Exhaust Re-Entrainment Guide

Checking your building systems potential for exhaust re-entrainment is a good thing to do during the Systems Analysis Check listed in the earlier section to identify any potential concerns if the building were to have people who have COVDI-19 in their building. 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.

In addition, if the re-entrainment potential is high with Epidemic Conditions in Place, it is also an issue for Post Epidemic Conditions in Place and should be an item in your Work Orders to get corrected.

The document utilizes ASHRAE Standard 62 guidance that general exhaust is based on the class of air. The cleanest air is Class 1 and air that is classed as 4 is "Air with highly objectionable fumes or gases or with potentially dangerous particles, bio-aerosols, or gases, at concentrations high enough to be considered harmful." Class 1 air can be used in another space without cleansing.

For exhaust re-entrainment, Class 4 air has a minimum separation distance of 30 ft (10m) from an intake (per ASHRAE 62.1 Table 5-1 "Air Intake Minimum Separation Distance).

However, in the new world created by the COVID-19 outbreak, we can no longer guarantee that all exhaust will remain general exhaust.

- the minimum size of the viable virus dose required to become sick is unknown.
- in addition, the lifespan of a viable COVID-19 virus in an evaporated droplet nuclei is unknown.
- Until research clarifies these and other questions, exhaust of spaces with known COVID-19 cases cannot be assumed to be clean unless active measures are taken.

Hence, facilities are not in a position to assume they are releasing clean air. However, the chances of aerosolized droplets reaching the exhaust are remote.

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Exhaust Air Re-entrainment Guide: Purpose

The purpose of this guidance is to provide recommendations regarding issues of what to do with exhaust from buildings as it relates to minimizing re-entrainment.

- This information is supplementary to other guidance in that it should not be used to lower requirements for any exhaust stacks where source guidance for that specific exhaust type is more rigid or has higher requirements.

- This is also intended for office, residential and other such spaces that are not laboratory or healthcare facilities. Those facilities will typically have included guidance on exhaust re-entrainment from their Safety Management Engineer (SME) or Environmental, Health and Safety (EH&S) department.

Exhaust Air Re-entrainment Guide: Re-entrainment Risk

The risk of re-entrainment is typically expressed in the estimated dilution target from the exhaust source to the air intake receptor. This looks at the two extreme conditions, safe and danger, to establish the top and bottom end of a risk scale. Keep in mind that the majority of buildings are some in between these two extremes.

At the extreme safe end:

- If the exhaust is general exhaust from within a building, with a low probability of infectious occupants, has UV irradiation and HEPA filtration on the outlet, then chances are it is clean.

- If the dilution as the air travels from the exhaust to an intake (or other sensitive receptor) takes a route that provides on the order of 75:1 external dilutions, then it is likely that the risk associated with re-entrainment is low.

At the extreme danger end

- If the exhaust is being released directly from a room containing infectious individuals without any form of control, chances are there are droplets / aerosols / particles with viable viruses in them.

- If the estimate of dilution between the exhaust point and the intake is less than 10:1, then the risk is higher of a contaminant re-entering.

Most building exhausts will be somewhere in between. Note that elements in the system configuration such as the level of filtration, degree of UVGI, energy recovery wheels, combined exhaust (which increases internal dilution) and other aspects can reduce the required external contaminant dilution.

There are a variety of ways of setting a total dilution target. Given that neither the source strength is known (e.g. the number of particles emitted by an infectious individual) nor the dosage required to catch COVID-19 is known, setting a firm criterion is hard to do. There are therefore three target dilution methods described here:

1) Base the total dilution rate on an N95 mask that only sees a single pass of air. An N95 mask, when worn correctly, removes 95% of the particles at 0.3 microns. This equates to a dilution of 20:1. ADD Sidebar: The person wearing the N95 mask will also see the benefit of the 300:1 internal dilution for the well mixed space, in addition to the mask. This would equate to a total dilution of 6,000:1.The 300:1 dilution can be thought of as 1 cough or sneeze of 1.0 L (1 quart) every minute is diluted in a room that receives 300 L/min/cough (10.5 cfm/cough) of room ventilation.
2) Base the total dilution rate on a HEPA filter.
    a) A HEPA filter is designed to be 99.97% efficient at removing particles at 0.3 microns in size. That equates to a dilution of 3,333:1.
    b) A HEPA filter's most penetrating particle size is slightly smaller at approximately 0.2 microns and that capture efficiency is 99.994% efficient. That equates to a dilution of 1,785:1.
3) Base the total dilution rate on the target for Tuberculosis (TB) since it is confirmed to be airborne with a known infectious dose. That target total dilution rate is 22,500:1. Hence, for the same internal dilution of 300:1, the external dilution required would be 75:1 to meet the Conversion Percentage (I) of 0.1% without any filtration.

The value 300 L/min (10.5 cfm) is based on the airflow required by ASHRAE Standard 62.1 for a person in the space allotted for a variety of occupancy and building types.

Potential Hierarchical Re-entrainment Risk Assessment Process

The potential risk of adverse re-entrainment is a function of:

- The potential for the contagious particles to be released into the atmosphere;
- The susceptibility of individuals to be adversely impacted by exposure to these particles that are within the indoor spaces served by the air handler unit; and
- The relative quantity of the exhausted air that might be re-entrained at the air intakes.

Since exact release rates and exposure limits are unknown, risk levels are compared against ventilation systems that have been designed to meet the requirements of ASHRAE 62.1 Class 2 or Class 4 air. Class 2 air may have moderate contaminant concentrations, mild sensory-irritation intensity, or mildly offensive odors. It is assumed that these systems may result in a moderate risk of adverse re-entrainment. Class 4 air may have highly objectionable fumes or gases or with potentially dangerous particles, bioaerosols, or gases, at concentrations high enough to be considered as harmful. Therefore, it is assumed that systems designed to meet Class 4 requirements will have a low risk for adverse re-entrainment for the purpose of this risk assessment.

To assess the level of re-entrainment risk, we recommend the following steps that include a field investigation and / or calculations. These should be done in escalating order from simple to complex and are therefore arranged in that manner. This guide does not expect all of the levels to be done for each building, just until it is believed that your systems are in the lower risk ranges.

To assess the risk of re-entrainment, steps that should be included in the field investigation are:

- 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

Level 0 - Observation for Re-entrainment Risk Assessment

The intent of this assessment is to walk the building and look at the exhaust points in relation to the air intake and then to ask these 8 questions to assess a high or low level of risk. (Note, the questions are phrased so that “Yes” answers indicate a higher level of risk and “No” answers are a lower risk level.

1. Is there a direct line of site from the exhaust to the intake?

   Yes - higher risk / impact

   No - lower risk/ impact

2. Are the exhaust and intake within the same screened enclosure ?

   Yes - higher risk / impact

   No - lower risk / impact

3. Are the exhaust and intake within an air flow recirculation region (ASHRAE Handbook Fundamentals, Chapter 24, Figure 4) ?

   Yes - higher risk / impact

   No - lower risk / impact

4. Is the separation distance between the exhaust and intake less than required distances described in Std 170 (25 feet) and Std 62.1 for Class 4 air?

   Yes - higher risk / impact

   No - lower risk / impact

5. Is the intake louver above the exhaust/relief?

   Yes - higher risk / impact

   No - lower risk / impact

6. What is the general condition of the air handler and/or exhaust units: has maintenance been deferred?

   Yes - higher risk / impact

   No - lower risk / impact

7. Was the exhaust system designed to remove only non-hazardous compounds (ASHRAE 62.1 Class 1, 2 or 3 exhaust)?

   Yes - higher risk / impact

   No - lower risk / impact

8. Does the exhaust point release sideways, down or capped in lieu of straight upwards ?

   Yes (sideways, down, or capped) - higher risk / impact

   No (Upwards without restriction) - lower risk / impact

If you have mainly answered “No” and feel you have a lower risk then you might not need to move to the next level of Re-entrainment Risk Assessment. If you do not feel like you are at lower risk for re-entrainment, then the next level is appropriate.

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Level 1 – Semi-Quantitative Assessment Re-entrainment Risk Assessment:

The following risk assessment procedure provides an indication of the risk of potential adverse re-entrainment of building exhaust into nearby air intakes if there is a potential for contagious airborne particles in the exhaust stream. This uses more portions of the building system to evaluate the potential for re-entrainment.

This process separates the re-entrainment risk into different categories of potential source:

- Potential Emissions
  - Ventilation
  - Occupants
  - Filtration
- Allowable Exposure
  - Occupant Health
- Relative Dilution
  - Outside Intake versus Exhaust Location

Emissions Potential

1. Ventilation System
   a. Ventilation Rate – [1/(cfm/ft^2)]
   b. Recirculation - [1/(% Recirculated Air)]

<u>Rational:</u> The volume flow rate and the percentage of recirculated air is used to define the relative dilution of the exhausted air. Greater volume flow rates and greater % of recirculated air increase the relative dilution being exhausted.

Baseline is 1 cfm/ ft^2 of 100% outside air (no recirculated air) – higher ventilation rates provide proportionally greater initial dilution, while lower ventilation rates provide proportionally lower initial dilution. Points are based on the ratio of the actual ventilation rate to the baseline.

Note: The typical requirement for outside air for a class 2 space is on the order of 0.06 to 0.18 cfm/ft^2. Therefore, we could certainly justify lowering the baseline to something closer to 0.1 cfm/ft^2.

1. Occupants
   i. Density – [36 / (ft^2 / occupant)
   ii. Activity
      1. High Respiratory Activity 2
      2. Average Respiratory Activity 1
   iii. Low Respiratory Activity 0.5

Rational: The occupant density and activity values are used to define the relative respiratory volume within the exhaust. Higher density of people and/or higher activity of the occupants will create greater respiratory volume.

Baseline occupancy is 1 occupant per 36 ft^2; while the baseline activity is for average respiratory activity (defined as an intermittent activity or normal walking). Research indicated that respiratory rates increase by about a factor 2.5 during a moderate workout[1] and decrease by factors ranging from 45% during deep sleep to 55% for awake, but resting[2].

[1] – Gastinger, S, A Sorel, et. al, "A Comparison Between Ventilation and Heart Rates as Indicator of Oxygen Uptake During Different Intensities of Exercise," Journal of Sports Science & Medicine, Vol. 9 pp 110-118, March 2010.

[2] – Gutierrez, G, J. Williams, et. al, "Respiratory rate variability in sleeping adults without obstructive sleep apnea," Physiological Reports, Vol. 17, September 2016.

1. Filtered Air (Based on a 0.3-micron particle size)
    a. No Filter 1.00
    b. MERV 6 0.95
    c. MERV 8 0.90
    d. MERV 11 0.85
    e. MERV 12 0.75
    f. MERV 13 0.55
    g. MERV 14 0.35
    h. MERV 16 0.25
    i. HEPA / UVGI 0.003

Rational: Filtration is used to remove a portion of the emitted particles from respiration. Points are based on the portion of 1µm particles that pass through the filter (1 / filter efficiency). Base case is No Filter.

Overall Emissions Potential

Emission Score = Ventilation Score x Occupant Score x Filtration Score

Rational: The emission score is the overall relative quantity of respiratory emission particles that are 1µm or larger.

Allowable Exposure

1. Occupant Health
    a. Higher Risk per CDC – would fall into the stay at home category – 5
    b. Everyone Else – Not in the CDC stay at home category – 1

Rational: The allowable exposure score is an attempt to quantify the susceptibility of occupants to be adversely impacted by exposure to respiratory emissions defined above. The factor applied to facilities which include higher risk individuals will require the allowable intake concentrations (a combination of the emission potential and the relative dilution) to be no greater than 20% of allowable levels for facilities which do not include higher risk individuals. Note that factor is not based on any scientific knowledge of the increased risk of exposure to these high-risk individuals. Once this information is better defined, this factor can be adjusted accordingly.

Relative Dilution

1. Intake to Exhaust Relation
   a. Intake/Exhaust on Opposite Sides of Building 5
   b. Intake/Exhaust co-located within mech. screen 0.5
   c. Intake "hidden" from exhaust 2
   d. Vertical exhaust of 10 ft or higher above intake 5

Rational: The relative dilution score is used to quantify the additional dilution of the building exhaust that can be expected based on certain characteristics of the placement of the exhaust and the nearby air intakes. Base case is an exhaust system that meets the requirements for ASHRAE 62.1 Class 2 air (i.e., a minimum 10 ft separation distance with "free air" between the exhaust and the intake).

The factor 5 five for exhausts on the opposite sides of the building is a conservative estimate of the additional separation distance between the exhaust and the intake. Dilutions increase with the square of the distance, so doubling the distance increases the dilution by a factor of 4. So, increasing the distance to at least 25 ft will increase dilutions by at least a factor of 5.

Placing an exhaust and an intake within the same mechanical screen wall will "trap" a portion of the exhaust. The factor of 0.5 assumes that the dilution at the nearby intake will only be half that without the screen wall.

ASHRAE research project TP-1168 "Exhaust Contamination of Hidden vs. Visible Air Intakes" found that just avoiding a direct line of sight between the exhaust and the nearby air intake increased the dilution of the exhaust at the air intake by at least a factor of 2.

Vertical stacks of at least 10 ft in height are commonly used when the exhaust contains contaminants which are in concentrations above their allowable exposure level (ASHRAE 62.1 Class 4 air). The 10 ft minimum stack height is required under NFPA 45 and ANSI/ACGHI Z9.5 for these types of emission sources. Class 4 air requires a minimum dilution factor of 50 (STD 62.1 Table B-3), Class 3 air requires a minimum dilution factor of 15; and older versions of 62.1 (prior to 2004) required a dilution factor of 10 for Class 2 air. Therefore, the factor of five is the ratio of the Class 4 dilution factor (50) and the older Class 2 dilution factor (10).

Final Score:

The final score for the risk of adverse re-entrainment of building exhaust into nearby air intakes takes into account the relative risk scores associated with the quantity of respiratory emissions; the allowable exposure levels based on building occupants; and the relative dilution between the exhaust source at nearby air intakes. Higher scores for either the emissions or the allowable exposure increase the risk of adverse exposure, while a higher score of the relative dilution decreases the risk of adverse exposure. Therefore, three risk categories are combined by dividing the dilution score by the product of the exposure and exposure scores).

An overall score of 1.0 means that the risk of adverse re-entrainment is equivalent to a properly designed ASHRAE 62,1 Class 2 exhaust system. Values less than 1.0 indicate an increased risk of adverse re-entrainment; while values greater than 1.0 indicate a decreased risk of adverse re-entrainment, as shown in the table below.

Reentrainment Risk Score	Reentrainment Risk Category
< 0.5	High Risk of Re-entrainment (Further analysis may be warranted)
0.5 to 1.5	Moderate Risk of Re-entrainment (Equivalent to expected re-entrainment from a Class 2 exhaust system)
1.5 to 5	Moderately Low Risk of Re-entrainment (Unless facility if highly risk averse, no additional analysis may be warranted).
>5	Low Risk of Re-entrainment (Little to no concern for adverse re-entrainment)

Level 2 - Experimental Re-entrainment Risk Assessment

The Odor Test for potential Re-entrainment is to place a material just inside of the exhaust duct or someone in the space at an exhaust grille and then to observe. You need to define the release chemical and quantity per cfm of exhaust air flow. Note that proper fall arrest precautions should be taken by individuals conducting assessments on rooftops following OSHA Guidelines.

1. Calculate dilution of release at the roof top exhaust location
2. Calculate additional dilution required to avoid detection (recommended between 1:10 and 1:100)
3. Release odorous substance within the exhaust stream. Evaluate whether it is possible to detect odors on the roof between the exhaust location and the farthest possible distance from the exhaust. Walk the entire radius around the exhaust at the maximum possible distance to detect potential odors up-wind, downwind, and crosswind from exhaust.
4. Start from a distance where odors cannot be detected and walk inward towards the exhaust.
5. Define distance from intake where odors are first detected.
    a. Odors w/ 1:100 dilution threshold not detected w/in ½ distance between intake and exhaust – Low External Re-entrainment Risk
    b. Odors w/ 1:10 dilution threshold detected w/in 2x distance between intake and exhaust – High External Re-entrainment Risk
6. Combine Internal and External Risks to define overall risk factor.
    a. High Internal and/or High External — High Exposure Risk
    b. Moderate Internal Risk and Low External Risk — High to Moderate Exposure Risk
    c. Low Internal Risk and Moderate External Risk — Low to Moderate Exposure Risk
    d. Low Internal and External Risk — Low Exposure Risk

Level 3 – Qualitative based on known emissions Re-entrainment Risk Assessment

At this time, the shedding amount and infectious dose are unknown. Once this information is available the Level 3 Assessment could be completed.

Estimated Level of Potential Contamination

1. Number of Occupants / ft^2
2. Air flow rates / ft^2
3. Health of Occupants
    a. Percentage of Likely Emitters
    b. Risk Factor for Occupants
4. Activities of Occupants (respiratory rates)

Define Acceptable Exposure Limit

Dispersion Modeling (Numerical)

1. Dilution > 10 times Exposure Limit	Risk Low
2. Dilution < Exposure Limit	High Risk

Level 4 – Expert Re-entrainment Risk Assessment

If you have completed the previous levels, and or got through a level and felt that you are at high re-entrainment risk, then soliciting the guidance from professionals is the next logical step.

The following list the different people that could help with your analysis and some potential actions that they could take to help with your re-entrainment concerns.

Industrial Hygienist:

1. Identify potential emission rates.
2. Determine acceptable exposure limits.

Internal Airflow Modeler (CFD)

1. Determine internal ventilation and contaminant removal effectiveness.
2. Calculated exposure dosages based on various emission and internal ventilation scenarios.
3. Predict the probability of adverse internal transmission based on the various emission scenarios.
4. Estimate the concentration leaving the room.

External Wind Consultant (Physical, Numerical Dispersion Modeling, Exhaust Re-entrainment)

1. Determine potential for re-entrainment utilizing appropriate dispersion modeling technique.
2. Combined with estimated emission rates and acceptable exposure limits to determine potential for exceedance.
3. Evaluate re-entrainment potential vs. wind direction and wind speed along with the local wind frequency distribution to predict the probability of adverse exposure.