Contra Costa Community College District Fall 2021 Facilities Readiness

HVAC Guidance

EXECUTIVE SUMMARY

The Contra Costa Community College District (4CD) COVID-19 Return-to-Worksites Operational Plan sets out procedures, protocols, and guidelines in several key categories to promote the health and safety of the campus community. As we begin planning for scaling of in-person services districtwide, this document outlines the pertinent information and 4CD's plan in regards to the heating, ventilation and air conditioning (HVAC) systems on our campuses, centers and at the District Office site. This document also outlines the districtwide efforts in preparing our building HVAC systems in time for the fall 2021 in-person return preparations in response to the COVID-19 pandemic in accordance with the Centers for Disease Control (CDC) and the American Society of Heating Refrigeration and Air Conditioning Engineers (ASHRAE) recommendations.

4CD is taking steps to ensure campus ventilation and filtration systems provide appropriate COVID-19 risk mitigation based on CDC and ASHRAE recommendations. Most of our buildings are connected to a centrally controlled HVAC system, giving building occupants and campus operations limited ability to modify their systems, including increasing ventilation or filtration. As part of the overall facilities readiness, Facilities is evaluating performance and capabilities of each building's HVAC system. This evaluation process is well in progress. In order to address buildings that, as of early April, were planned for increased in-person return in the fall 2021, the Colleges provided their prioritized buildings. Further evaluations will continue into May and June for the building that at the time of planning were planned with less of in-person occupancy. All buildings will be assessed, and necessary modifications will be made as we transition back in person on our worksites.

Changes to building operations, including the operation of HVAC systems, can reduce airborne exposure. However, as noted by CDC and ASHRAE, HVAC systems alone cannot prevent the spread of COVID-19. Any HVAC modifications must be combined with proper masking, social distancing, avoiding crowds, testing, quarantining and encouraging vaccinations. The image below is commonly referred to as the Swiss Cheese Model and it shows the personal and shared responsibilities we all have in helping to prevent the spread of COVID-19. The HVAC assessment addresses one slice of the swiss cheese model: ventilation and air filtration.

While no single intervention can fully eliminate spread, ***a collection of safeguards can achieve the desired level of protection.***

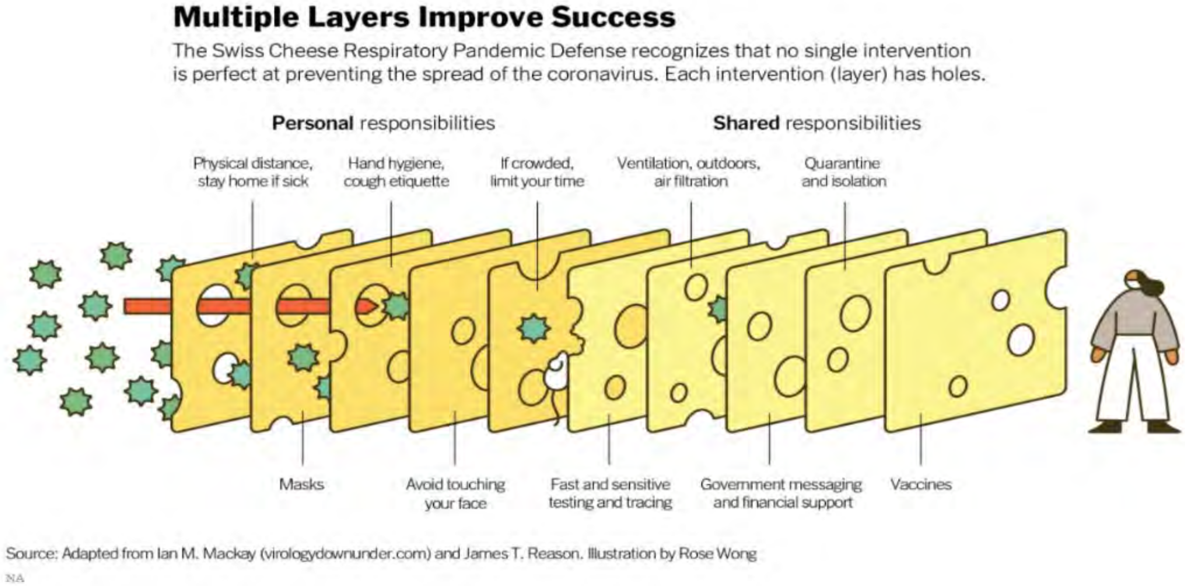


Figure 1: Swiss Cheese Metaphor for Preventing Spread of COVID-19 (source: New York Times)

ASHRAE and CDC have determined HVAC systems alone cannot prevent the spread of the coronavirus, but they can significantly mitigate the risk of infection in HVAC systems by addressing two key factors:

- Improved Filtration
- Increased Ventilation

As such, the District Facilities team moved quickly to bring on board two engineering teams that are working collaboratively to complete the air ventilation and filtration assessments districtwide. The team is comprised of Taylor Engineering (TE) and TRC. TE is a local firm that specializes in mechanical systems design and construction, energy conservation, indoor air quality, controls, and system commissioning of higher education and commercial buildings. They are leaders in the industry and experts in their field. They have written white papers and supported the development of codes, standards and guidelines for these systems for ASHRAE, the organization that CDC references for ventilation and filtration guidelines. TRC is a national firm with local offices that focuses on HVAC system assessments, including testing and inspections. Their firm also has leading indoor air quality specialists who will help guide and support the assessment process and recommendations to help ensure the health and safety of our students, faculty and staff when returning in-person in the fall.

The team will be assessing over 400 HVAC systems serving over 108 buildings, 2,812 rooms and 1.7 million square foot of space across our six sites. The teams are evaluating the capabilities of individual systems (e.g., control systems, heating/cooling capacity) to ensure the proper amount of outdoor air is supplied to indoor spaces and the proper ventilation is in place. The team is focused on prioritized buildings determined by the colleges that reflect the instructional and student services intended for in-person use for fall. All of the work is being closely coordinated with on-site Maintenance and Operations teams in each campus Facilities Departments. Our colleges' Maintenance and Operations staff can adjust HVAC systems to help ensure adequate ventilation (outside air) rates are maintained and replace air filtration devices to meet current recommendations. Where additional support is needed, repairs and upgrades will be performed by outside contractors.

Improved Filtration

Air filtration for HVAC systems is maintained by replacing air filters on regularly scheduled intervals throughout the year based on ASHRAE guidelines. This interval generally varies depending on the type and size of filter, and the conditions of the air being filtered. Filtration helps mitigates the risk of COVID-19 transmission in buildings with recirculated air by reducing the concentration of virus-containing particles. As air moves through a building's HVAC system, air filters trap and collect large and small particles such as dust, allergens and microorganisms.

What does MERV mean? MERV stands for Minimum Efficiency Reporting Value (MERV) and the rating number is a measure of how effectively the filter stops dust and other contaminants from passing through the filter and into the air stream. Filters with higher MERV ratings are denser and trap small particles more effectively than filters with lower MERV ratings. The MERV-13 filters recommended by CDC and ASHRAE capture lint, pollen, dust, mold, dust mites, bacteria, smoke and viruses.

Most of our buildings are typically fitted with MERV-8 or higher rated filters depending on the age and type of the HVAC system. However, as part of this HVAC assessment, each HVAC system is being evaluated and, where viable, will be upgraded MERV-13 filters. Upgrading HVAC system filters is not always feasible in some instances because higher rated filters can impair system performance or require costly modifications, or simply will not fit. Where MERV-13 filters cannot be used directly in existing systems, additional air filtration may be provided by portable air purifying units.

Increased Ventilation

Respiratory aerosols can build up in rooms over time. The time aerosols spend in a given room is largely controlled by a room's air exchange rate, typically characterized as the number of air changes per hour (ACH) and typically provided by a centralized HVAC system. Ventilation is the intentional introduction of outside air into a space to maintain indoor air quality (IAQ). Many of the District’s HVAC systems recirculate some indoor air to save energy, and mix in outdoor air based on the code requirements for the space type and its designed occupancy (number of people in a space). In these systems, both the outdoor air and the recirculated indoor air are filtered by the HVAC system.

SUMMARY OF THE HVAC ASSESSMENT AND RECOMMENDATIONS APPROACH

Contra Costa Community College District (4CD) has engaged Taylor Engineering to provide support with assessing the condition of its building heating, ventilating and air-conditioning (HVAC) systems to prepare for plans to gradually resume in-person instruction, student services and administrative functions in the fall of 2021. The HVAC systems are being evaluated based on current public health guidance and in accordance with recommendations from leading industry organizations, including the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE), Centers for Disease Control and Prevention (CDC), and the World Health Organization (WHO). This is a brief summary of the overall HVAC recommendations that will guide the efforts across 4CD facilities to help mitigate disease transmission in buildings.

Note: Taylor Engineering is a mechanical engineering firm – while we are experts in HVAC and ventilation systems, we are not medical doctors or epidemiologists. The positions and recommendations described herein are based on the review of hundreds of related research articles and recommendations from national industry groups and health organizations.

Types of Mitigation Measures

Measures that mitigate the transmission and health impacts of airborne contaminants can be broken into three broad categories (listed in general order of effectiveness and practicality):

1. Source Control,
2. Source Removal, and
3. Dilution.

Source control relates to reducing the source strength of the contaminant. Vaccinations, isolation of infected and symptomatic individuals (through COVID testing or screening for symptoms), requiring that masks be worn at all times indoors, and maintaining physical distancing are all highly effective source control measures that are the primary means of mitigation. HVAC systems have no impact on source strength.

Source removal refers to measures such as air cleaning that remove those contaminants that are released into the air, and dilution refers to reducing the concentration of the contaminant using ventilation. Source removal and dilution are the focus of the HVAC-related mitigation measures.

Can COVID-19 be transmitted through HVAC systems?

Public health authorities and leading health experts agree that COVID-19 disease transmission starts with virus-laden respiratory particles of varying sizes that are expelled through the mouth or nose from activities such as sneezing, coughing, singing, talking, and even simply breathing. For disease transmission to occur, these particles must (1) make contact with another individual's eyes, nose or mouth or be inhaled into the respiratory system, and (2) contain a sufficient quantity of viable virus (dose) to cause disease. The path can be indirect via contaminated objects or surfaces (fomites) followed by a hand-to-face transport. But research has shown that COVID-19 is primarily transmitted through the air via both near- and far-field transmission as shown in Figure 2.

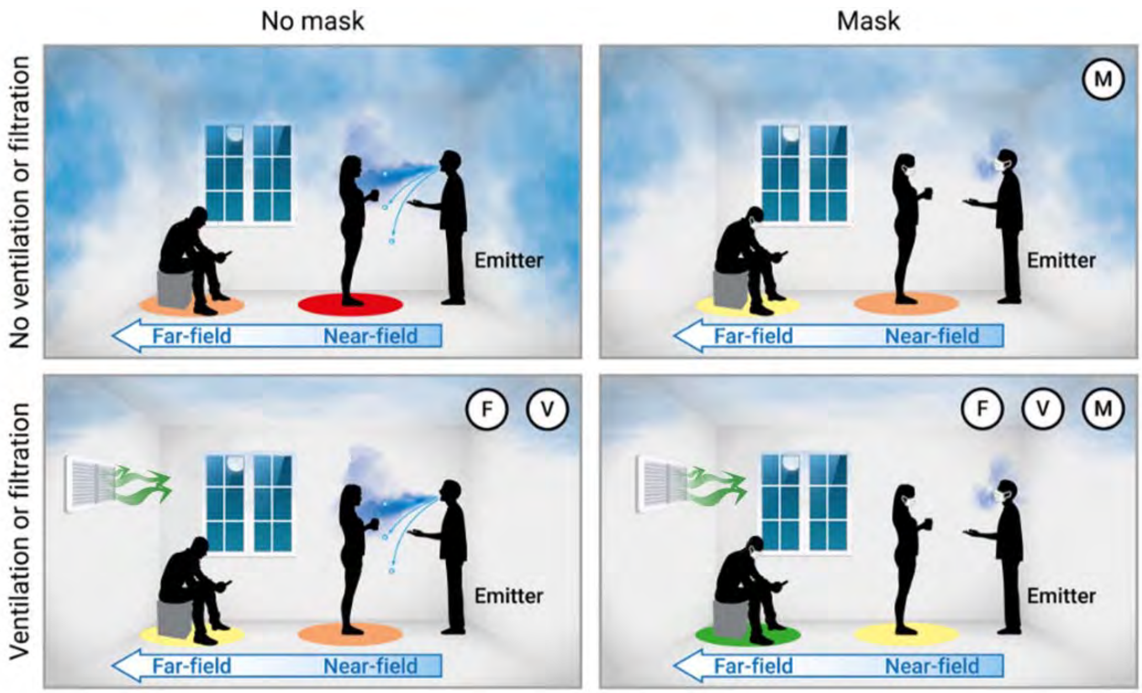


Figure 2: Transmission Paths with and without masks (M) and with and without either ventilation (V) or local filtration (F), from Pohlker et al, https://arxiv.org/abs/2103.01188. (Note that the image was modified to show ventilation and filtration as graphically represented in the images as a wall-mounted supply air grille, with a window if needed, respectively, for simplicity. Mechanical ventilation from HVAC systems is the primary form of ventilation at 4CD buildings.)

Near-field (close range) transmission can be by larger droplets that tend to fall out of the air after relatively short distances (e.g. 6 feet) and are largely unaffected by HVAC systems. Close range transmission can also occur from small- and medium-sized droplets over longer distances; this path can be affected by air currents, such as from HVAC outlets and open windows. Far-field (long range) transmission occurs via small particles, called aerosols that are small enough to behave like a gas and remain aloft almost indefinitely. Currently, the CDC and WHO state that short-range transmission, either via large droplets or dense clouds of small and medium size particles, is the dominant path; long range aerosol transmission is acknowledged to occur but considered much less common.

As depicted in Figure 2, local room filtration (source removal) and ventilation (dilution) are only effective at mitigating the far-field aerosol transmission path. This figure also shows the effectiveness of masks at reducing the source strength of the virus shedding from coughing, talking, etc. Only masks can mitigate transmission when individuals are within a few feet of each other and they are also effective, although to a lesser degree, at reducing the source strength of small aerosols, thus mitigating long-range transmission.

The amount of ventilation needed to provide acceptable risk of aerosol-path transmission is unknown at this time. But the research that has been done on several super-spreader events has indicated that no practical amount of ventilation can mitigate transmission without masks; the source strength is simply too high. With masks, research suggests that the ventilation rates currently required by code (largely based on ASHRAE Standards 62.1 and 170, which also align with California's equivalent codes in Title 24) will provide acceptable risk. This is ASHRAE's current recommendation.

Figure 2 depicts "room scale" transmission paths. Another possible aerosol transmission path is called "air-handler scale" transmission, depicted in

Figure 3, where an infected person sheds aerosols that can be drawn into the HVAC system return air grilles, up the return air path to the air handler, then back to another area of the building served by the same air handling unit. So far, no research has demonstrated that recirculation from air handling systems has caused any infections of any disease, not just COVID-19. This is likely due to the continuous dilution of the virus laden aerosols as they mix in the room, mix with clean air from other rooms served by the system, mix with outdoor air at the air-hander, and with final particle reduction from the air handling unit filters.

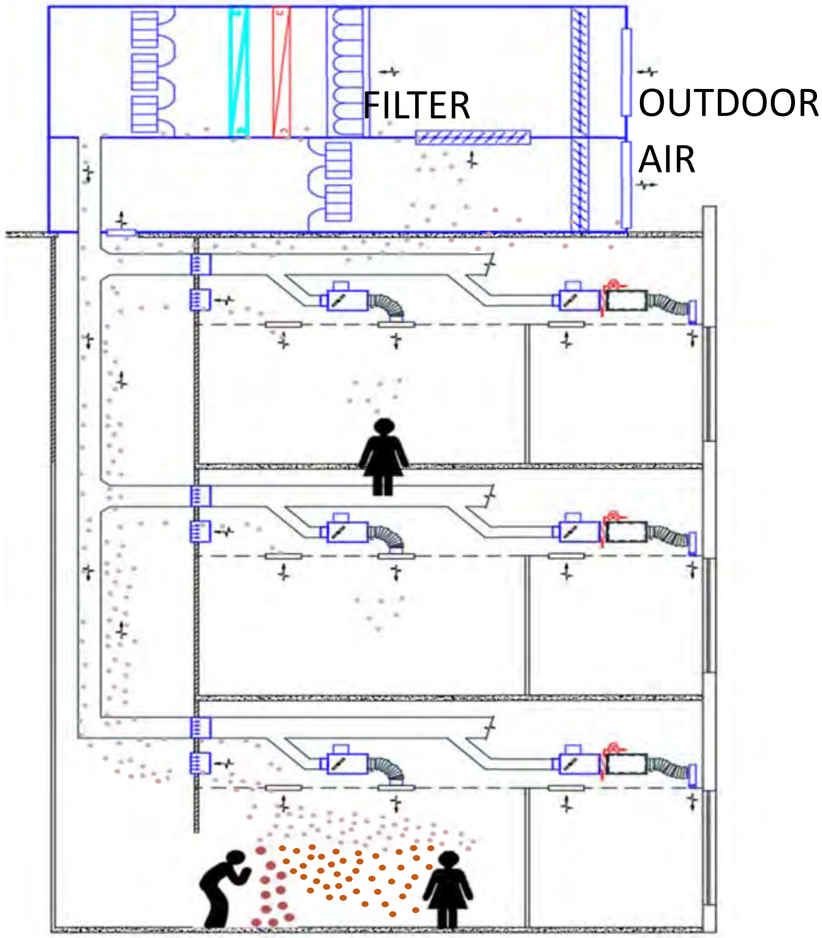


Figure 3: Air Handler Scale Transmission

In summary,

- The most effective defense against disease transmission is always "source control", primarily wearing masks but also by testing to isolate infected individuals and distancing. In the case of COVID-19, the predominant transmission path is via short-range particles of all sizes, and wearing masks is the only effective mitigation measure, as depicted in Figure 2.
- With masks, the amount of ventilation required to address room-scale aerosol transmission is about what building codes (Title 24 in California) already mandate for mechanical ventilation systems.
- Since "air-handler scale" transmission does not appear to be a significant path, the use of high efficiency filters is unlikely to provide significant benefit with respect to disease transmission for larger HVAC systems. However, high efficiency filters may be more beneficial for smaller HVAC systems (more akin to what 4CD has), are also valuable for improving air quality by removing

outdoor air contaminants, especially during wildfire season, and they are relatively inexpensive to employ as a broad measure.

- For older buildings that do not have mechanical ventilation system, e.g. those using only operable windows, or where older systems cannot maintain current standard ventilation rates, portable room air cleaners can be used effectively dilute aerosol concentration.

For a detailed discussion and literature review supporting this summary, please refer to the Taylor Engineering COVID-19 whitepaper.

HVAC System Recommendations:

Ventilation:

- Confirm that HVAC systems provide at least the minimum required ventilation rates per applicable codes and standards. These minimum outdoor air rates are generally equal to the greater of 0.15 cubic feet per minute (cfm) per square foot (ft^2) of occupied space or 15 cfm per person, according to California Title 24. Overall supply airflow rates (outdoor air plus recirculated air) at 4CD buildings will typically range from 0.5 to 1.2 cfm/ft^2, or roughly 3 to 6 air changes per hour (ACH). Outdoor air rates will be tested at all units that provide outdoor air ventilation. Systems that have been successfully tested within the past 3 years will be considered acceptable without the need for retesting. Operation will be confirmed at fans that provide code-required exhaust ventilation, such as restrooms.
- Many HVAC system are capable of providing up to 100% outdoor air when ambient conditions are favorable, as a means to reduce energy costs and improve indoor air quality. At other times, these systems are controlled to recirculate air and only provide minimum outdoor air rates for ventilation. For these systems, proper system functionality will be confirmed through on-site testing as well as remote monitoring of the control systems.
- HVAC system schedules will be confirmed to operate to provide a flushing period at least 1 hour prior to expected building occupancy in accordance with California Title 24 and at least 1 hour after classes/occupancy has ended.
- Building energy codes require the use of energy conservation measures that reduce airflow and ventilation rates during periods of partial occupancy such as through carbon dioxide monitoring or occupancy sensing in each space. These demand controlled ventilation measures will be temporarily modified or disabled to ensure that higher ventilation rates are maintained.

Air Filtration

- The efficiency of air filters at capturing particulates of varying sizes is rated according to the Minimum Efficiency Reporting Value (MERV). MERV 13 filters are now required by building codes and standards for new construction, and are recommended for use where feasible as a COVID-19 mitigation measure. Air filtration at all HVAC systems will be inspected to confirm filtration efficiency and to identify any potential locations where air may be bypassing the filters. Where possible, system filters will be changed to use MERV 13 or higher filtration efficiency.

HVAC-driven Air Currents:

- Where not critical for thermal comfort, ceiling fans and local fans will be disabled or modified to operate at lower fan speeds to reduce high velocity air currents that may lead to spread of respiratory droplets.

Potential Mitigating HVAC measures (when the HVAC Systems Recommendations above are unable to be met):

Every reasonable effort will be made to address any deficiencies in the HVAC systems that are identified as part of the assessment. In some cases, existing systems may not be capable of achieving all of the recommendations. For example, some fans may not have been designed with the capacity to handle high filtration efficiency. In these cases, as well as in some cases where the HVAC systems do meet the minimum recommendations, additional mitigating HVAC-related measures may be undertaken, including:

- Equivalent outdoor air calculations take into consideration the benefit of actual outdoor air as well as the effect of filtration and air cleaners on recirculated air, according to current ASHRAE Building Readiness guidance. Where necessary, the equivalent outdoor air rates will be considered as an additional mitigating measure.
- Portable air cleaners with high efficiency particulate air (HEPA) filters will be considered for spaces that do not meet mechanical ventilation or filtration criteria.
- The use of ultraviolet (UV) air cleaners may be considered in high occupant density spaces to kill or inactivate airborne microorganisms . Upper-room UV-C lamps are mounted on walls, high in the room where radiation in the UV-C wavelength band is directed horizontally across the upper level of the room, called the disinfection zone. The lamps are mounted high and directed away from occupants to avoiding causing eye injury and skin burns. While this may be an option, being able to utilize portable air cleaners, if and where needed, is a preferred method at 4CD.
- Operable windows may be opened where they exist and can be opened safely, and weather permitting. However, some precaution is required with this measure. Opening windows on opposite sides of the room is ideal, but airflow will be dependent on wind and ambient conditions, and leaving windows open may introduce other security and/or cleanliness issues. If the open window affects a thermostat, the outdoor temperature could cause other spaces served by that system to be overcooled or overheated.

Assessment and Implementation Plan

HVAC system assessments will be conducted at high priority areas throughout 4CD campuses through May, with the net set of priority areas evaluated immediately thereafter. These assessments will evaluate each building and HVAC system based on the criteria outlined above, based on review of system documentation (drawings, reports, etc), monitoring of the digital control systems, and from on-site inspections and testing. In May, the findings and recommendations from the assessments will be reported. 4CD anticipates engaging service providers and contractors to rectify identified HVAC system deficiencies throughout the summer, along with implementation of other non-HVAC mitigation measures, to prepare facilities for the fall re-opening. This work may include additional testing; equipment adjustment, repair, or replacement; and control system modification.

4CD HVAC Assessments

Contra Costa Community College District (4CD) hired TRC to assess the condition of the air handling units (AHUs) and ventilation air volume for all their buildings at all their campuses. TRC is focused on assessing the total outside air provided to the building and collecting information to support calculating the total amount of clean air delivered to the building. This will include outside air (OA) and supply air (SA) measurements for many of the AHU at the High Flow condition (full supply air flow & maximum OA), Low Flow condition (minimum supply air flow & minimum OA), and an Intermediate Flow condition (full supply air flow & minimum OA).

TRC will work with 4CD staff to identify independent exhaust fans (ones that are not an integrated part of an AHU). We will focus on exhaust fans that are the primary source of mechanical ventilation for a space. We will document any identification tags and if the exhaust fan is operating.

TRC will also perform a limited room-level review of a sample of spaces within a building to identify the presence of operable windows, ceiling fans, or evidence of air distribution issues. If we identify systems with significant deficiencies, we will work with 4CD and Taylor Engineering to determine if we need to perform a more detailed zone level investigation.

Taylor Engineering is developing a list of air handlers by building that identifies key parameters so that TRC can segment the HVAC systems into three major categories:

1. New or retrofit in within 3 years that included testing, adjusting, and balancing (TAB) activities. TRC will perform visual inspection only. No air measurements will be taken.
2. Supply fan and economizer controlled by the building management system (BMS). 4CD staff will override and force conditions for air flow measurements. TRC to perform visual inspection and field measurements.
3. Supply fan and/or economizer NOT controlled by BMS. TRC to perform visual inspection and override local controls at the unit to force conditions for air flow measurements.

Visual inspections

- Identify unit and take pictures of the unit and nameplate.
- Collect supply fan motor size and take a picture of the fan motor nameplate.
- Review the outside air source, collect details, take pictures, and note economizer functionality.
- Collect the filter rating, type, size, and condition. Take pictures and note if air is bypassing the filter.

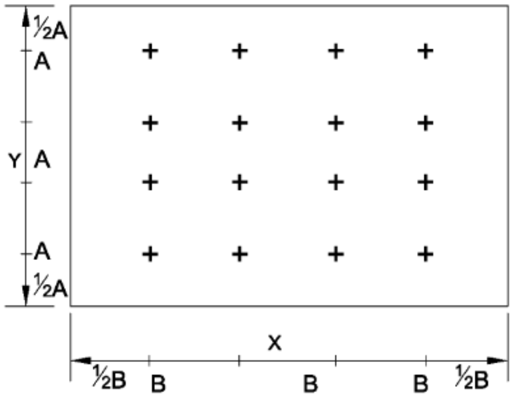
Air Flow Measurements

- TRC will take measurements that allow us to quantify the total air flow delivered by the AHU and the total outside air delivered. Ideally, we will measure each of these parameters directly, but in some circumstances, it may be better to measure the return air (RA) and through mathematics quantify either the OA or supply air (SA).
- Ideally, TRC will measure velocities 7.5 duct diameters downstream and at least 3 duct diameters upstream from any turns or flow obstructions, but due to actual AHU and duct

layouts this will often not be feasible. We will take measurements in locations where we can find the cleanest air flow profile (no negative regions or center duct low flow). Realistically we will find the longest straight duct run and take measurements at least 2 ½ duct diameters from the fan, obstruction, or fitting or at the midpoint between those components.

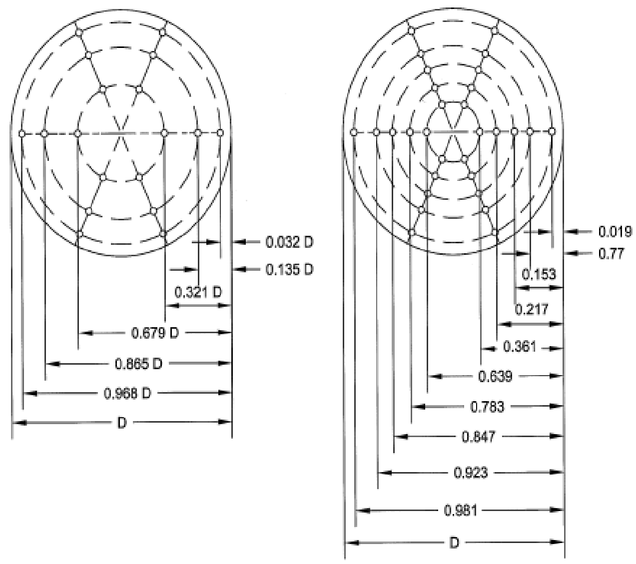
- TRC will try to take OA measurements on the downstream side of dampers, louvers, or ducts. This may be very close to the opening due to physical limitation and mixed air plenum geometry. In some cases, OA measurements may need to be taken upstream of dampers, louvers, or ducts. If we can better determine OA values by subtracting RA measurements from SA measurements, we will do that instead. Note the RA measurements must quantify the air into the mixed air plenum.
- TRC will measure the height and width (or diameter) of the section where the air flow traverse will be performed. TRC will also photograph the test locations.
- The number of measurements for each traverse will vary based on duct (opening) size and geometry. TRC is generally following the ASHRAE Standard 111 equal area rule, but will limit the number of measurements for a traverse array to a maximum of 30 points for larger openings (this aligns with the max required for large round ducts).
- For consistency, TRC will take and record the velocity readings - starting at the lower left corner for rectangular duct/openings and with the horizontal traverse for round duct.
- For measurements in supply ducts, we will plug the holes not used in the current traverse measurements.
- TRC will use a hot wire anemometer to measure air velocities. The devices will be auto calibrated prior to use. Air flow measurement will be trended over five second samples and we will include a minimum of two samples.
- For units with small OA openings, we may use a flow hood instead of a hot wire anemometer to measure air flow.

Figure 4 ASHRAE Standard 111 Rectangular Equal Area Rule



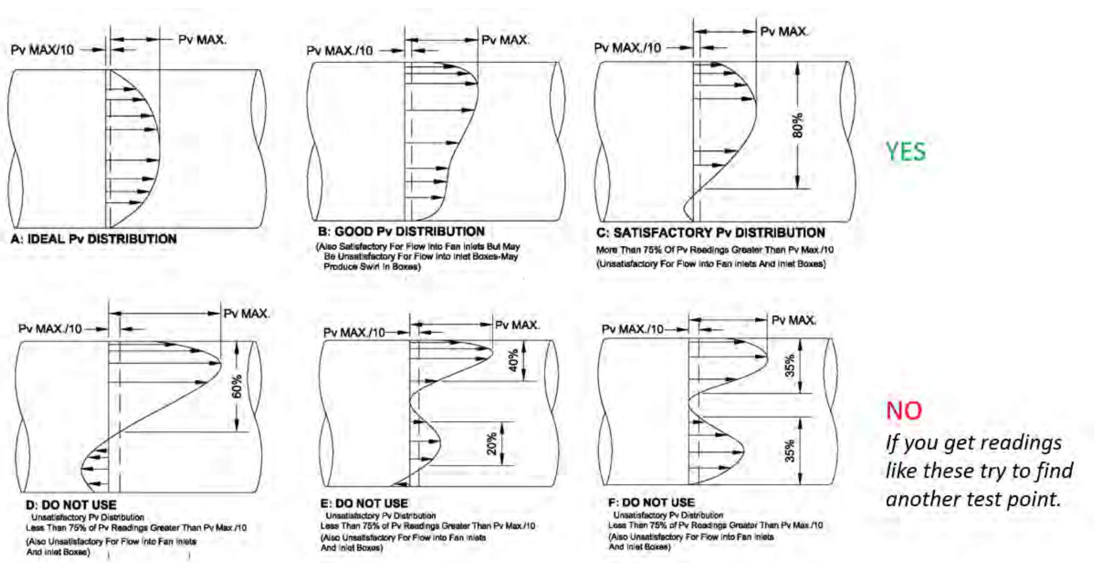
IF X OR Y ARE LESS THAN OR EQUAL TO	MINIMUM NUMBER OF READINGS
4" OR LESS	2
15"	3
24"	4
35"	5
48"	6
63"	7
80"	8
99"	9
100" OR GREATER	10

Figure 5 ASHRAE Standard 111 Round Duct Equal Area Rule



NO. OF MEASURING POINTS PER DIAMETER	POSITION RELATIVE TO INNER WALL	USE WITH DIAMETER
6	0.032, 0.135, 0.321, 0.679, 0.865, 0.968	<10"
10	0.019, 0.077, 0.153, 0.217, 0.361, 0.639, 0.783, 0.847, 0.923, 0.981	≥ 10"

Figure 6 Acceptable Air Flow Profiles



Package Rooftop Units (RTU)

Performing air flow measurements on small curb mounted RTU is difficult due to the geometry and limited area. TRC will use the following procedure:

1. Measure as found pressure differential from SA plenum to RA/MA plenum (total static).
2. Open the access hatch to RA/MA plenum and fully block RA to the supply fan with cardboard effectively turning unit into 100% OA with all air coming from the open access hatch.
3. Adjust the size of the of the access hatch opening with cardboard to match the as found total static. This simulates the RA duct resistance.
4. Measure airflow at the adjusted hatch opening as this is effectively the same as the existing supply air.
5. Return the unit to as found condition and measure air flow at the OA grill.
6. For variable air volume RTUs the SA and OA flow will be measured with the RTU forced to minimum and maximum flow conditions.

Constant Air Volume (CAV) AHU

- All measurements will be taken at the current supply fan flow.
- For AHU with full economizers OA measurements will be taken with the economizer forced to maximum and minimum OA position.
- For AHU with manually adjustable dampers OA measurements will be taken at the as found damper position. The OA damper position will be marked and OA measurements will be taken with the OA damper set in the maximum open position. The OA damper will then be returned to the as found setting.

Variable Air Volume (VAV) AHU

Low Flow Air Measurements:

- Force fans into minimum flow and force any economizers to minimum outside air.
- Supply fan flow should be lowest flow allowable during normal operation.
- Outdoor air dampers should be at the minimum position allowable during normal operation.
- For adjustable dampers that have no automated control, we will use the current damper settings.
- Record the individual point measurements.

Intermediate Flow Air Measurements:

- Where/when possible, force fans into maximum flow and force any economizers to minimum outside air.
- This mode is complicated with the need to open VAV boxes to establish full flow and it may not be possible. If TRC is not able to force full flow, we will attempt to time our measurements to coincide with periods of high heat load when the control system will generally increase air flow.

- Where/when it is NOT possible to achieve full flow conditions, determine % supply fan flow (fan speed, inlet damper position, etc.) from control signals and force economizers to minimum outside air.
- For adjustable dampers that have no automated control, we will use the current damper setting.
- Record the individual point measurements.

High Flow Air Measurements:

- Where/when possible, force fans into maximum flow and force any economizers to maximum outside air.
- This mode is complicated with the need to open VAV boxes to establish full flow and it may not be possible. If TRC is not able to force full flow, we will attempt to time our measurements to coincide with periods of high heat load when the control system will generally increase air flow.
- Where/when it is NOT possible to achieve full flow conditions, determine % supply fan flow (fan speed, inlet damper position, etc.) from the control signals and force economizers to maximum outside air.
- Where/when it is NOT possible to achieve full flow and maximum OA conditions (unlikely), determine % OA flow and damper position from control signals.
- For adjustable dampers that have no control, we will mark the current location and then adjust the damper to as open as possible.
- Record the individual point measurements.