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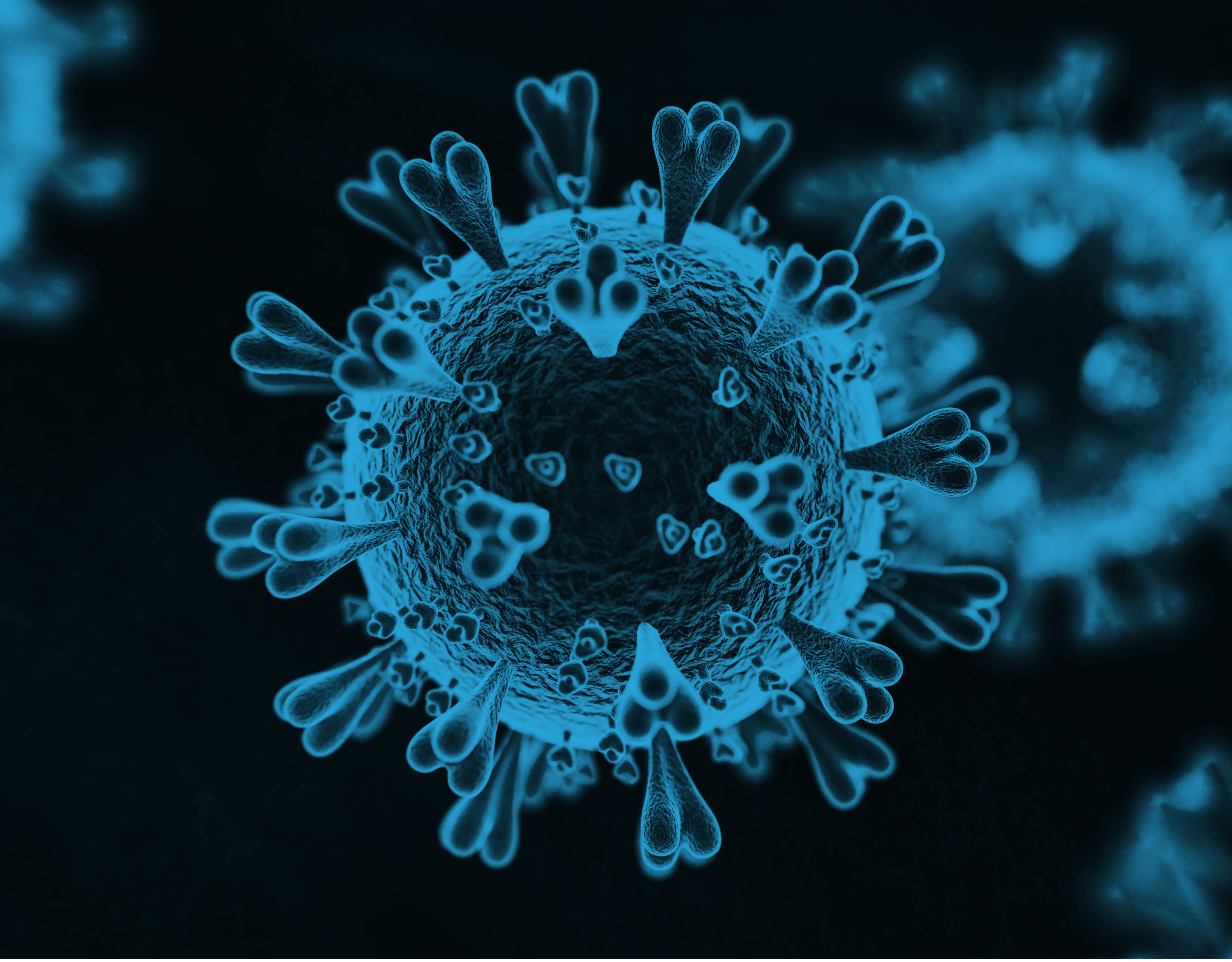
NOTE:

The following Harris Technical Snapshot, titled "Healthy Spaces: Mechanical Systems," was published in July 2020.

As a result, some of the data and statements made within the Technical Snapshot may be outdated. Please keep this in mind as you read the document.

Should you have any questions or comments about this document, please contact DesignStudio@harriscompany.com.



HARRIS

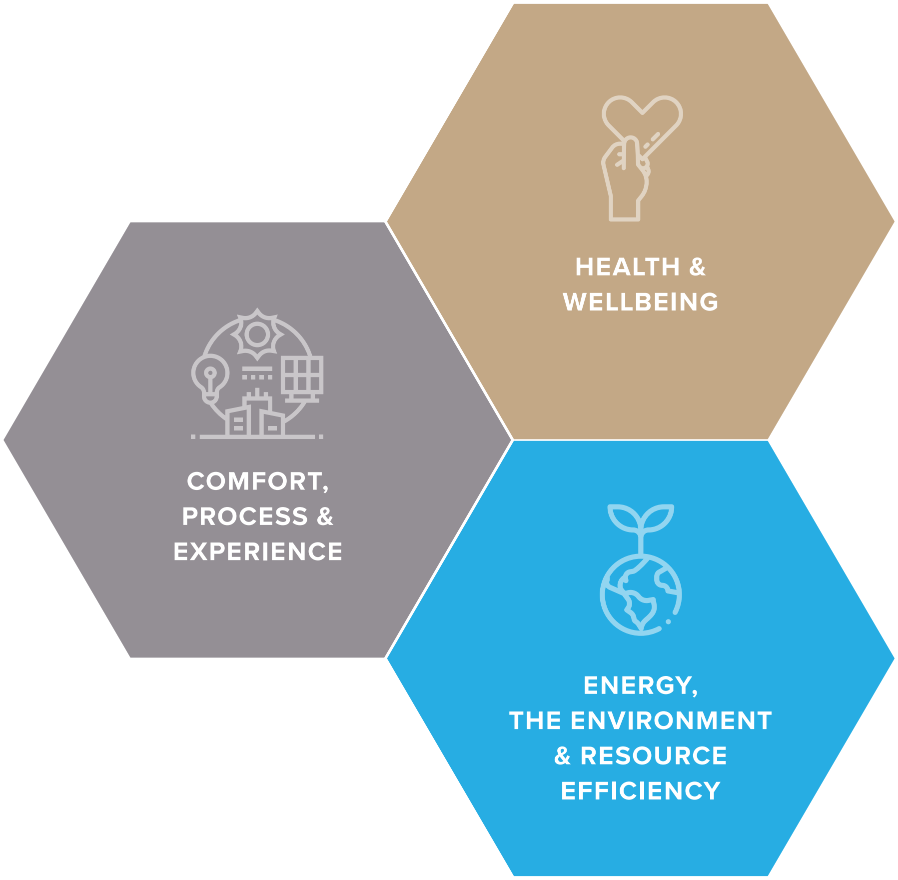
HEALTHY SPACES: MECHANICAL SYSTEMS

APPLICATIONS, BENEFITS + LIMITATIONS

design studio

TECHNICAL SNAPSHOT

JULY 2020
REVISION 2



HEALTHY SPACES: **MECHANICAL SYSTEMS**

Driven by the Covid-19 pandemic, there has been an increased concern and consideration by the mechanical engineering community. Harris' technical snapshot is written around the latest and on-going observations, advice and technical developments in the field.

Harris provides mechanical services for building systems in design, construction, controls and service. We want to ensure confidence in the systems we provide to our clients and customers.

We are entering a new era for mechanical and HVAC design, where three pillars of importance must be strengthened to provide spaces which are healthy, efficient and offer a great experience for their owners, occupants and facility teams.

INDOOR AIR QUALITY (IAQ)

Indoor air quality is a measure of potentially harmful contaminants and pollutants which can be found within buildings. Since the increase in industrialization and urbanization, we spend up to 90% of our time indoors and often within mechanically conditioned spaces. In the USA, general spaces follow procedures for managing IAQ set out by ASHRAE Standards. Higher targets have been developed through some ratings systems, like those produced by USGBC, the Living Building Challenge and WELL by the IWBI.

These standards address management of such contaminants through the introduction of filtered outside air to air-conditioning systems.

More specific guidelines are also codified in some jurisdictions, particularly for healthcare, laboratory or clean room isolation needs, which are using filtered outside air or use carefully-managed pressure differentials to limit cross contamination within the facilities.

AIRBORNE PARTICLES AND THEIR SIZES

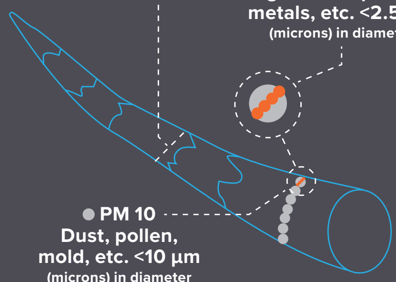
Particles which affect human beings come in many sizes, described in microns (µm). Anything smaller than around 5 µm in diameter become invisible to the eye.

Airborne particles can be breathed into our lungs and cause irritation or a potential larger threat.

Humans emit particles when we breathe, talk, cough, sneeze and sing from our nose and mouth. The size, velocity, mechanism and rate of particles emitted vary depending on our activity. There are two important distinctions regarding infectious respiratory aerosols:

- **droplets**—moisture laden respiratory aerosols (> 5 µm)
- **droplet nuclei**—desiccated, or dried out, particles (≤ 5 µm) that results from evaporation of droplets in the air or by aerosolization of an infective material. These particles can stay suspended in the air as an aerosol.

Due to the weight of droplets, these usually settle to the floor within a meter or three feet of a person. Analysis is on-going with respect to droplet nuclei, but more evidence and concern is being raised since these particles remain present in the air much longer and may act as a transmission path which is not yet addressed by the HVAC industry.[7]



Typical Contaminants

GASES
CARBON MONOXIDE
RADON
VOLATILE ORGANIC COMPOUNDS (VOCS)

PARTICULATES
POLLEN
DUST
COMBUSTION PRODUCTS

MICROBES
VIRUSES
BACTERIA
FUNGI AND MOLDS
OTHER MICROBES

MECHANISMS FOR INFECTION CONTROL[3]

PERSONAL BEHAVIORS

The way we interact and our personal hygiene regimes have long been understood to be part of the cross contamination process.

The pandemic has changed our social norms and forced us to consider, as part of our daily life, the mounting knowledge and remaining uncertainties of the hazards we now face.

A new implementation of social etiquette is leading to the use of social distancing, physical barriers, face masks and an increase of washing and disinfection of hands, materials and surfaces.

There is **little impact** that improvements in mechanical systems can help with regards to this transmission mechanism.

TRANSMISSION IN BUILDINGS

Transmission in buildings occurs through tiny particles suspended in the air (aerosols), which given their small mass can travel through mechanical systems, subsequently fall on surfaces or further than a meter (3 feet) if moved by an HVAC air stream and potentially retain active microorganisms within those aerosols.[1]

Mechanical systems can help **be part** of the solution for this transmission mechanism, with the following areas of design and engineering showing likely benefits:

- Fraction of outside air ventilation
- Air filtration and purification
- Humidity controls[1]
- Pressurization between spaces
- Associated controls strategies
- Air distribution and velocity

PERSONAL VULNERABILITY

The human body is around 65% water. Dehydration in people prevents our biological mechanisms from having optimal health and comfort. Humidity in spaces, usually monitored as Relative Humidity (RH) and temperature controls help human bodies to best maintain homeostasis (healthy balance).[2]

- Low Humidities
  - Skin barrier dries
  - Eye's tear film breaks down
  - Nose and throat membranes dry[4]
  - Exhaling and inhaling smaller particles likely deeper into the lungs
- 50% RH optimizes a person's defenses
- High Humidities
  - Larger moisture-laden particles impact respiratory moisture-laden functions
  - Impacts on sweating, the body's natural cooling mechanism

Other wellness issues, such as drinking enough water, comorbidities, gender and genetic susceptibiliy and a healthy balanced diet and exercise also impact our body's natural defenses. People with weakened immunity are more at risk.

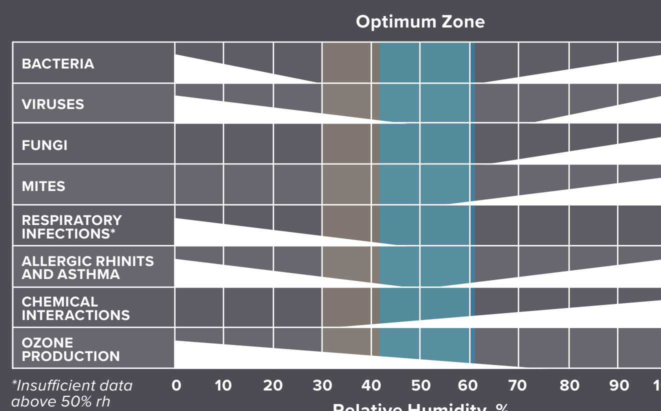
RELATIVE HUMIDITY

ASHRAE, first published in 1985, recommended through the Sterling Chart, that a focus should be given to relative humidity (RH) regarding allergens, pathogens, chemicals and ozone.

In 2016, the advice was clarified further in the HVAC Systems and Equipment Handbook to drive systems to give an environment with a range of 30-60% RH as optimal.

Today's on-going studies show this band should be more controlled between 40 and 60% RH to limit a person's vulnerability and the ability of pathogens to survive in the air and on surfaces.

DECREASE IN BAR WIDTH INDICATES DECREASE IN EFFECT



ASHRAE major principles

1. DO NO HARM
2. INCREASE CLEAN OUTSIDE AIR
3. INCREASE FILTRATION EFFICACY
4. AIR CLEANING AND DISINFECTION
5. SUPPLEMENTAL SYSTEMS

OUTSIDE AIR CHANGE RATES

KEY CONSIDERATIONS:

- UP TO 60% INCREASE IN OUTSIDE AIR FLOW
- CHECK SYSTEM CAPACITIES FOR OPERATIONAL FUNCTION
- EXTRA ENERGY IN OPERATION

For mechanically conditioned spaces, increasing the amount of ventilation or outside air through an occupied space helps dilute and remove contaminants. ASHRAE 62.1 sets out minimums for these rates. USGBC's rating systems promotes increasing these rates by 30% and 60% to benefit general health and cognitive functions, which have been supported by studies.[8]

Important areas to balance with the increase in ventilation rates are the system's ability to still have adequate capacity in system coils and other elements to ensure needs for heating, humidity and cooling remain under control. Further dilution of spaces can be provided by extending the hours of operation to allow spaces to be flushed of contaminated air while unoccupied.

Another consideration is the extra energy-use of the system in moving more air and for a longer period, and also meeting heating and cooling loads.

Note: Purely recirculating systems, such as fan coil units, without adequate filtration are highly suspected to worsen the cross contamination in enclosed spaces and in these type of systems, increasing air change rates is not recommended.[10]

FILTRATION

KEY CONSIDERATIONS:

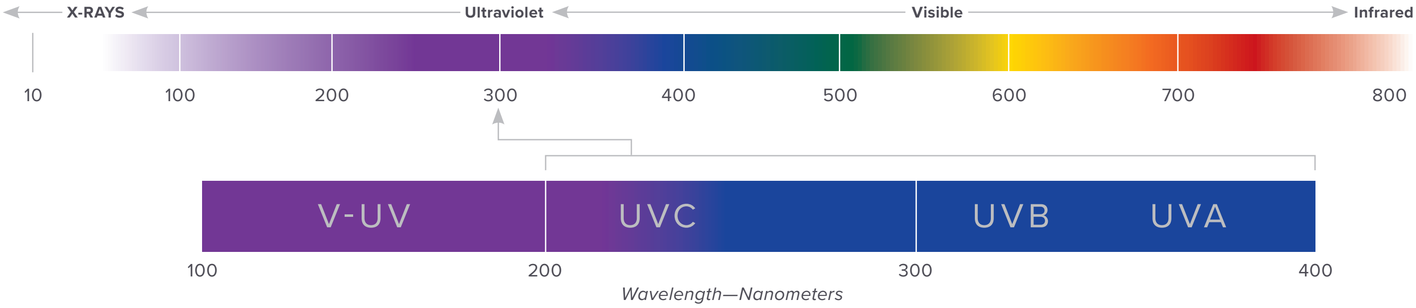
- MERV 14 OR BETTER
- ADVANCED FILTRATION TECHNOLOGIES
- FAN ENERGY AND PERFORMANCE

MERV (Minimum Efficiency Reporting Value) classification system (ASHRAE 52.5) is in a scale of 1-20 and describes a filter's ability to stop and capture different size particles. ASHRAE 62.1 calls for a minimum of MERV 6. WELL and LEED have been recommending increases to MERV 13 for many years which works well for heavier droplets. MERV 16 appears to be the best target that the industry needs to move to eliminate such small particles in the air by filtration alone.

Traditional filtration media use fabrics, either natural or synthetic polymers, to create woven elements which traps small particles while letting air to pass through. These systems increase the energy used to push the air through the filter, and could impact system performance if the fan cannot overcome the added obstruction to the airflow. An alternative using ionization technology charges air particles so that they become sticky and creates larger particles which can be collected in less densely packed media than traditional filters. A further advance is chemical phase changing filtration which uses a mix of ionization and chemical processes to do a similar effect. When looking to switch out filters, ensure that the sides of filter banks are well sealed to limit bypass.

MERV Rating	Air filter will trap air particle size:			Typical Application	Typical Filter Type	Typical Contaminants	Typical Pressure Drop	Pre-filter Needed
	0.3 to 1.0 microns	1.0 to 3.0 microns	3 to 10 microns					
20	99.99997%	> 99%	> 99%	Clean Rooms	**HEPA**		Varies	Varies
19	99.9997%	> 99%	> 99%	Radioactive Materials	**ULPA**	Viruses		
18	99.997%	> 99%	> 99%	Pharmaceutical Manufacturer		Carbon Dust		
17	99.97%	> 99%	> 99%	Carcinogenic Materials				
16	> 95%	> 95%	> 95%	General Surgery	**12-36" Bag Filter - frame mounted** Micro fine fiber glass or synthetic **6-12" Box Cartridge** Lofted or Paper Media		1.4"	MERV 5-8
15	> 85%	> 90%	> 95%	Hospital Inpatient Care		Bacteria		
14	> 75%	> 90%	> 95%	Smoking Lounges		Most Tobacco Smoke		
13	>50%	> 85%	> 90%	Superior Commercial		Most Droplet Nuclei		
12	>35%	> 80%	> 90%	Superior Residential	**12-36" Bag Filter - frame mounted** Micro fine fiber glass or synthetic **6-12" Box Cartridge** Lofted or Paper Media	Legionella	1.0"	Varies
11	> 20%	> 65%	> 85%	Better Commercial		Lead and humidifier dust		
10	n/a	> 50%	> 80%	Laboratories		Milled flour		
9	n/a	> 35%	> 75%	Laboratories		Auto ad Welding emissions		
8	n/a	< 20%	70% - 85%	Commercial Buildings	**Pleated** Fiber glass or synthetic **Cartridge** Graded Density Coated Synthetic **Throw-away** Synthetic		0.6"	None
7	n/a	< 20%	50-69%	Better residential		Mold spores and hair spray		
6	n/a	< 20%	25% -49%	Industrial Workplaces		Fabric protectors		
5	n/a	< 20%	20% -34%	Paint Booth Inlet		Cement Dust		
4	n/a	< 20%	< 20%	Residential	**Throw-away** Fiber glass or synthetic **Washable** Aluminum Mesh **Electrostatic** Self charging woven panel		0.3"	None
3	n/a	< 20%	< 20%	Minimum level residential		Pollen, Dust mites, Sanding dust		
2	n/a	< 20%	< 20%	Window Units		Spray paint dust		
1	n/a	< 20%	< 20%	Equipment Protection		Textiles and carpet fibers		

ELECTROMAGNETIC SPECTRUM



ULTRAVIOLET GERMICIDAL IRRADIATION

KEY CONSIDERATIONS:

- AIRSTREAM AND SURFACE DISINFECTION OPPORTUNITIES
- INCREASE IN DESIGN

Ultraviolet light in the range of 225 to 302 nanometers is lethal to microbes including viruses and most bacteria except their spores. This has been used in environmental disinfection in many industries, notably healthcare, shelters and prisons. There are two main applications using air-stream and surface disinfection.[9]

In ventilation systems, UV Lamps are typically placed in air handling units after the mixing of outdoor and return air streams. This helps in two ways by disinfecting not only the air stream but also nearby components such as filters and coils which may become localized contaminant sources.

Low-level far-UVC light (207-222 nanometers) is being studied for its potential to limit airborne pathogens in spaces occupied by people. Preliminary research has shown that UVC can effectively inactivate >95% of aerosolized influenza viruses, and has no harm to mammalian skin.[6] However, there is more research to be done in this area to find a safe balance. UV light is carcinogenic and cataractogenic with UVC rays being the most energetic and potentially damaging. Multiple studies are in need of validation or remain on-going.

HUMIDITY

KEY CONSIDERATIONS:

- 40-60% RH
- ADVANCED FILTRATION TECHNOLOGIES
- ADDS ENERGY AND WATER USE

ASHRAE 62.1 recommends maintaining a relative humidity below 65% to reduce mold growth and since this is codified, it has been well regarded and generally implemented. Other studies and ASHRAE's own inclusion of the Sterling chart recommending a mid-range of between 40-60% RH have been largely ignored until now in most typical settings. Below 40% RH, transmission of airborne desiccated aerosol pathogens is increased as desiccated droplets remain suspended in the air longer.[5] Furthermore, these dried out droplet nuclei can be preserved and remain suspended longer in the air or on surfaces creating an infection path. The Environmental Protection Agency (EPA) recommends keeping the RH between 30 and 50%.

Today, we must look at methods and practices to minimize this transmission mechanism and also improving our own natural defense and comfort at low levels of humidity. This is generally seen to be more of a technical requirement during the colder winter months due to the already implemented practices at higher RH levels.

Different ways of increasing humidity during the heating season can be implemented through steam or vaporizing (adiabatic) technologies, with both water supplied needing treatments to protect the equipment and people in most climates and areas. This comes with added power needs for a building's system. This can be partially offset using moisture recovery technologies such as desiccant or enthalpy wheels in centralized systems.

Opportunities for natural sources of moisture-adding elements can also help in interior design with planting or water features.

PRESSURIZATION

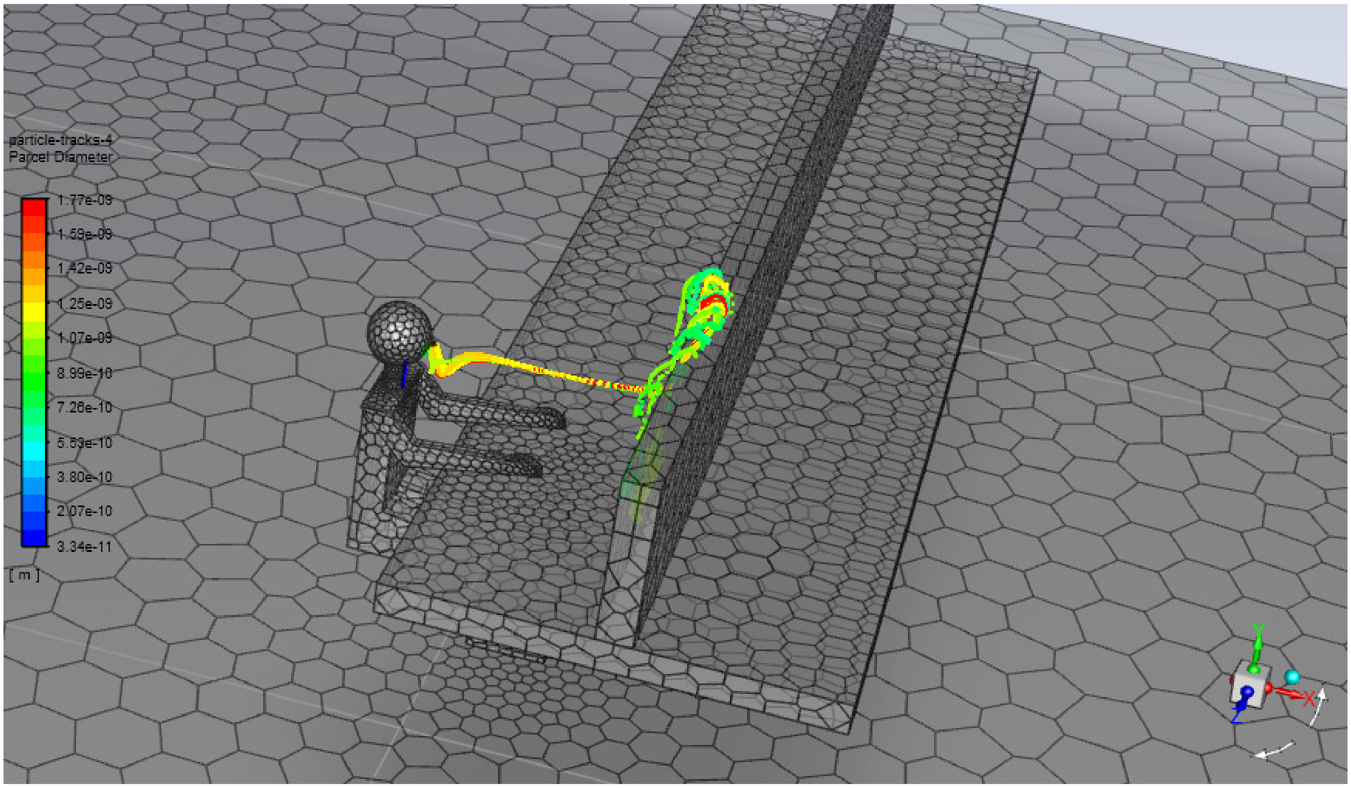
KEY CONSIDERATIONS:

- INTEGRATION OF ARCHITECTURE AND ENGINEERING SOLUTIONS NEEDED.
- MODELING MAY HELP IDENTIFY SPACES WHICH COULD FURTHER THIS

Healthcare facilities, semi-conductor and battery-plant manufacturing and research laboratories utilize pressure differentials between spaces to ensure containment of air between spaces. Airflow is directed to spaces of most contamination by maintaining these spaces at a lower pressure to adjacent spaces. Hence air should always flow from cleaner environments to less clean environments. In addition to the closely controlled supply and return airflow regimes, these systems use space layouts and architectural features, such as doors, anterooms and so on to ensure the air management can be maintained.

Such techniques have been of lesser concern in design and operation of typical commercial and residential buildings, where they are mostly used without any true contamination control in relation to bathrooms, copy rooms, and janitor closets. Applying knowledge of practices from critical facility building types to more general building stock needs consideration between architects and engineers to find solutions which meet the need of the spaces being designed.

Computational fluid dynamics (CFD) models can be used to optimize new concepts to allow different solutions to be studied and optimized before implementation. Harris is currently working on different schemes which consider how some of these ideas may work.



Harris Design Studio’s Development of Coughing Human Model for Analysis of Contamination Spread through Spaces by Mechanical Systems

CONTROLS, INSTRUMENTATION AND BUILDING AUTOMATION SYSTEMS (BAS)

KEY CONSIDERATIONS:

- INCREASED AIR QUALITY MONITORING
- DISABLE DEMAND CONTROL VENTILATION (DCV)
- EXTEND HOURS OF OPERATION FOR FLUSHING
- EXTEND AIRSIDE ECONOMIZER HOURS

Air Quality Monitoring by third parties through one-off, phased or continuous implementation are growing in their use due to the reduced cost of sensors and computing memory storage. A number of rating systems which focus on health and wellbeing are implementing such performance based requirements.

A practice to reduce energy has been to implement demand control ventilation (DCV) in many commercial office spaces. These systems use CO2 monitoring and/or occupancy detection to reduce mechanical ventilation and space heating and cooling loads. It is recommended that these control sequences are disabled to prioritize IAQ over energy savings.

Flushing out buildings before and after occupancy is recommended. Depending on the maximum quantity of air possible to bring in, this could result in up to 24/7 operation of equipment with appropriate set back temperatures to limit energy use.

In milder climates and/or spaces which do not need closely controlled temperatures, consider widening the temperature deadband for airside economizer to bring in more outside air for longer periods of time.

AIR DISTRIBUTION SYSTEMS RECIRCULATION SYSTEMS AND AIR VELOCITY

KEY CONSIDERATIONS:

- "LIKE ALL HAZARDS, RISK CAN BE REDUCED BUT NOT ELIMINATED, SO BE SURE TO COMMUNICATE THE LIMITATIONS OF THE HVAC SYSTEM AND OUR CURRENT STATE OF KNOWLEDGE ABOUT THE VIRUS AND ITS SPREAD."
  LAWRENCE J. SCHOEN, P.E
  ASHRAE JOURNAL, MAY 2020

There is insufficient data available regarding air distribution and appropriate velocities that should be used within spaces. However, what is apparent is that well mixed systems will cause distribution of very small particles which are held in aerosol in the air. Attention is needed when evaluating systems, such as typical VAV or RTU systems, that encourage air mixing and may further distribute microbes possibly spreading infections to those around them.

This work needs to be done in conjunction with how space layouts may develop in the future and a better understanding is gained of what is a minimum infectious dose in different communities and in people with different health conditions.

Underfloor air displacement (UFAD) systems may be a way of reducing cross contamination in offices or other commercial spaces, however, more work is needed to quantify the benefits. Clean and tempered supply air enters at low level and then the return air is collected at the ceiling, giving a once through airflow across the breathing zone of occupants. A similar approach could be to provide supply air at the ceiling in a laminar flow pattern and take return air at low-level similar to operating rooms systems. These approaches may be hard to do in many existing core and shell commercial buildings. Furthering this approach, an increase in ceiling-only supply diffusers and ducted-return grills should be explored to understand the benefits this may deliver.

Recirculating systems for heating and cooling, such as fan coil units or VRF/DX indoor units will need to be evaluated carefully for how they may be improved for filtration needs. Their basic air-supply patterns are often directed at occupants in less sophisticated arrangements.

Ceiling fans have been installed increasingly to help improve a person's comfort in many different space types. These, along with space fans, increase velocity of the air in the occupied zone to help improve comfort conditions. However, they can also be transmission paths of contagions in occupied spaces. Their use should be carefully considered.

BUILDING SYSTEMS
HEALTH CHECK

HARRIS

Operation and building teams need to work together to devise an assessment of the building or facility's operational needs to determine what needs should be considered in the short-term versus long-term planning. Harris recommends that these are done considering the transmission mechanisms to help determine which mechanical systems should be influenced to minimize impact to the operational needs.

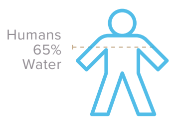
These considerations should not just focus on the on-going pandemic but consider longer-term health and wellbeing issues such as influenza, improved comforts, energy-use impacts and so on.

Operational Needs and Personal Behaviors

Consider operational needs when people cannot work remotely, when PPE is impaired, or social distancing is impractical.

Operational Needs and Transmission in Buildings

Consider known challenges with your spaces which could impact health and wellbeing.



Operational Needs and Personal Vulnerability

Known areas of occupants' health and wellbeing status which may increase the overall risk.

Operational Needs (impact transmission mechanisms)	Transmission Mechanism Impacted (Check the box)			Risk Assessment				
	Personal Behavior	Building Transmission	Personal Vulnerability	SEVERITY		LIKELIHOOD		RISK
1					X		=	
2					X		=	
3					X		=	
4					X		=	
5					X		=	
6					X		=	
7					X		=	

Risk assessments help owners, operators and facilities to understand how much should be done immediately or what can be done as a longer-term solution to allow a return to a more regular condition.

In conjunction with this, Harris has produced your risk assessment proforma to help guide our customers and clients to consider what could be done in their facilities. By combining the risk assessment with the proforma, Harris can help guide finding the right solution for your buildings and facilities.

HEALTHY SYSTEMS
CHECKLIST

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Building: ____________________

System: ____________________

Assessment Date: ____________________

Assessment By: ____________________

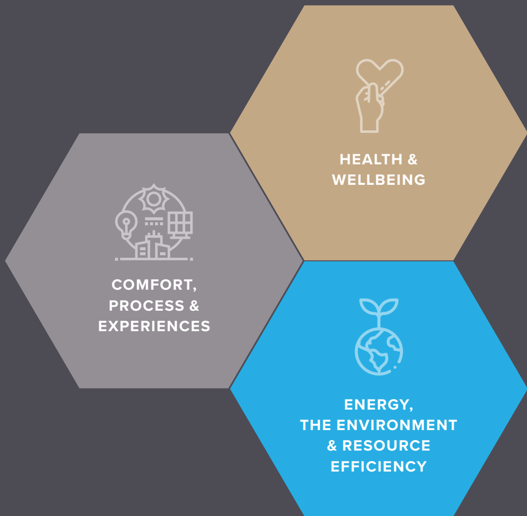
Space Description: ____________________

____

System Description: ____________________

____

	Existing Condition (Describe, where possible, what is known about your systems for each area.)	Opportunities for improvement or supplemental systems (Based on risk assessment need)	Immediate Actions (Could include additional investigations, release of RFPs or actions)	Longer Term Actions (Could include additional investigations, release of RFPs or actions)
Outside Air Change Rate				
Filtration				
UVGI (or other air purification system)				
Humidity Control				
Pressurization Control				
Air Distribution or Flow Patterns				



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Useful Industry Resources:

ASHRAE – American Society of Heating, Refrigeration and Air Conditioning Engineers - https://www.ashrae.org/

USGBC – United States Green Building Council - https://www.usgbc.org/

EUROVENT - https://www.eurovent-certification.com/en

NADCA - National Air Duct Cleaners Association (the HVAC Inspection Cleaning and Restoration Association - https://nadca.com/

CDC – Centers for Disease Control and Prevention - https://www.cdc.gov/

WHO – World Health Organization - https://www.who.int/

NIOSH – National Institute for Occupational Safety and Health - https://www.cdc.gov/niosh/index.htm

EPA – United States Environmental Protection Agency - https://www.epa.gov/

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