterns and the probable flow paths of airborne contaminants in a lab space. Such analyses can be employed as a valuable design tool in developing appropriate mitigation strategies for existing spaces and during the early stages of new designs to optimize occupant comfort and indoor air quality, and to minimize the concentration of airborne contaminants.

A recent CFD study of a typical laboratory space indicated that the contaminant distribution can be highly non-uniform despite the "well mixed" airflow patterns. Such non-uniformity especially in the breathing zone can expose occupants to various degrees of health risks. This analysis showed occupants closer to the exhaust grille can be exposed to a higher-level contaminant concentration than those closer to the source of contaminants. Furthermore, this study indicated that monitoring of the laboratory environment using concentration levels in the exhaust duct can compromise the safety of occupants. Due to the highly non-uniform nature of the contaminant distribution, monitoring in the exhaust duct may underestimate the chemical exposure (dose) for some occupants. However, a simple modification such as an addition of an extra exhaust grille can significantly affect the contaminant distribution in the space resulting in reduced contaminant concentration levels and lower chemical exposure (dose) of occupants. Another CFD study emphasized that the design of HVAC systems can more significantly influence the contaminant exposure levels than just air changes per hour (ACH). Under certain circumstances high ACH can pose higher risk of chemical exposure than low ACH.

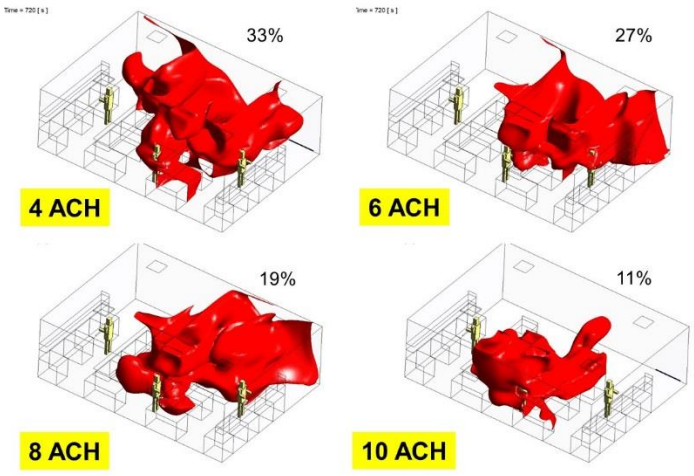

Figure 4. Cloud of 25 ppm concentration showing the spread after 720s release of contaminant shows contaminant spread is a volumetric phenomenon. Increasing ACH would help in minimizing the Spread Index, however, the location of the highest concentration depends on several HVAC related factors. (CFD analysis is performed by AnSight LLC, Ann Arbor, MI, USA.)

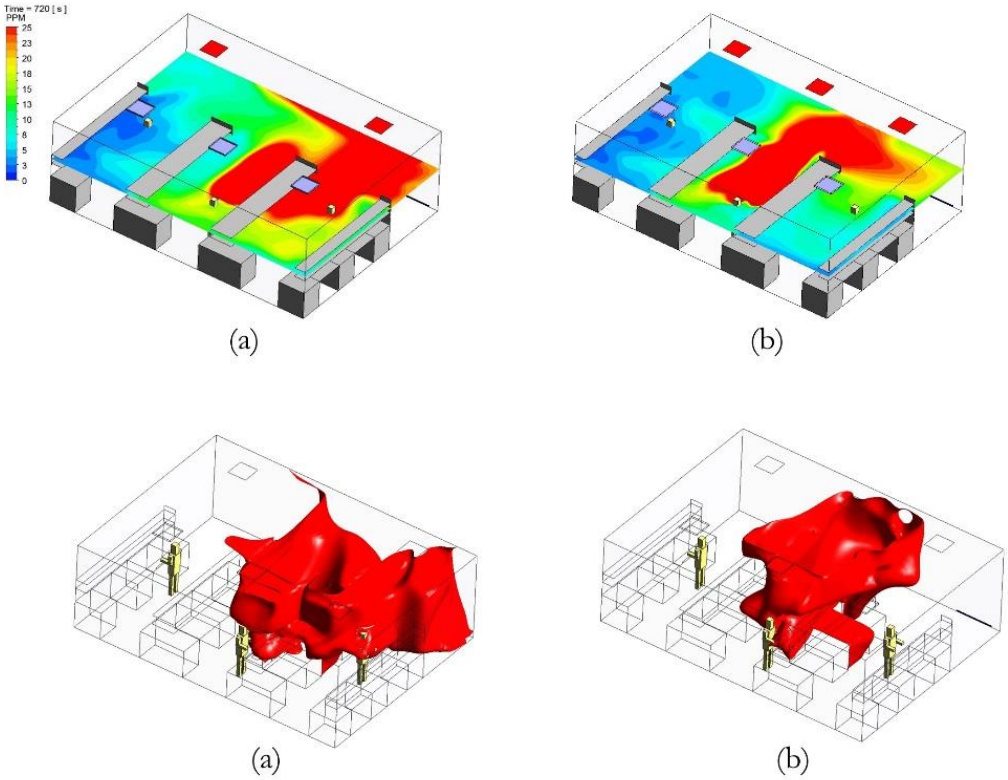

Figure 5.Distribution of contaminant concentration at the breathing zone after 720 s of release of contaminant for a typical laboratory setup with two and three exhaust grilles shows location and number of exhaust grilles can significantly impact the ventilation effectiveness. (CFD analysis is performed by AnSight LLC, Ann Arbor, MI, USA.)

Exposure at the front of the hood when the hood is used as the primary exhaust

Where a healthy person may occupy a lab with an infected person, the risk of exposure is predominantly associated with their proximity to each other (near-field concentrations), the airflow patterns within the space, the resulting concentration profile (far-field concentrations) and the length of time either person stays in the space. In a lab where the air supply and exhaust are designed to work in tandem to effectively dilute and remove contaminants will yield the lowest risk. However, a person standing in front of a fume hood that serves as the sole exhaust for a lab, as depicted in Figure 6, would undoubtedly be exposed, but the dose may be minimized through more effective dilution and quicker removal of the contaminants. Wearing masks within the lab may also be beneficial to reduce the generation and spread of contaminants from the source. Fume hood users should consult AIHA and/or their health and safety personnel for guidance on the appropriate PPE that should be worn while working in front of the fume hood.

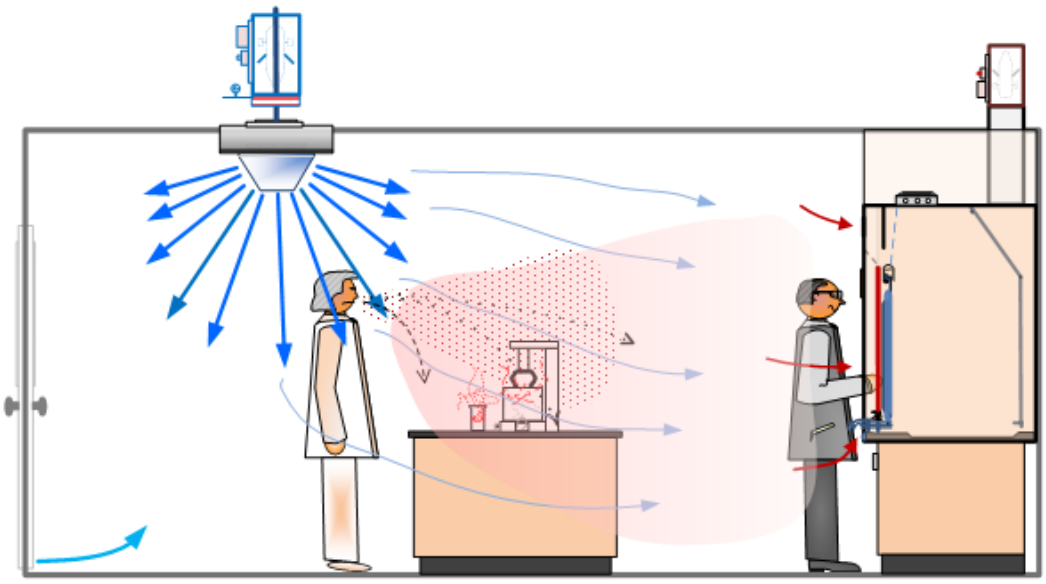

Figure 6. Diagram of laboratory with ventilation system that maximizes dilution and removal of contaminant to reduce exposure dose.

(Figure Courtesy of 3Flow)

References

ASHRAE

Laboratory Design Guide, Second Edition, 2015

Classification of Laboratory Ventilation Design Levels

Applications Handbook, 2019, Chapter 17

Epidemic Task Force

Standard 180 – Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems, 2018

Standard 62.1 – Ventilation for Acceptable Indoor Air Quality, 2019

Non-ASHRAE

AIHA/ASSE Standard Z9 – Ventilation System Standards

NFPA 45 – Standard on Fire Protection for Laboratories Using Chemicals

CDC - Biosafety in Microbiological and Biomedical Laboratories, Fifth Edition, 2009

ILAR – Guide for the Care and Use of Laboratory Animals, Eighth edition, 2011

NIH – Design Requirements Manual for Biomedical Laboratories and Animal Research Facilities (DRM) Policy and Guidelines, 2019

CCAC – Guidelines on: Laboratory Animal Facilities - Characteristics, Design and Development, 2003

CCAC – Addendum to the CCAC Guidelines on Laboratory Animal Facilities - Characteristics, Design and Development, 2019

PHAC – Canadian Biosafety Standard (CBS) - 2nd Addition, 2015

Guidance from Outside Agencies

ABSA- The Association for Biosafety and Biosecurity
(https://absa.org/covid19toolbox/**)**

ABSA developed a SARS-CoV-2 / COVID-19 Toolbox on their website that is a compilation of information published by other organizations, government agencies, etc.

CDC –U.S. Centers for Disease Control and Prevention
(https://www.cdc.gov/coronavirus/2019-ncov/community/index.html**)**

The CDC provides information on SARS-CoV-2 / COVID-19 and mitigation strategies. The guideless are for the general building environment and may not be applicable for a laboratory. The following are items that should be taken into consideration when reviewing these guidelines.

- *CDC Recommendation* - Consider using natural ventilation (i.e., opening windows if possible and safe to do so) to increase outdoor air dilution of indoor air when environmental conditions and building requirements allow. (
  ASHRAE ETF Laboratory Subcommittee Response: Natural ventilation is not recommended for laboratories.
- *CDC Recommendation* - Consider using portable high-efficiency particulate air (HEPA) fan/filtration systems to help enhance air cleaning (especially in higher-risk areas).
  ASHRAE ETF Laboratory Subcommittee Response: The use of portable air filtration is not recommended for laboratories.
- *CDC Recommendation* - Consider using ultraviolet germicidal irradiation (UVGI) as a supplemental technique to inactivate potential airborne virus in the upper-room air of common occupied spaces, in accordance with industry guidelines.
  ASHRAE ETF Laboratory Subcommittee Response: The impact of UVGI on experiments and procedures in the laboratory space need to be reviewed before implementation UVGI or other types of air cleaning technologies.

AIHA – American Industrial Hygiene Association
(https://www.aiha.org/public-resources/consumer-resources/coronavirus_outbreak_resources)

AIHA provides SARS-CoV-2 / COVID-19 information related to industrial hygiene.

ANSI/ASSP - American National Standard Institute/American Society of Safety Professionals Standard Z9.5 Laboratory Ventilation (https://www.assp.org/resources/covid-19/latest-resources**)**

General guidance SARS-CoV-2 / COVID-19 is available on their web site.

EPA – Environmental Protection Agency
(https://www.epa.gov/coronavirus**)**

The EPA web site provides key EPA resources on the SARS-CoV-2 / COVID-19.

I^{2}SL/SLCan – International Institute for Sustainable Laboratories
(https://www.i2sl.org)

I^{2}SL and SLCan formed a joint task group to assemble a guidance document on the operation of laboratories.

CSHEMA – Campus Safety, Health, and Environmental Management association
(https://www.cshema.org/covid-19**)**

CSCHEMA has developed their guidance related to the reopening and operation of laboratories.

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