Best Practices for Managing Indoor Environments for Reducing COVID-19 Spread: Discussion with Clients

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South Dakota State University
EDA University Center
https://www.sdstate.edu/eda-university-center

About the SDSU EDA University Center

- University Centers, funded by the US Department of Commerce Economic Development Administration (EDA), have historically been an effective conduit for matching University expertise to real-world industry challenges to foster economic development.

- SDSU has been involved in University Centers at varying capacities since the 1990s and have worked with clients in manufacturing, product and process realization, and technical assessments, to name a few.

A Collaborative Effort

South Dakota State University Jerome J. Lohr College of Engineering

Brookings Economic Development Corporation

Research Park

Mission

The mission of the SDSU EDA University Center is to **foster innovative economic development** throughout the state of South Dakota by

- utilizing university resources
- forging strategic collaborative partnerships
- addressing industry-driven needs that include
  - sustainable energy
  - precision agricultural technologies
  - **COVID assessment and mitigation strategies.**

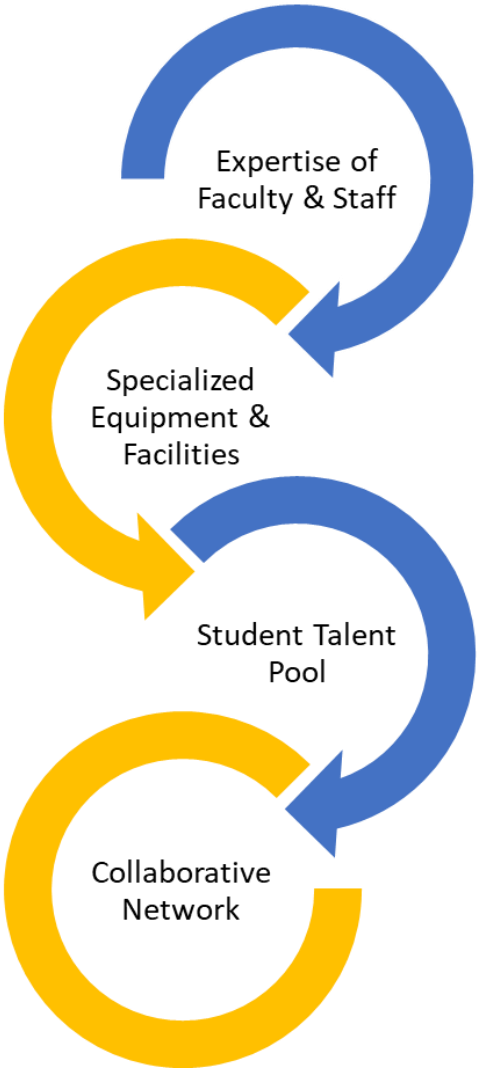
South Dakota State University
Jerome J. Lohr College of Engineering

Goals of COVID Assessment Program

1. Inform stakeholders (owners, managers, maintenance, etc.) of indoor ventilation fundamentals

2. Provide objective, methodical, science-based insight of best practices for existing buildings and new construction

3. Provide recommendations to stakeholders to identify areas of concern and mitigation strategies



What We Do…

- Disseminate general best practices for indoor environment and management
- Site visit consultations
  - Walk-through of facility
  - Catalog observations
  - Report recommendations
  - Offer guidance for next steps
- Detailed assessments
  - Room layout assessment
  - Fluid flow modeling & simulations
  - “What-if” scenarios
  - Interface with HVAC companies to determine projected equipment, installation, and costs of multiple scenarios

What we DON'T do…

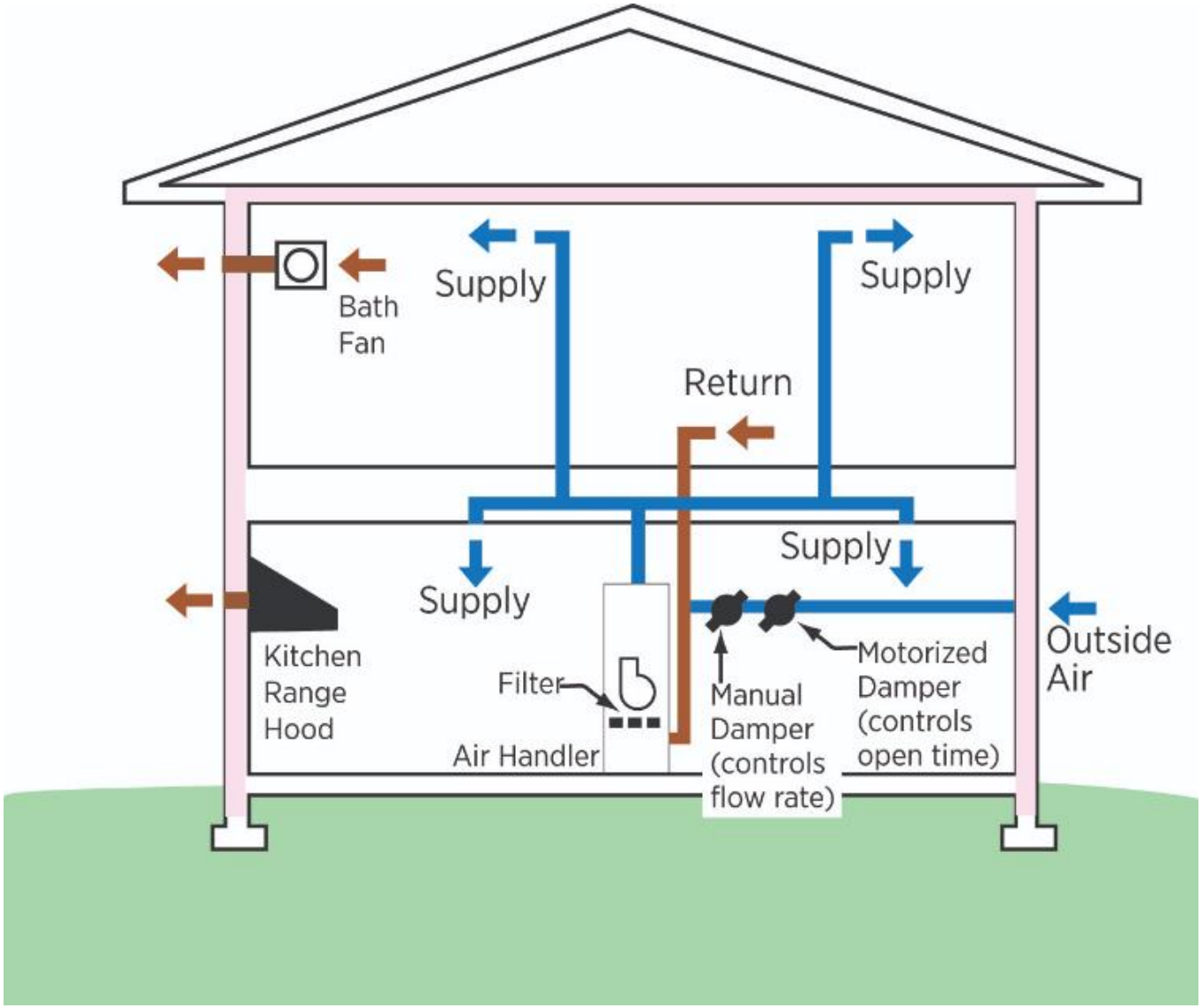
- Detailed design of HVAC systems
- Retrofitting or installations
- Medical-focused assessments of facilities
- Provide absolute guarantees of COVID-free facility operation

SOURCE: https://www.creativeimplementations.com/dont-engage-in-questionable-business-practices/

Importance of Indoor Air Quality

- Concentration of certain pollutants indoors is often 2 to 5 times higher than outdoor concentration
- People more susceptible to pollutants often spend even more time indoors
- Indoor concentrations of certain pollutants have increased in recent decades due to
  - Energy efficient building construction & operation
  - Increased use of synthetics in building materials, furnishings, personal care products, cleaners, pesticides, etc.

Basics of HVAC Systems



SOURCE: https://www.energy.gov/eere/buildings/downloads/building-america-top-innovations-hall-fame-profile-low-cost-ventilation

What can YOU do to reduce the risk of COVID spread in your facility?

Reference Guides (selected):

- CDC—Interim Guidance for Businesses and Employers Responding to COVID-19, March 2021
- CDC—Resuming Business TOOLKIT
- OSHA—Guidance on Preparing Workplaces for COVID-19
- ASHRAE—Coronavirus Response Resources from ASHRAE and Others, January 2021

What can YOU do to reduce the risk of COVID spread in your facility?

In Reference to Current CDC Guidelines

- Implement flexible worksites, hours, and meeting/ travel options
- Increase physical distance between employees and customers
- Place physical stickers 6 feet apart
- Adjust business practices to reduce close contact
- Close or limit access to common areas
- Perform routine cleaning and disinfection

Healthy Workplace Environment from the CDC

- Increase outdoor air ventilation, using caution in highly polluted areas
- Open windows and doors when good weather is available
- Use fans and place in front of windows
- Ensure ventilation systems provide good quality indoor air
- Reduce occupancy
- Consider layout of the room and of the ventilation system to increase air quality
- Use ultraviolet germicidal irradiation (UVGI) as a supplement

Reducing Airborne Infectious Aerosol Exposure

- Provide at least minimum outdoor airflow rates for ventilation specified by code
- Use of filters and air cleaners in tandem
- Air supplied is always for max occupancy
- Limit re-entry of contaminated air
- Wearing masks and other PPE
- Social Distancing

Guidance on Workplace Controls

- Hierarchy of Controls—best way to control workplace hazard is to systematically remove it from the workplace, rather than rely on workers to reduce their exposure.
- Ranked from Most Effective to Least Effective
  1. **Engineering Controls**
  2. Administrative Controls
  3. Safe Work Practices
  4. Personal Protective Equipment (PPE)

Engineering Controls

- Increase Ventilation Rates in work environment
- Install high-efficiency air filters
- Install physical barriers, e.g., clear plastic sneeze guards
- Promote curbside or drive-through service
- Specialized negative pressure ventilation in some settings, particularly for aerosol generating procedures

General Practices

- Ensure hand sanitation stations are placed in high traffic areas
- Change layouts of rooms to guide people to promote social distancing if possible
- Consider having items that are no-touch or no-handle

Deeper-Dive for Engineering Controls—Air Ventilation

- Assess Heating, Ventilation, and Air Conditioning (HVAC) System
- Assess Room Layout
- Assess Auxiliary Facilities (restrooms, kitchens, entry ways, etc.)
- Additional Considerations

Ventilation Considerations

Supply Air

- Outside Air Intakes and Air Dampers
- Demand-controlled system ventilation
- HVAC Filtration, Disinfecting, Ionization

In-Room Air

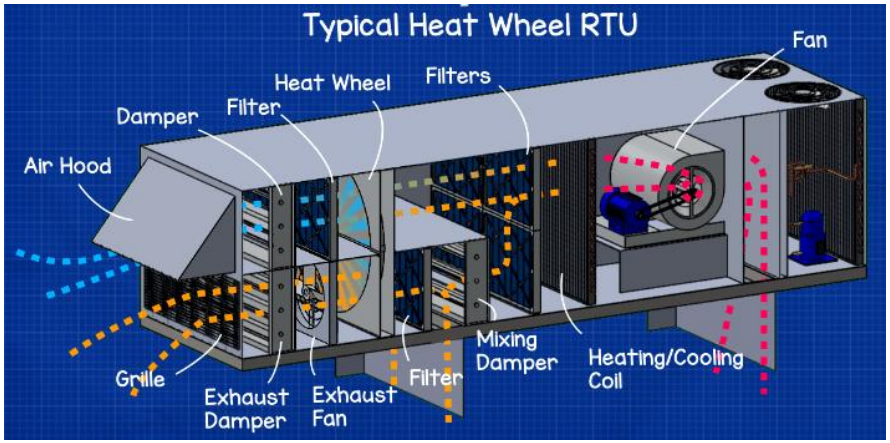
- Room humidity levels
- Room “purge” or “flush”
- Air flow assessment in-room

Return/Exhaust Air

- Return line assessment
- Restroom exhaust air

Supply Air:
Equipment

https://theengineeringmindset.com/rtu-rooftop-units-explained/



Air Handlers

- Can house dampers, filters, heating/cooling coils, fans, etc. for distributing air to spaces

Fan Motors

- "On-off" constant speed (ex., PSC) vs. variable speed (ex., ECM)
- Variable speed fans are ideal for multiple reasons:
  - More energy efficient
  - Less maintenance
    - Softer starts and stops
  - Spend more time "on"
    - More consistent airflow, including outside air ventilation
    - Prevent air pollutants from settling in ductwork
    - Filters tend to perform better

Supply Air:
Managing Outside Air

Outside Air Intakes

- Any rooms served by a fan-coil unit (FCU), simple split system (condensing unit & furnace), etc. may not have adequate outside air supply to the room, if any at all
- Code allows some rooms to claim that they have an outside air supply if they have operable windows, even if these windows are rarely opened

Air Dampers

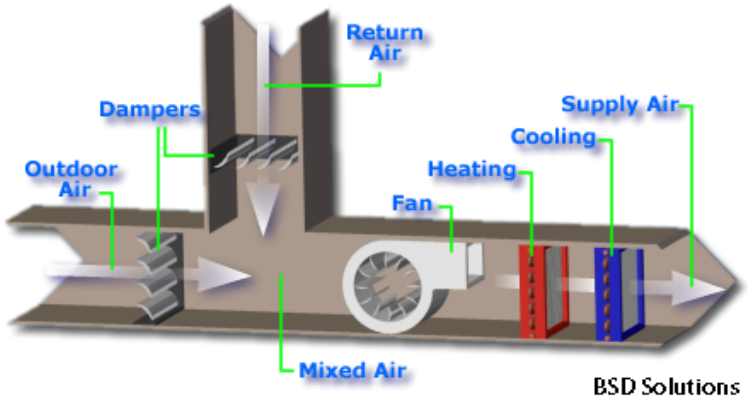
- Increased outside air ventilation can help dilute the concentration of COVID particles by regularly providing new, fresh air to the space
- Heating and cooling of the fresh outside air is one of the largest energy requirements of a building's HVAC system, so these functionalities are sometimes disabled after installation for energy-saving purposes

Other

- ASHRAE is currently working on allowing decreased outside air requirements when air purification/treatment methods are in place (such as UV, ionization, etc.) that essentially "refresh" the air in a space
- Payback period from annual energy cost-savings could make these technologies more financially feasible

Supply Air:
Economizer

https://svach.lbl.gov/what-is-an-economizer/



Economizer

- Senses outside ambient conditions
- Increases energy-efficiency by strategically blending more or less outside air ventilation into the return air stream

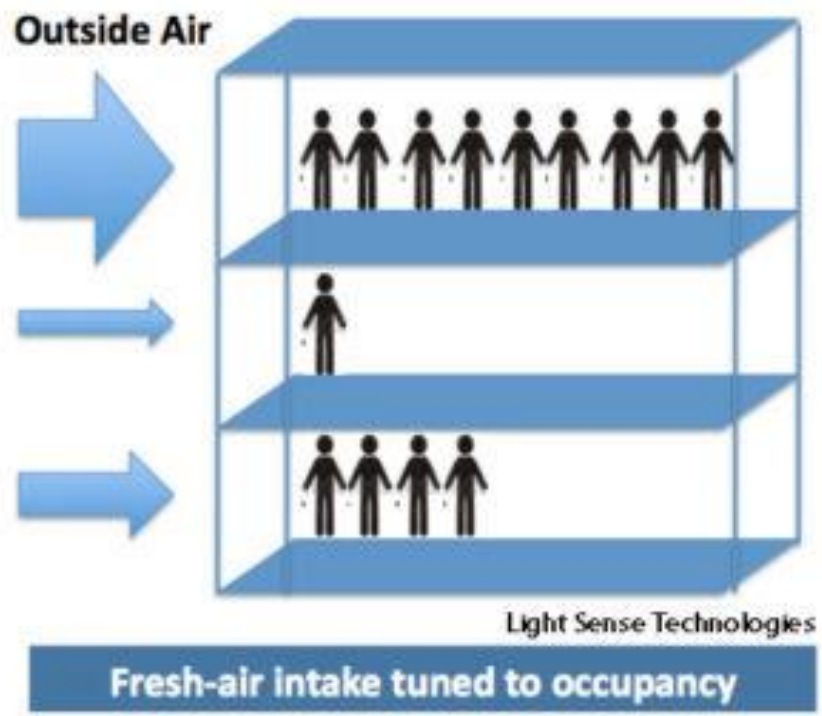
Potential recommendations

- Override standard economizer settings to higher outside air baseline
  - Energy penalty, but reduces times of minimum outside air supply
- However, modify in moderation
  - Too much outside air in rain/snow conditions can create humidity issues
  - Too much outside air on cold days can cause coils to freeze and other equipment malfunctions
  - Cooling and heating coils may not be capable of properly conditioning large amount of outside air in extreme conditions

Supply Air:
Demand Controlled Ventilation

Demand-controlled system ventilation (DCV)

- Often seen when there are motion sensors, CO2 sensors, etc. to reduce energy usage in non-pandemic scenarios
- Consider disabling such a system, which turns off ventilation to a space during unoccupied hours, as this does not allow the space to be "purged" with fresh air during uninhabited periods



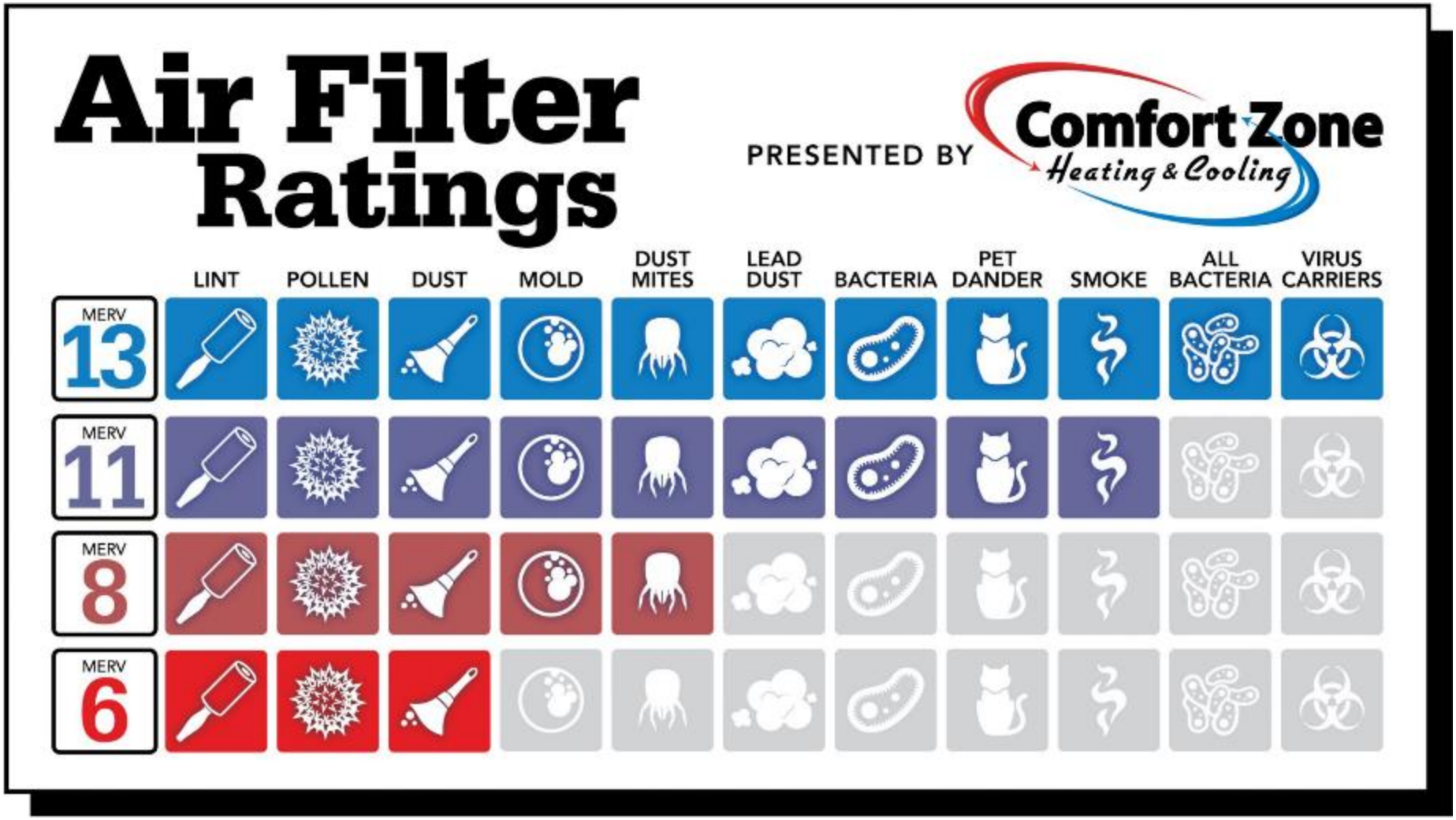
https://svach.lbl.gov/demand-controlled-ventilation/

Supply Air:
Filtration

HVAC Filtration

- MERV 13-15 filters can trap 50-85% of particles in the reported COVID particle range (0.06-1.2 microns)
- HEPA filtration = traps 99.97% of 0.3 micron particles
- Note: one should inspect the pressure drop on the system to make sure that the existing HVAC unit can account for added resistance from a finer filter
    - Other options include:
        - “Sidestream filtering” or “bypass fan/filter units” on the HVAC system
        - “Portable fan/filter units” located within the room
        - Heated filters with UV-C light treatment to catch and kill virus spores (ex., Medistar filter)

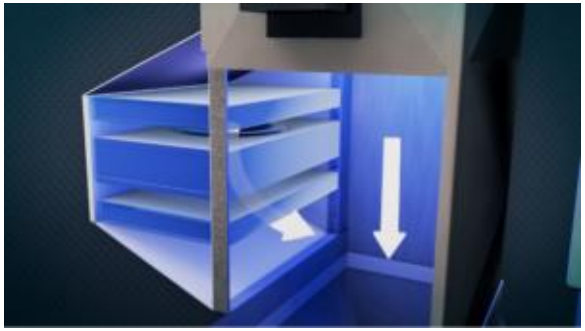
MERV Rating


Air Filter Ratings
PRESENTED BY
Comfort Zone
Heating & Cooling
LINT
POLLEN
DUST
MOLD
DUST MITES
LEAD DUST
BACTERIA
PET DANDER
SMOKE
ALL BACTERIA
VIRUS CARRIERS
MERV 13
MERV 11
MERV 8
MERV 6

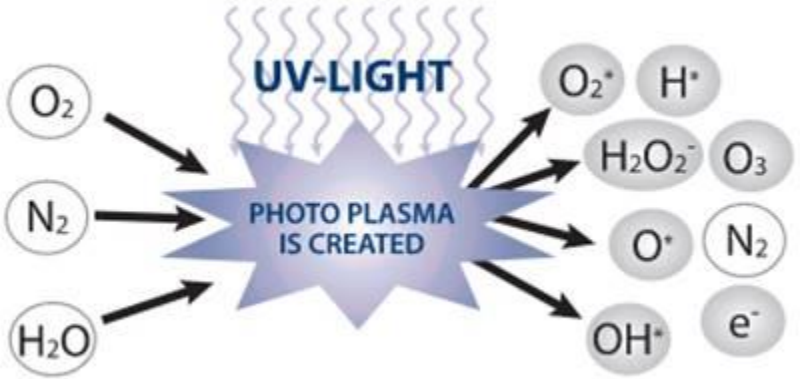
Supply Air:
UV-C Disinfectant

Air Disinfectant

- UV-C light in ventilation duct
- ASHRAE has published several studies supporting effectiveness of UV-C inactivating microorganisms
- HOWEVER, air needs to have sufficient residence time exposure to UV to kill microorganisms



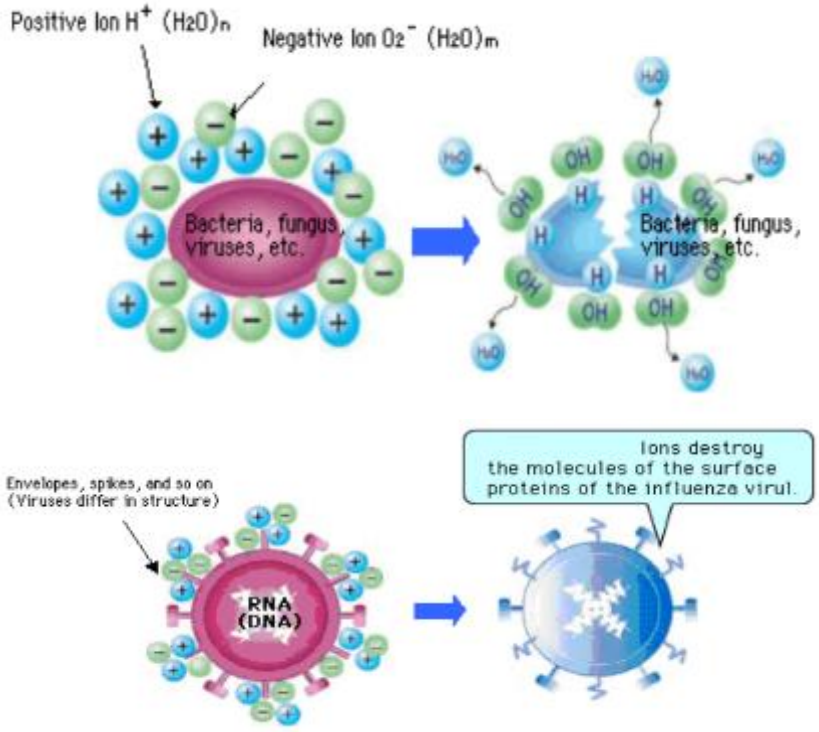
How UV-C Disinfecting Works



"LuminIce II Virus and Bacteria Inhibitor" cutsheet, from Manitowoc

- UV light acts on O_2, N_2, and water vapor to create photoplasma (a gas that is fully ionized by UV light containing electrons, hydroxyl radicals, and ozone)
- Each ion is reactivated with any microorganism it contacts and inhibits its growth
- Concerns
  - UV light is harmful to eyes, skin, etc. if it ever becomes exposed—do not install where it causes exposure to people
  - Ozone generation is not desirable

Supply Air:
Ionization

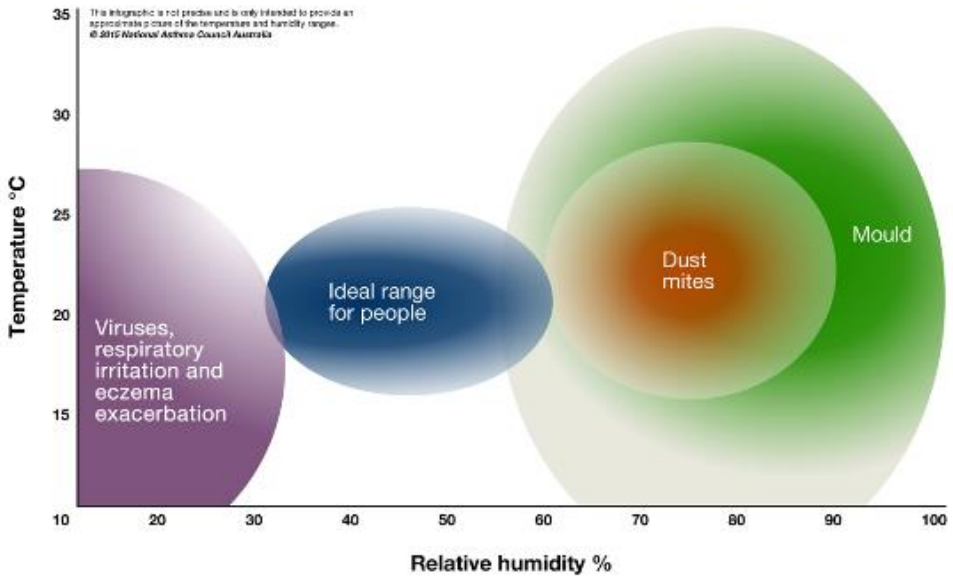


"What does Plasma Kill and Inactivate?", report from Global Plasma Solutions

- Positive (H^+) and negative ions (O_2^-) created from water vapor in the air handler air stream
- Ions propagate toward microparticles and gases in the room, including:
  - Mold
  - Viruses
  - Bacteria
  - Allergens
  - Volatile Organic Compounds (VOC's)
    - ADDED BENEFIT: Reduced odors
- Chemical reaction pulls hydrogen from microparticles, and removes important proteins in the process
  - Microparticle is inactivated
  - Ionization makes the molecule larger so it is filterable

In-Room Air:
Humidity

- Room humidity levels (40-60% RH is preferred range for human comfort, with 50% being ideal)
- Viruses prefer lower humidity, so aim for RH to be on the higher end of comfort range
- HOWEVER, higher RH may lead to water condensation and mold growth issues if not monitored carefully



https://www.sensitivechoice.com/indoor-humidity/

Flu Season

Season	Transmission Rates	Humidity Control
Winter	High	Less Common
Summer	Low	More Common

Flu Season

- Humidity control (dehumidification) is more common in summer months
  - Portable room dehumidifiers
  - Hot-gas reheat HVAC systems
- 20% humidity is common practice for most commercial buildings in America during the summer
- 40% humidity is recommended for optimal immune system strength to reduce transmission rates
- Commercial buildings typically see less than 10% relative humidity in the winter season
- Heating dries the air, which can absorb moisture and weaken immune systems
- Adding humidification in the winter can help decrease transmission rates of disease during the flu season, with proper design and operation
  - Potential for condensation on cold surfaces, like windows and exterior walls
  - Potential mold formation
  - Personal comfort issues

In-Room Air:
Room Layout

https://www.inc.com/jeff-pochepan/successful-startups-follow-these-office-design-rules.html

https://apparelresources.com/business-news/sourcing/industrial-engineering-in-apparel-manufacturing-viii/

- HVAC Systems manage the supply and return air within a room
- The physical layout of the room can also contribute to the air quality of the room
- In-room management is important for one to consider in assessing and mitigating COVID spread

Parameters Affecting In-Room Air Quality

Affixed Items (Examples)

- Air Vent (Diffuser) Locations
- Air Return Locations (in certain instances)
- Window Locations
- Steam radiator Locations
- Large, immovable fixtures

Variable Items (Examples)

- Smaller, movable furnishings
- Locations and concentrations of inhabitants
- Breathing rates and activities of inhabitants
- Room dividers, acrylic walls, etc.

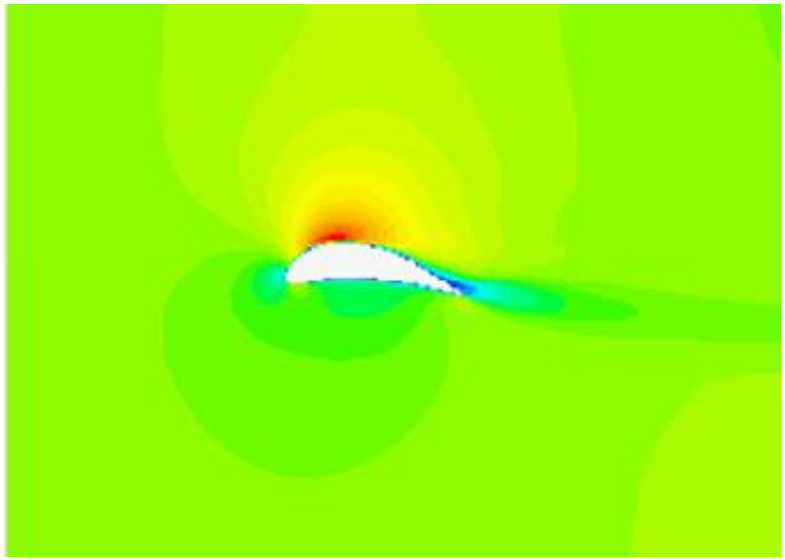
Assessing Indoor Environments

1. Experimental
   - Smoke or vapor entrainment

2. Modeling & Simulation
   - CFD (Computational Fluid Dynamics)

What is CFD?

- **Computer-Based:** Use of numerical methods and algorithms to solve and analyze problems involving fluid flows
- **Fluid Flow:** Simulate the interactions of fluids (liquids and gases) within a set of surroundings (boundaries)
  - Internal Flow (pipe, duct, or in-room flow)
  - External Flow (flow over a wing or a vehicle)
- May account for **additional phenomena**
  - Heat and mass transfer
  - Turbulence
  - Chemical reactions
  - Near-wall effects
  - Multiphase interactions



Air velocity over a wing
Red: High velocity
Blue: Low velocity

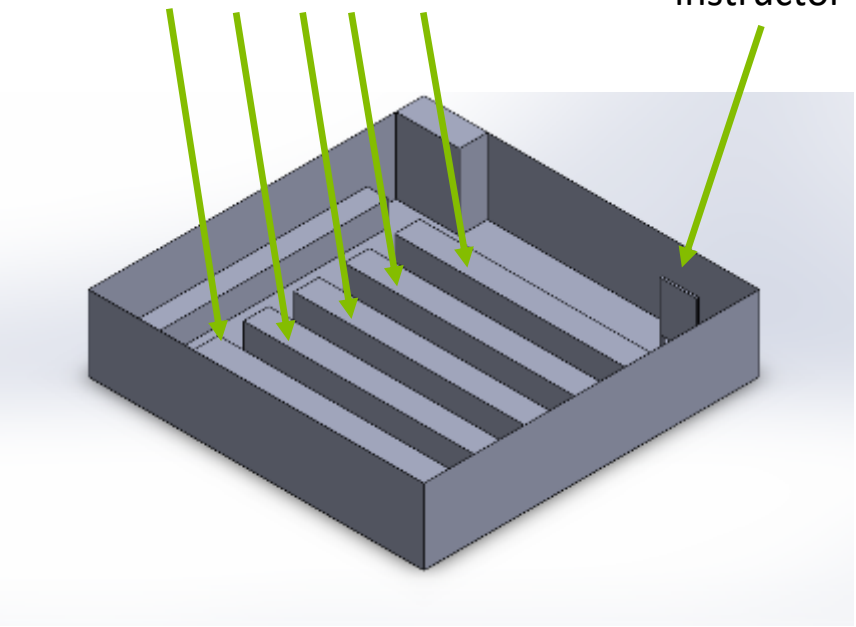
Demo Room Simulation

- University Classroom in the Mechanical Engineering department
  - 1,600 square feet, 9 ft. tall
  - Goal is to have 6-20 Air Changes per Hour (ACH)
- Six diffusers, 1 return
- Has divider for Instructor at front of class

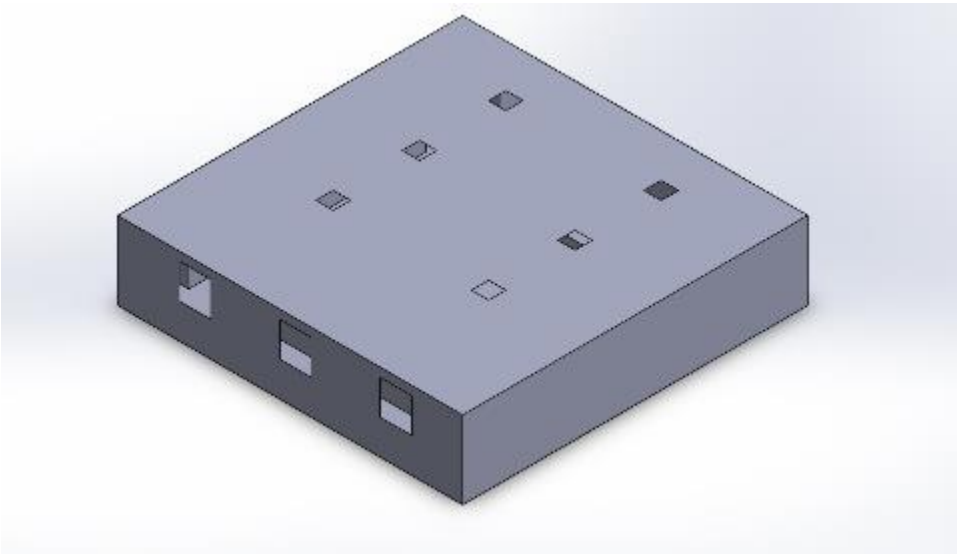
Demo Room Model and Floor Plan

Student Desk Locations

Divider in the classroom in front of instructor



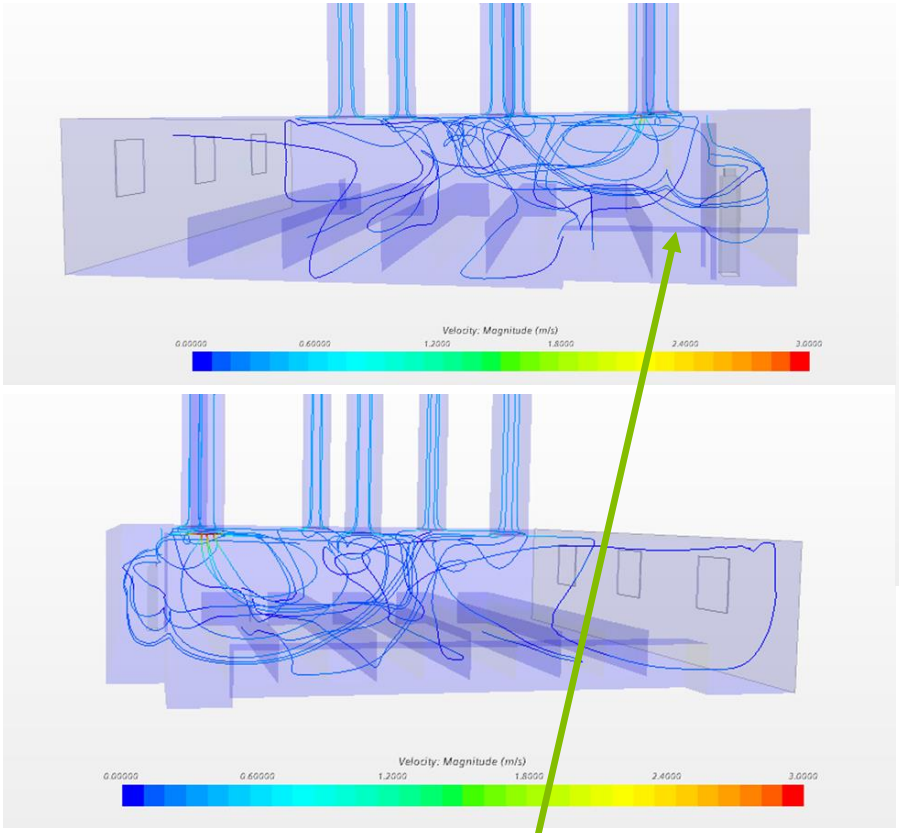
Room Model: Isometric view with ceiling removed.



Room Model: Isometric view with ceiling and diffuser locations in place, windows included.

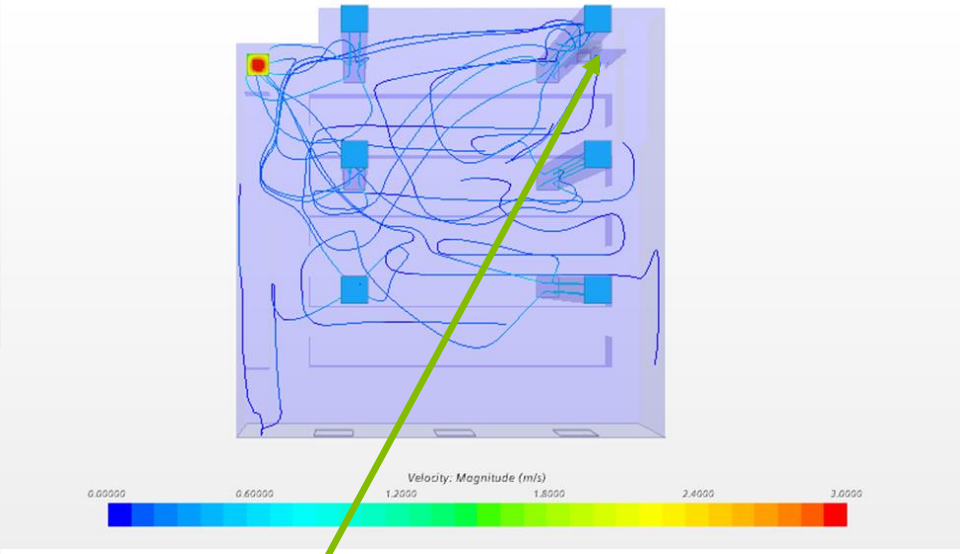
Demo Room Velocity Streamlines
(with angled diffusers)

South View: instructor on right side (top)



Divider in the classroom in front of instructor

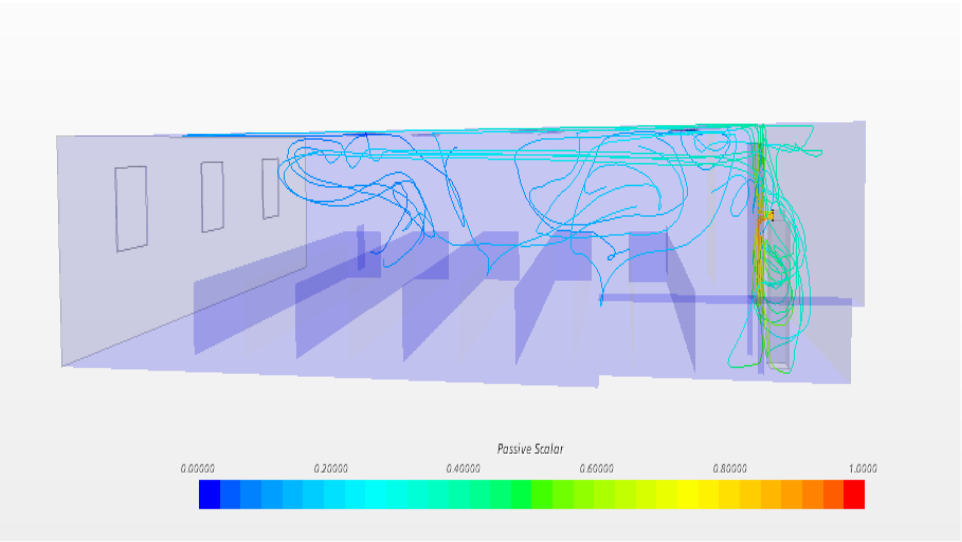
Blue rectangles are six air diffuser inlets

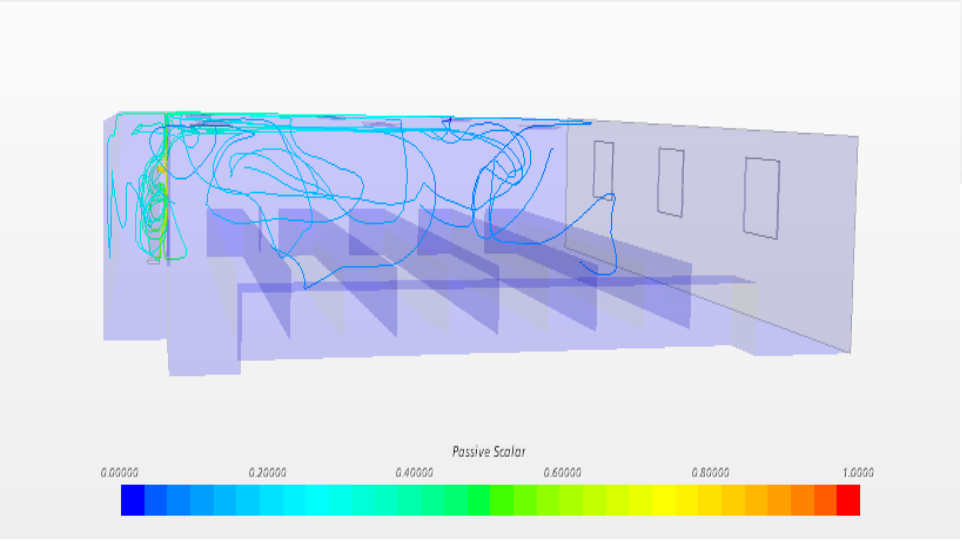


Top View: Divider in the classroom in front of instructor

Demo Room-Aerosol propagation from instructor with a barrier (streamline)

South View: instructor on right side (top)

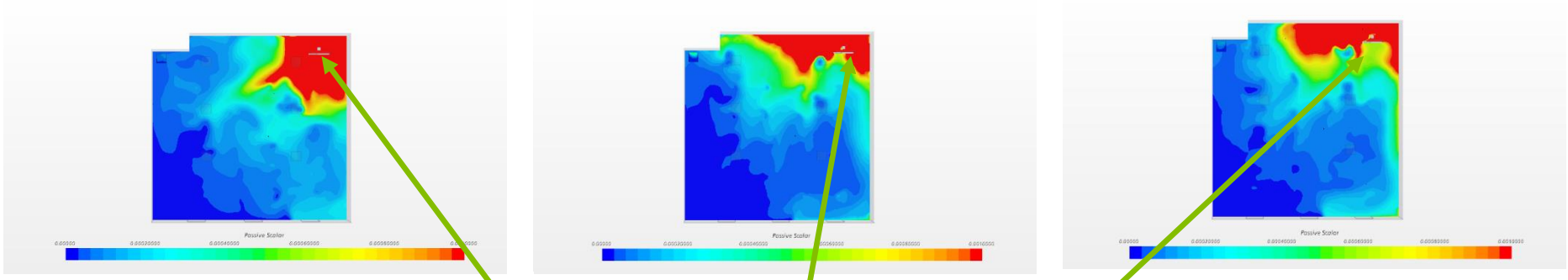




Top View: Aerosols from instructor significantly blocked by barrier

Ventilation Comparisons: Demo Room-Aerosol propagation from instructor with a barrier (scalar)

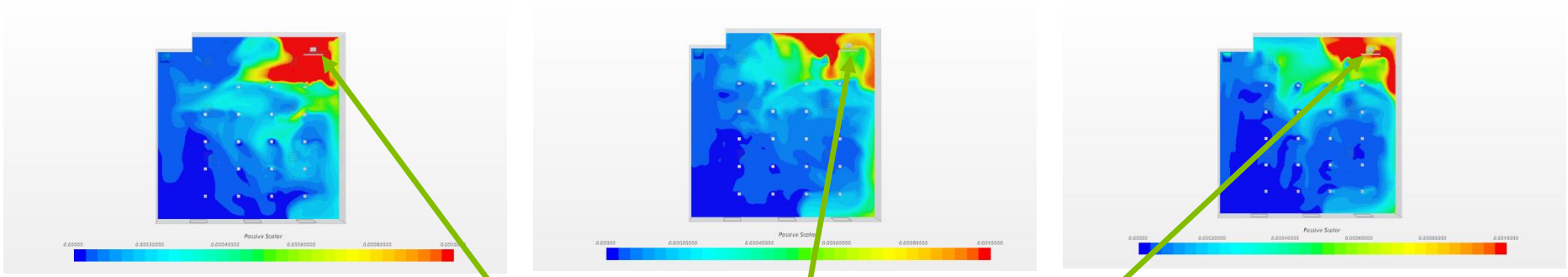
Left to right is 1600 CFM, 1100 CFM, 800 CFM at the standing breathing zone



Top View: location of instructor

Ventilation Comparisons: Demo Room-Aerosol propagation from instructor with a barrier (scalar)

Left to right is 1600 CFM, 1100 CFM, 800 CFM at the sitting breathing zone

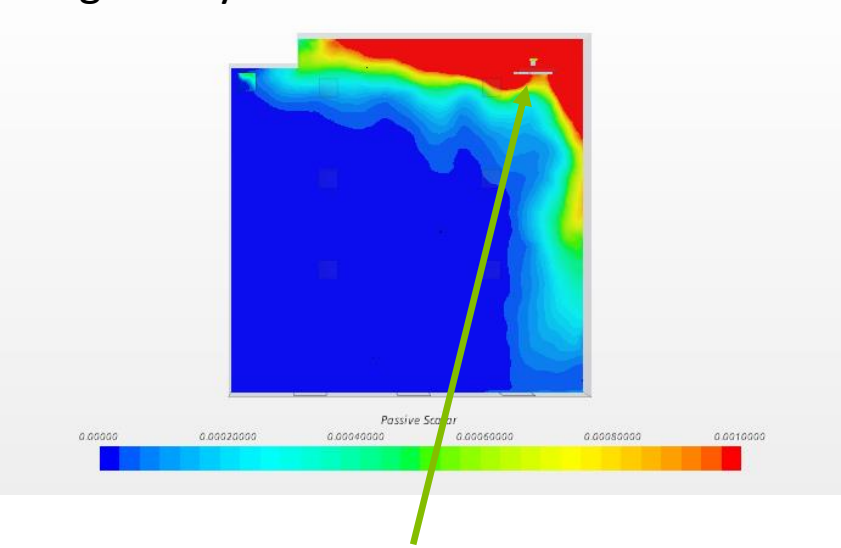


Top View: location of instructor

Original Vs New Layout Demo Room- Aerosol propagation from instructor with a barrier (scalar)

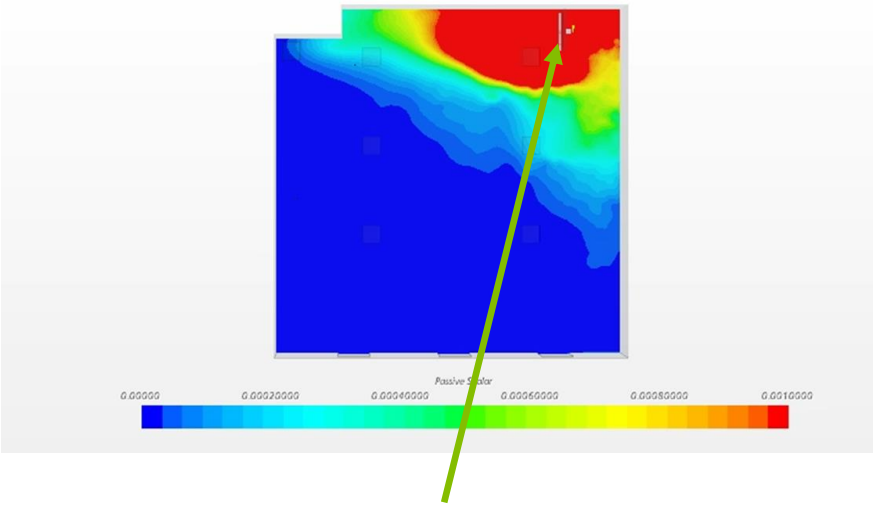
Standing Breathing Zone

Original layout



Top View: instructor facing south, students facing north

Proposed new layout

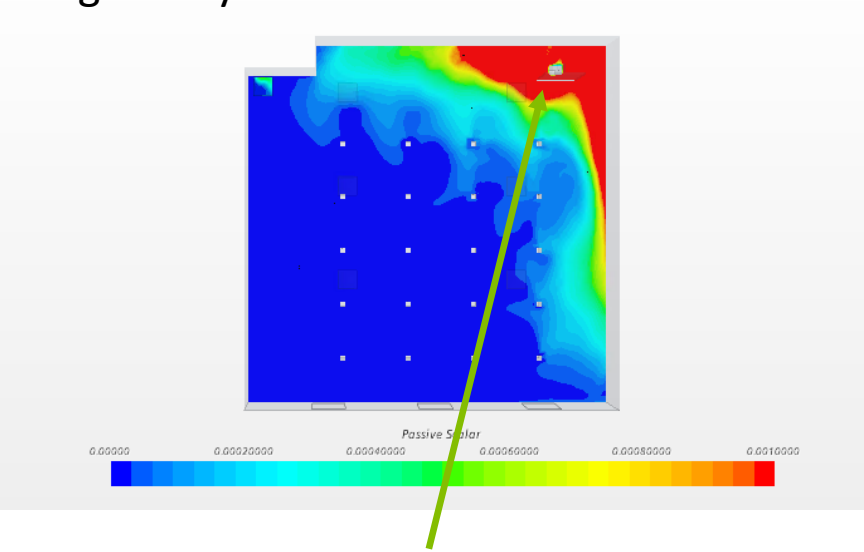


Top View: instructor facing west, students facing east

Original Vs New Layout Demo Room- Aerosol propagation from instructor with a barrier (scalar)

Sitting Breathing Zone

Original layout



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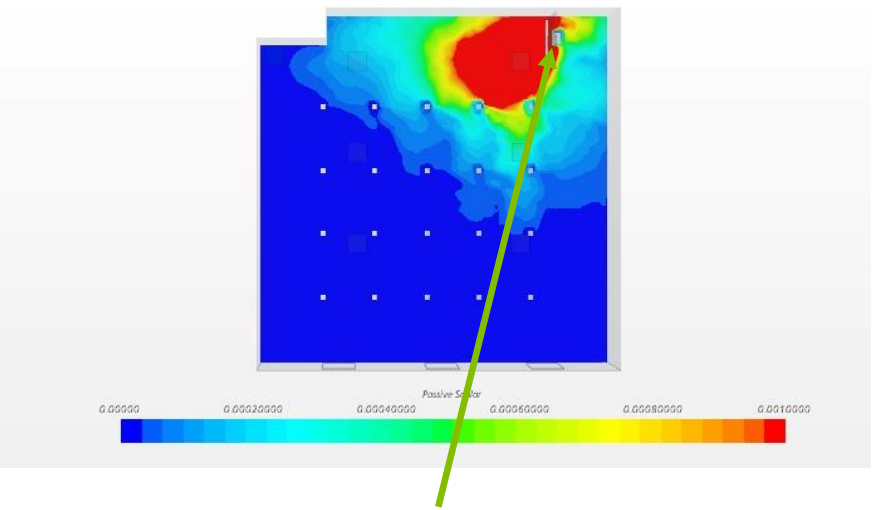
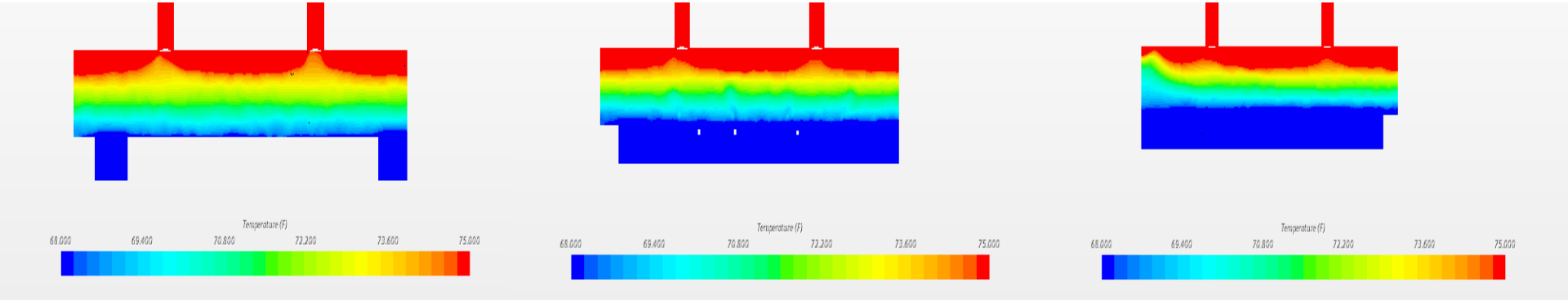
Proposed new layout



Top View: instructor facing west, students facing east

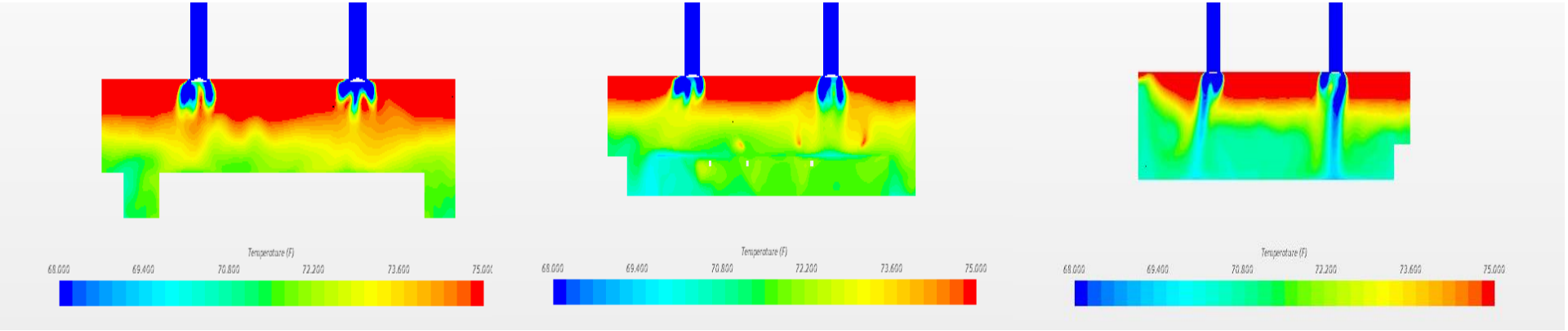
Heating Cycle of the HVAC System

- Left to Right is closest to farthest from the exterior wall at 1100 CFM
- Temperature profile at diffuser cross sections
- 68F – 75F



Cooling Cycle of the HVAC System

- Left to Right is closest to farthest from the exterior wall at 1100 CFM
- Temperature profile at diffuser cross sections
- 68F – 75F



Insight Models Provide

Air flow patterns

- Drafts, stagnant zones, etc.

Aerosol propagation

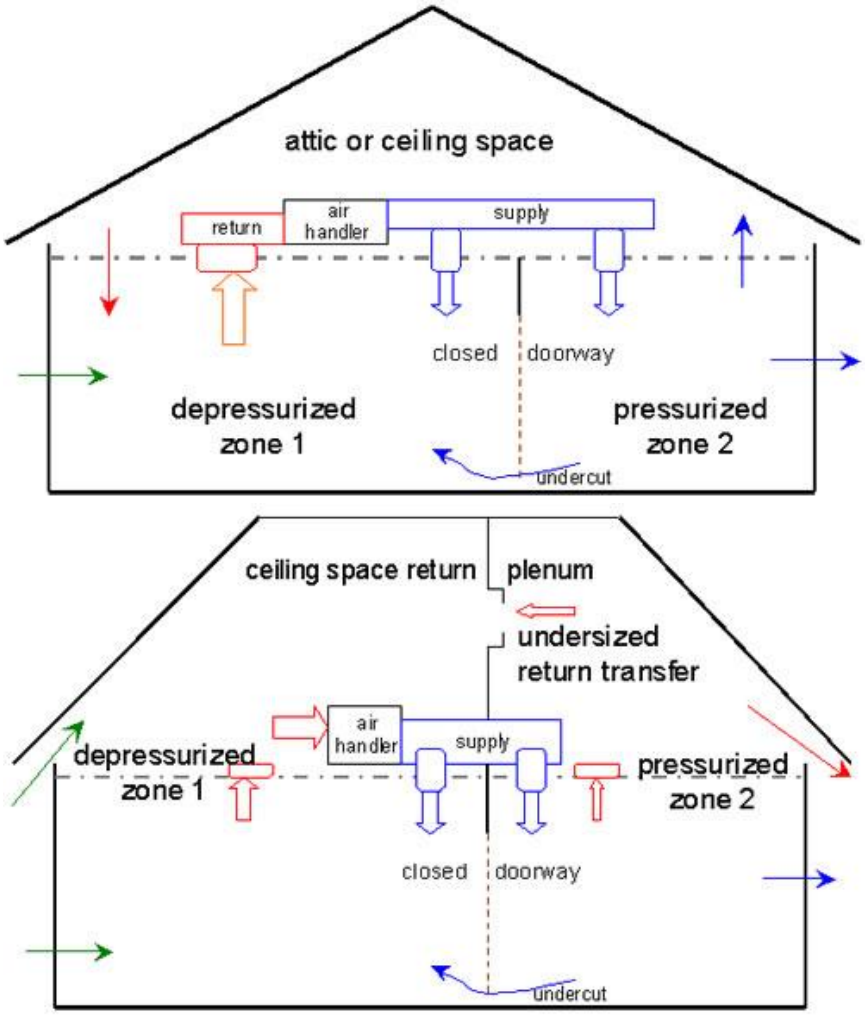
- Entrainment, dilution, evacuation

Assess “what if” scenarios

- Room layout
- People present
- Ventilation configuration
  - Traditional vs. Displacement Ventilation

Return Air
Evacuating Air in a Room

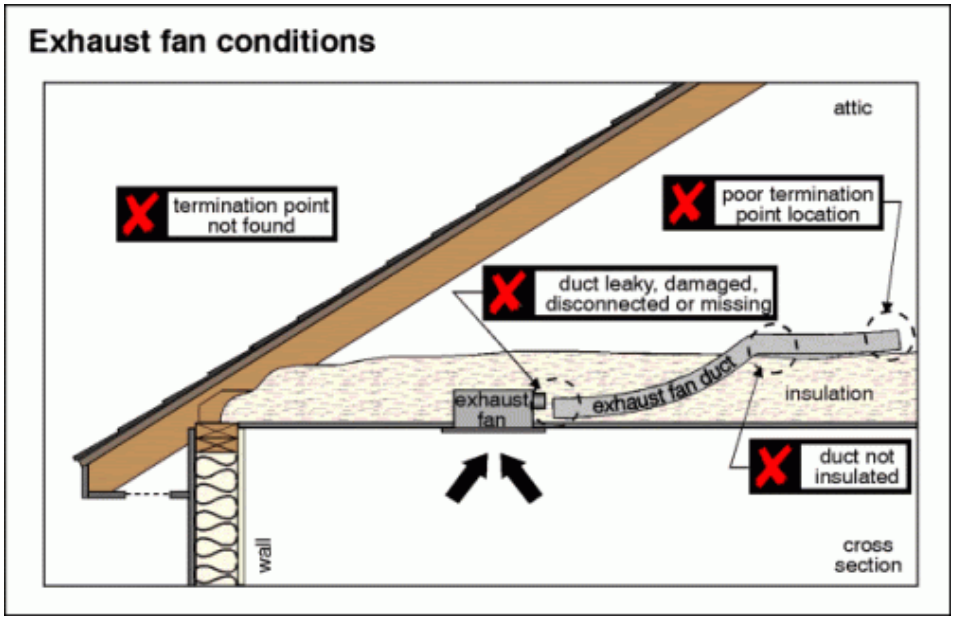
- Return air configuration heavily determines air flow patterns within the space
  - Supply air systems will almost always be ducted (less flexibility for cheap, easy modifications)
  - Return air can be un-ducted ("wild") in some cases, where code allows
    - Potential for easy adjustments to return air locations to modify air flow patterns



Withers, C.R., and Cummings, J.B., 2006

Exhaust Air

- COVID can spread through sewer matter and gases
  - Adequate air turnover and proper controls setup in restrooms is important
  - Other methods to reduce standing waste:
    - Sensor-operated toilets and urinals to eliminate missed flushes
    - Higher-flow flush valve toilets



http://www.jwkhomeinspections.com/bath-exhaust-vent.html

In Closing…

- Being proactive in managing your indoor environments has the potential in reducing COVID-19 spread
- Improving indoor air quality can help improve worker comfort and productivity
  - Increased alertness while on the job
  - Decreased sick days
- Increased productivity improves a company's bottom line!

For Additional Information

Please contact the SDSU EDA Center at

SDSU.EDACenterinfo@sdstate.edu

Thank you. Stay safe and healthy!!!