AIRPORT CONSORTIUM ON CUSTOMER TRUST

HVAC GUIDEBOOK

April 2021

Airport & Industry Working Together

Beginning early 2021 airport staff and industry thought leaders came together to discuss and record guidance on HVAC Systems in Small, Medium and Large Hub Airports. Below are the contributors to this Guidebook.

Guidebook Topics

Part 1 – Industry References and Recommendations

Part 2 – HVAC Systems and Technology

Part 3 – What are your peers doing?

Executive Summary

AAAE ACT HVAC Working Group recognizes Large, Medium, and Small Hub Airports across North America have heating, ventilation, and air conditioning (HVAC) systems that are engineered specifically to each Airport. We also recognize factors including Airport's campus layout, the age of mechanical and electrical systems, weather constraints, and adopted technology varies tremendously from one Airport to the next. This Guidebook should be used as supplemental information for Airport Directors and Facilities Teams when mapping out enhancement projects, new capital expenditures, and re-positions of your HVAC System. Information provided in this Guidebook was developed with feedback directly from our participating Airport Leaders and Industry Partners. This information, links, and whitepapers are up to date resources to streamline information gathering.

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INDUSTRY REFERENCES AND RECOMMENDATIONS

Part One

Start with Institutional References and Recommendations

Key Takeaways from Publications

- High **air change** rates are critical
- Code required ventilation rates used in conjunction with filtered **(MERV 13 or better**) recirculated air is effectively equivalent to using 100% outside air from ventilation.
- Focus on ventilation important **in areas of dense occupancy** Supplemental air cleaning recommended for employee break areas, especially if used to eat and interact socially.
- Important **to continue masking, social distancing**
- No evidence that viable virus has been transmitted through an HVAC system that results in disease transmission to people in other spaces served by the same system
- In Room & Transportation (APM & Busses) Air Cleaning devices with positive feedback
  - UVGI
  - Portable UV/HEPA

Harvard Aviation Public Health Initiative (APHI) Study Phase II
ASHRAE Guidance
CDC Guidance
GBAC Star Accreditation

What is the GBAC Star Accreditation?

The American Association of Airport Executives (AAAE) and the Global Biorisk Advisory Council (GBAC), a Division of ISSA, the worldwide cleaning industry association, have established a formal partnership to accredit airports that meet their highest levels of cleanliness and safety at their facilities to minimize risk from coronavirus and other infectious agents.

The following 20 program elements will each have specific performance and guidance criteria provided:

Facility Leadership, Commitment, and Planning

1. Organizational roles, responsibilities, and authorities
2. Facility commitment statement
3. Sustainability and continuous improvement
4. Conformity and compliance

Goals and Strategies

5. Goals, objectives, and targets
6. Program controls and monitoring
7. Risk assessment and risk mitigation strategies
8. Standard operating procedure

Supplies and Inventory Management

9. Tools and equipment
10. Cleaning and disinfection chemicals
11. Inventory control and management
12. Personal protective equipment (PPE)
13. Waste Management

Training, Preparation, and Prevention

14. Personnel training and competency
15. Emergency preparedness and response
16. Facility infection disease and prevention policies
17. Worker health program

Constant Vigilance

18. Audits and inspections
19. Control of suppliers
20. Documentation management

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Specifics from ASHRAE's Epidemic Task Force

ASHRAE Epidemic Task Force *Core Recommendations for Reducing Airborne Infectious Aerosol Exposure*:

1. **Public Health Guidance** – Follow regulatory and statutory requirements for PPE, social distancing, hygiene, sanitation, and other administrative measures.
2. **Ventilation** – Provide and maintain minimum outdoor airflow rates for ventilation specified by applicable codes and standards.
3. **Filtration** – Achieve MERV 13 or better performance for air-recirculated HVAC systems
4. **Air Cleaning** – use only air cleaners for which evidence of effectiveness and safety is clear
5. **Air Distribution** – promote mixing of space air without causing strong air currents that increase direct transmission from person-to-person
6. **HVAC System Operation** – maintain temperature and humidity setpoints. Maintain systems. Operate systems whenever a space is occupied. When necessary, flush spaces between occupied periods. Limit re-entrained contaminated air.
7. **System Commissioning** – verify that HVAC systems are functioning as designed.

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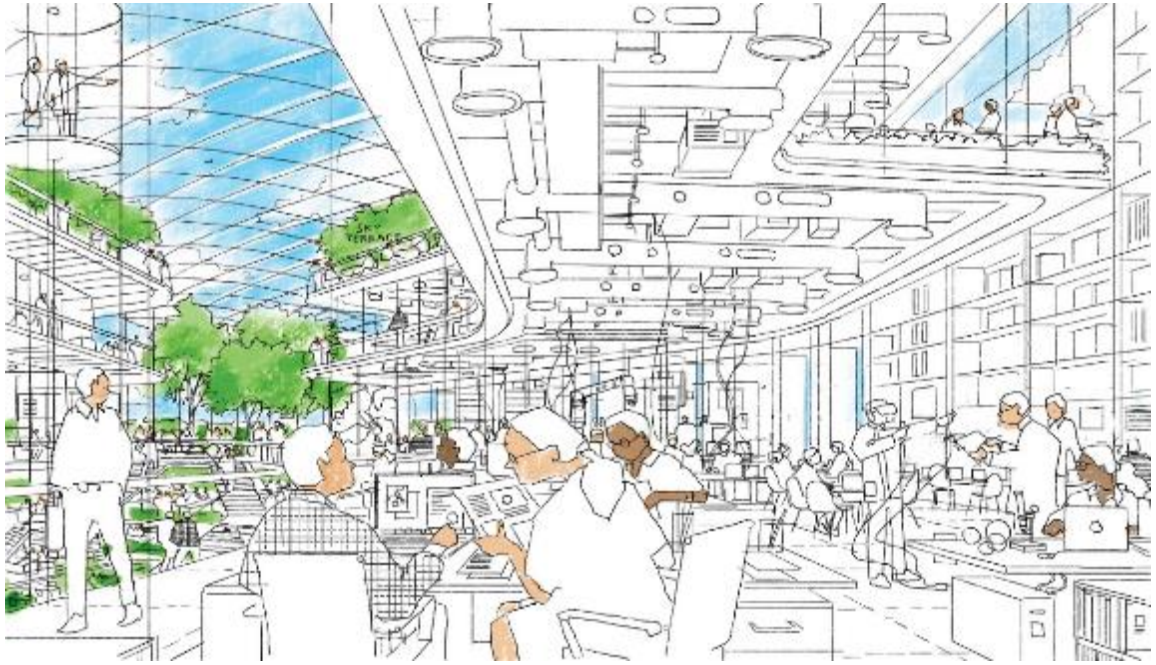
HVAC SYSTEMS AND TECHNOLOGY

Part Two

Understand Your System and Available Technologies



HVAC Systems

- Air Exchange
- Filters
- Building Controls & Analytics
- Air Purification Technology
  - UVGI
  - Bipolar Ionization technologies
  - In-room or portable air cleaners
- Energy Considerations

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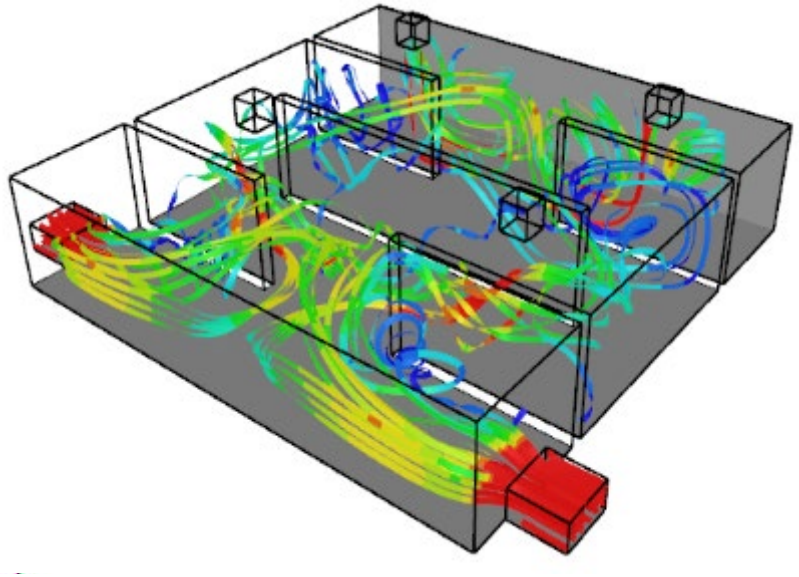
Ventilation and Air Exchange

Explanation & Intentions of Air Exchange

- Removes dirty air and provides fresh air
- Dilution and removal of containments and fumes
- Air changes per hour (ACH) is the standard calculation
- Important for managing pressure regimes
- Industry standards dictate minimum requirement of outdoor ACH



Monitoring and Pressure

- Airports are subject to odor and pollutants created by exhaust fumes from aircrafts, buses, fumes from fuel delivery systems.
- Terminal building should be maintained at a positive pressure in relation to outside

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Filters

Explanation of Air Filters

- Filters remove particulate matter and microorganisms from the air.
- Filter ratings corelate to particle size removal.
- Filter's lifecycles vary and can be monitored with pressure sensors by the Building Management System (BMS).
- The impact of additional resistance on air flow.

Harvard School of Public Health APHI Phase Two Report:

"MERV 13 would be nearly as effective as using 100% outdoor air, and in many climates much less expensive than cooling and dehumidifying additional outdoor air."

ASHRAE Epidemic Task Force

"Use combinations of filters and air cleaners that achieve MERV 13 or better levels of performance for air recirculated by HVAC systems."

Rating	Example Containment	Efficiency
HEPA	Carbon dust and virus	99.97% at 0.3 to 1µm
MERV-16	Bacteria, smoke and sneezes	95% or better at 0.3 to 1µm
MERV-15	Bacteria, smoke and sneezes	85-94% at 0.3 to 1µm
MERV-14	Bacteria, smoke and sneezes	75-94% at 0.3 to 1µm
MERV-13	Bacteria, smoke and sneezes	<75% at 0.3 to 1µm
MERV12	Dust and Fumes	<20% at 0.3 to 1µm

MERV = Minimum Efficiency Reporting Value, developed by ASHRAE to report filter effectiveness

HEPA = High-Efficiency Particulate Air filter

Building Controls and Analytics

Optimized HVAC

- Automatically maintain Air Change Rate efficiently at all times even as filters and equipment age.
- Monitor and manage your HVAC system temperature and humidity control within range.

Power management

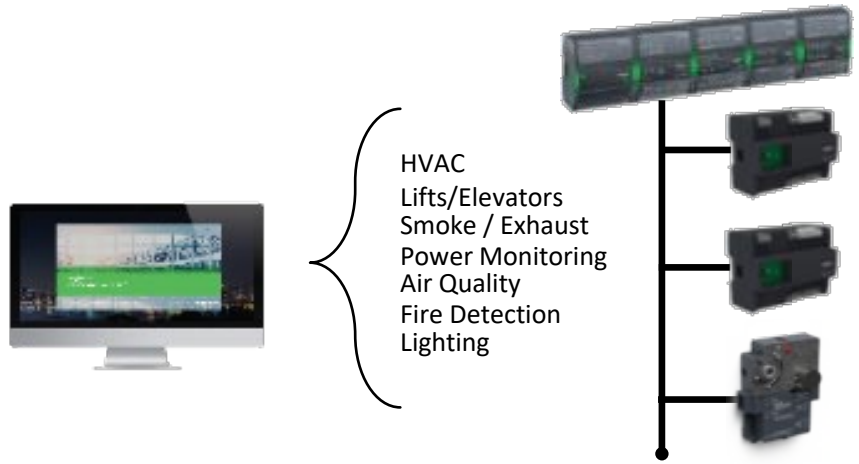
- Monitor and manage your motor and electrical infrastructure actively, to ensure power reliability and optimize use

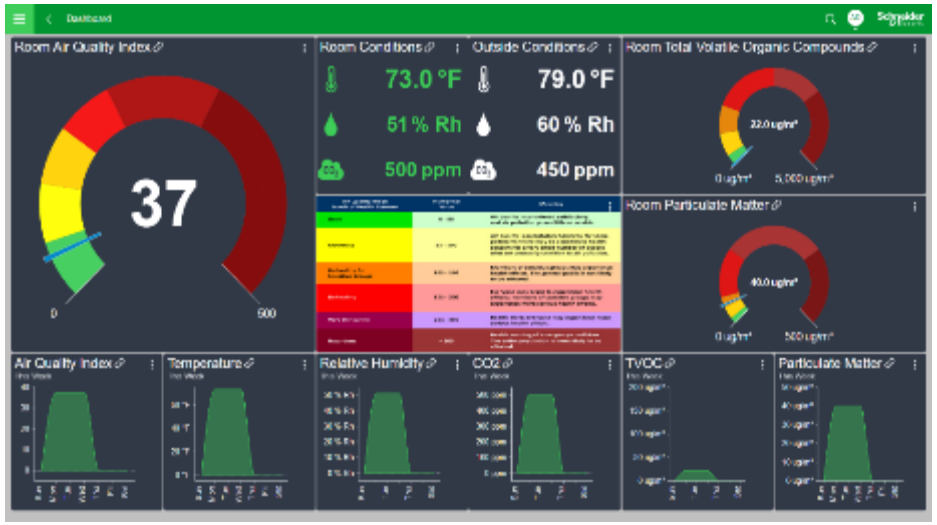
Volatile organic compound (VoC) control

- Improve air quality by tracking and venting VoCs
- Create Indoor Air Quality Dashboards both back office and customer facing.

Epidemic Mode

- Automate special control sequences
- Particulate monitoring of PM2.5 and PM10
- Provide remote BMS access to staff and trusted providers who can implement procedures for an emergency

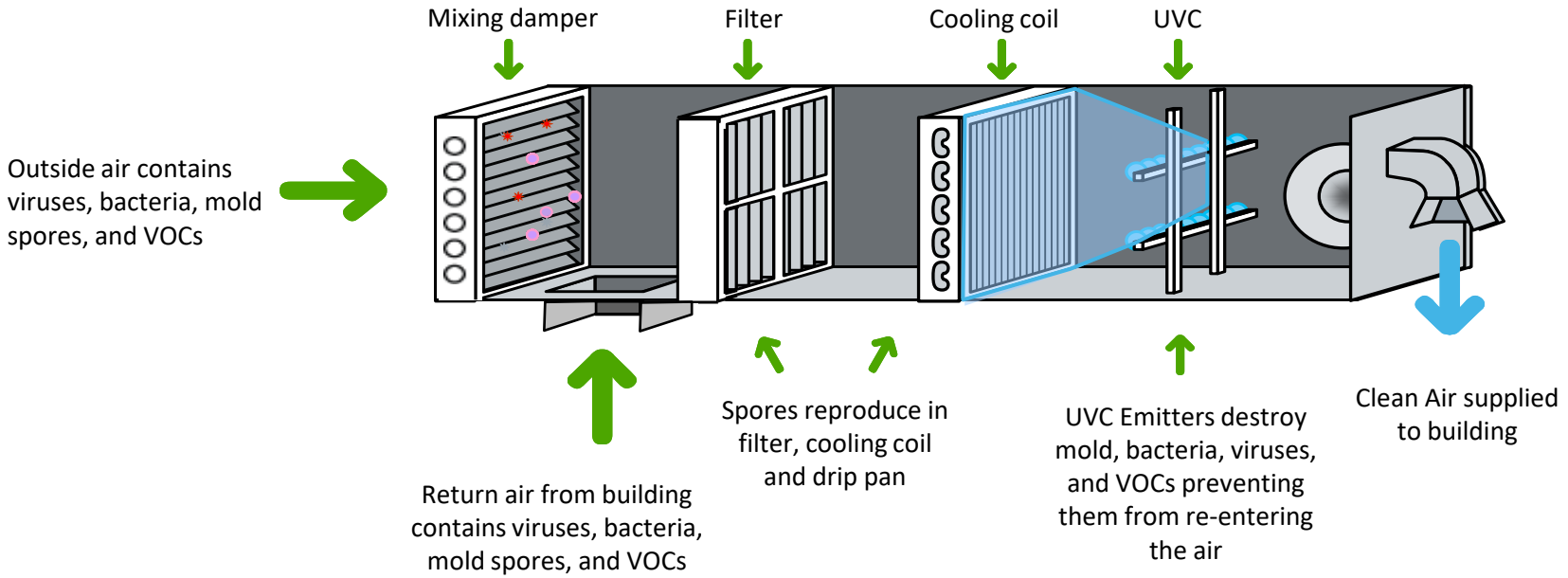




Harvard APHI Phase Two Report

"BMS might require additional evaluation by knowledgeable mechanical engineers and contractors, so that they can accommodate the unique requirements of mitigation for SARS-CoV-2"

Ultraviolet Germicidal Irradiation (UVGI)



Per CDC:

- UVGI is part of a layered strategy.
- Consider if options for increasing room ventilation are limited.
- Can be used to provide air cleaning within occupied spaces.
- In-duct UVGI can help enhance air cleaning inside central ventilation systems.

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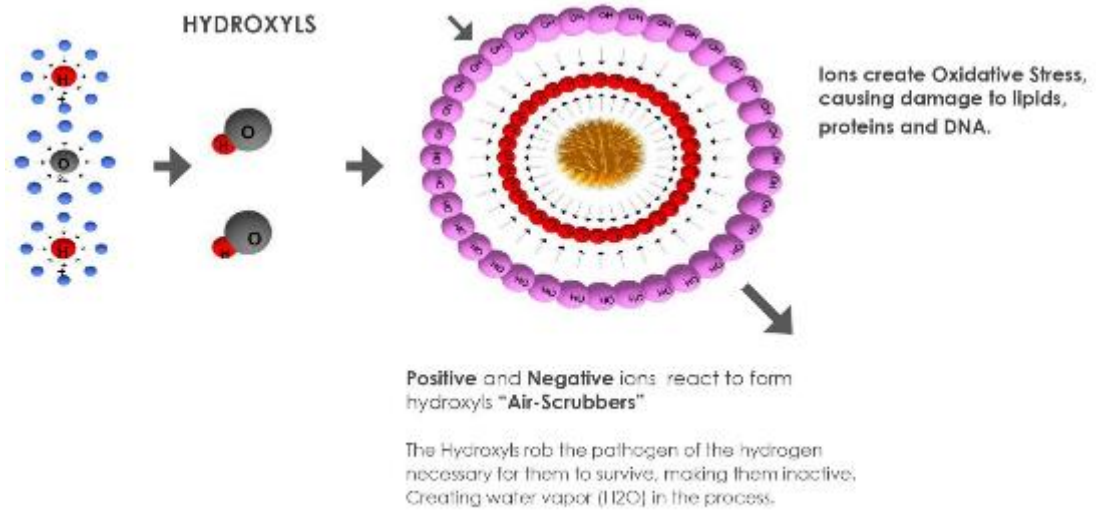
Needle Point Bipolar Ionization (NPBI)



TARGETS PARTICLES

When ions disperse throughout a room, they combine with particles suspended in the air. This creates a snowball effect, in which particles of opposite polarity cluster together. The larger a particle becomes, the easier it is to capture in filtration systems.

REDUCES PATHOGENS

During the NPBI™ process, contact with ions disrupts pathogens' surface proteins, rendering them inactive and unable to replicate.

TACKLES ODORS

GPS' NPBI™ technology breaks down chemical, pet, cooking and other odors into basic harmless compounds, leaving indoor air smelling fresh and substantially reducing odor-causing VOCs.

SAVES ENERGY

By keeping indoor air cleaner, NBPI reduces the amount of air required from outside to keep things fresh—saving you initial ventilation equipment costs and up to 30% on energy consumption.

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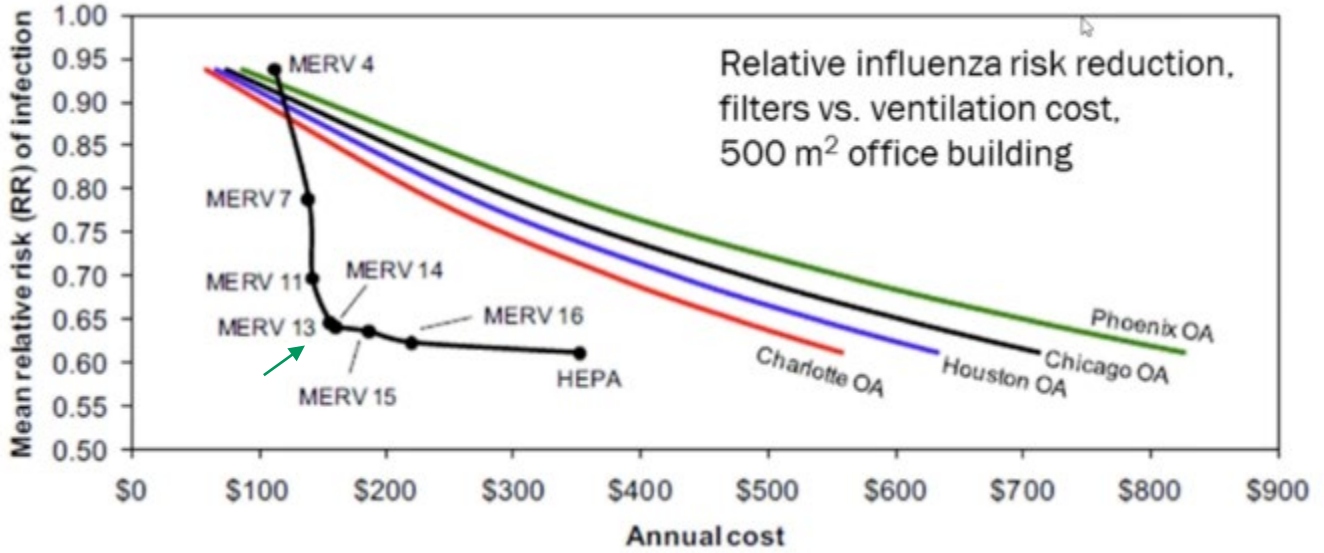
Energy Considerations

Factors that affect energy cost

- Additional electricity usage due to Filter type and age
- Additional electricity usage from increased ACH as you increase outside air percentage
- Your BMS can coordinate the outside air strategy, max air exchange, filter program, and energy usage.

Reducing Relative Risk (RR) of infection

*Comparing Filter and Outside Air settings to Energy Cost



*Azimi and Stephens, Building and Environment 70 (2013) 150-160 presented by Dr. Bahnfleth, chair of the ASHRAE Epidemic Task Force, in June 2020.

Notes on Graph:

ASHRAE & Harvard APHI recommend filters and outside air in combination. This graph does not show filters and OA in combination but shows each independently to highlight MERV 13 filters provide the highest RR/Cost benefit.

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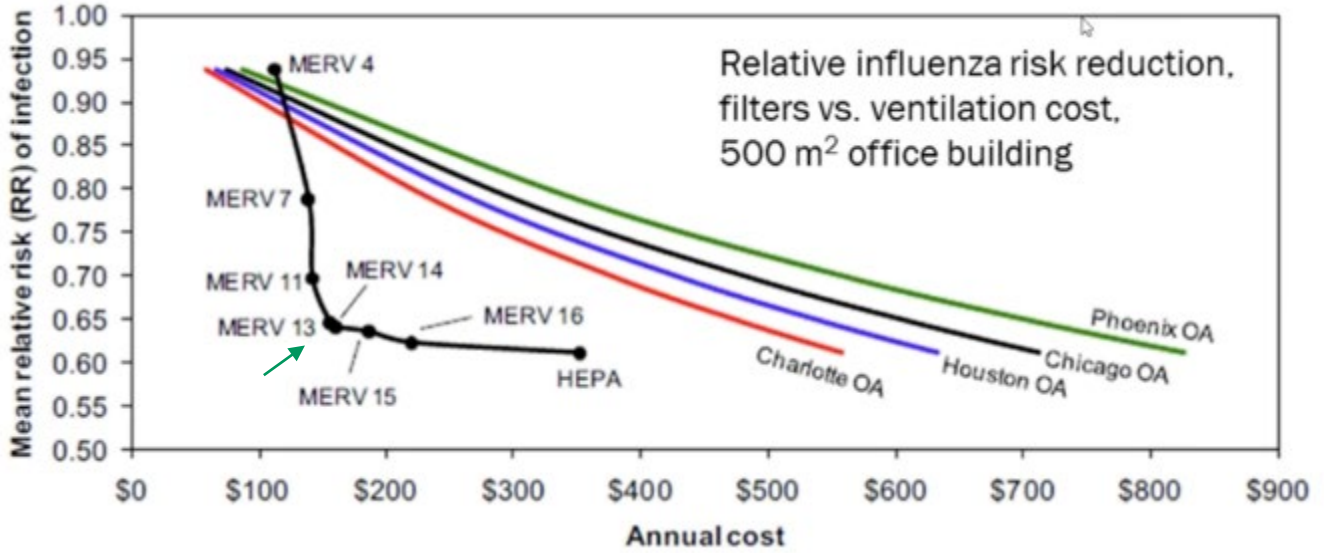

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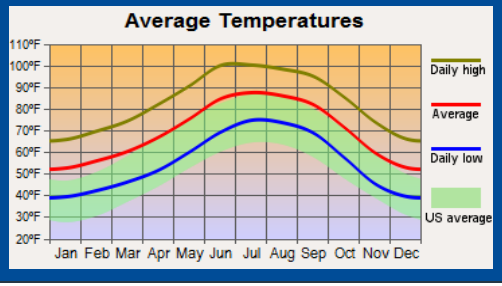
WHAT ARE YOUR PEERS DOING?

Part Three

Airport Enhancement Projects

Denver International Airport – Duct Cleaning

Tucson International Airport – Seasonal impacts to Covid19 Ventilation programs



John F. Kennedy International Airport T4 – Benefits of Proactive Maintenance

Dallas/Fort Worth International Airport – UVC pilot and efficacy testing

Norman Y. Mineta San Jose International Airport – HVAC Technology Evaluation

DEN - Duct Cleaning FIS Terminal

Key Insights and Takeaways:

- Insights
  - Low pressure side of systems were very dirty and requiring specialized cleaning.
    - ✓ Air Ducts, Coils and Return Air Grills
  - Strategy: Clean low pressure side of HVAC system and increase MERV 13-14 filter rating at Air Handling Units (AHUs) in FIS.
- Takeaways
  - Post cleaning consideration should be made towards upgrading MERV filters
    - ✓ FIS filters are currently being upgraded to MERV-14 filters
    - ✓ DEN is evaluating a MERV-15 filter and associated costs

	Before	After
Air Ducts		
Coils		
Return Air Grills		

JFK T4 – Preventative Maintenance

Key Insights and Takeaways:

- Insights
  - All HVAC systems are monitored and controlled by Building Management System (BMS).
  - Air Handler Units (AHUs) retro-commissioned and upgraded to MERV 13-15 filters as part of LEED O&M Certification in 2018.
  - AHU refurbishment project commenced in 2020 resulting in 18% airflow improvement.
  - Maximized the use of outside air as much as possible with energy usage and system performance in consideration.
  - Replacement of VFDs for all AHUs, hot water and chilled water pumps.
- Takeaways
  - JFK Terminal 4 concentrated on improving existing systems to maximize efficiencies and to improve indoor air quality.
  - Maximizing outside air helps remove airborne pathogens and improve indoor air quality.
  - MERV-13 requires an evaluation to ensure the equipment can handle the higher rating without negatively impacting the performance of the AHUs.
  - 2018 LEED O&M Certification prepared Terminal 4 with better air filtration prior to the pandemic.

Before

After

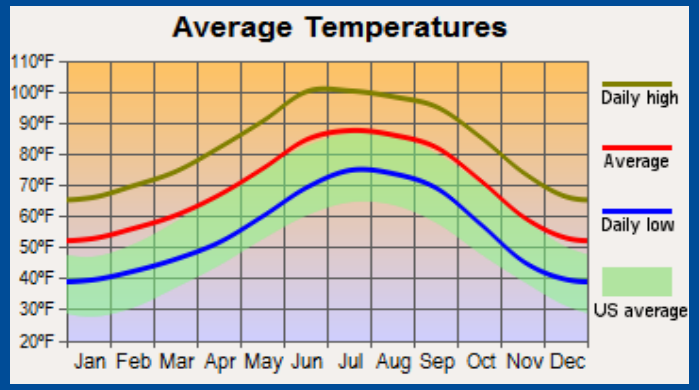
BMS Interface

TUS – Managing OA & Energy Cost

Key Insights and Takeaways:

- Early Pandemic Cycle Actions:
  - Increase Filtration (MERV13)
  - Increase Outside Air (OA) Ventilation
  - Programmed OA dampers to 100%
- Challenges
  - Buildings not engineered for complete OA Circulation, Return Air (RA) is a component of the building Supply Air (SA)
  - RA is used when OA is not compatible with the requested SA
  - Energy Efficiency suffers if the OA temperature is not in the requested range of the SA, which is 65 degrees F.
- Moving Forward
  - Continue the use of MERV13 filters to increase filtration.
  - As the pandemic subsides, program the OA dampers back into economization modes to conserve energy.

Seasonal impacts to COVID-19 Ventilation programs

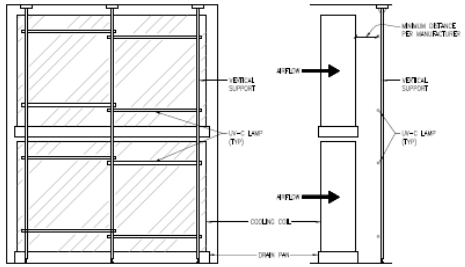


When OA ~ = SA, no req cooling at the AHUs and no reheat at the VAVs – Maximized energy efficiency.
When OA > SA, fans need to move more air, AHUs must lower temp further/work harder, chilled water demands skyrocket. Especially in a southwestern climate
When OA < SA, more reheat required at VAV box level. This will be more prevalent across America, especially central to northern tier areas

DFW – UVC Pilot and Efficacy Testing

Key Insights and Takeaways:

- Efficacy
  - UVC is installed after the air filter. Benefits are realized as increased sanitization on the pathogens that pass through the filter.
- Safety
  - UVC exposure can result in eye or skin injury. Include safety measures in the design to turn-off UVC light when AHU is not in use.
- Energy
  - Requires a high-intensity UVC light to achieve in-duct disinfection. Energy costs should be considered in the cost evaluation.
- Design/Install
  - Install according to ASHRAE guidelines for In-Duct Air Disinfection
  - Test to verify efficacy. Test chamber built and analysis conducted to assess the efficacy of UVC light install. Results indicate effectiveness on both culturable bacterial and fungal aerosols.



1 UVC BULB/COIL RETROFIT DETAIL
SCALE: NTS

SJC – HVAC Technology Evaluation

Conducted HVAC Study in October 2020 to evaluate three technology options:

Needlepoint Bipolar Ionization (NPBI), Ultra-Violet Spectrum C Light (UV-C), HEPA Media Filtration

Financial Evaluation of Options	Needle Point Bipolar Ionization (NPBI)	Ultra-violet Spectrum C (UV-C)	HEPA Media Filtration
First Cost	$1,017,917	$1,318,493	$626,065
Replacement Cost Per Year	$0	$217,481	$282,574
Maintenance Cost Per Year (Additional from Regular Maintenance)	$0	$40,000	$60,000
Design Cost (10% of Total Construction Cost)	$102,000	$132,000	No Design
Airport Public Works Project Delivery Cost (18%)	$183,225	$237,329	$112,692
Present Total Cost	$1,303,142	$1,687,822	$738,757
Simple Life Cycle Cost (20 Year Period)	$1,303,142	$8,606,433*	$10,892,914*

NPBI

UV-C

HEPA

**The Simple Life Cycle Cost included 3% escalation per year for the replacement and maintenance costs.*

SJC – HVAC Technology Evaluation

NPBI technology was recommended based on the following key considerations:

- Existing air velocity, displacement ventilation and ductwork length to passenger spaces
- Existing interior volumes and scale of hold room/concourse spaces
- Air Handling Unit (AHU) types and frequency
- Available electrical and data infrastructure
- Maintenance schedules and cost
- Lifecycle costs of NPBI System

Current Efforts as of March 2021

- Proceeded with Design efforts to deliver the NPBI across the SJC Facility

The HVAC and Indoor Air Quality working group has been actively supported by a range of airports, terminal operators, and industry participants

Airport & Terminal Participants

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