SECUREAIRE WHITE PAPER

New Applications for Operating Room Air-cleaning Soluaions: Open Office

by: John Wixson, BSC CP, Ryan T. Evans, PE, BSME, MBA, LEED AP BD+C,
Jeff Gattis, Jon Pahl, LEED AP BD+C

www.entegritypartners.com 800.700.1414 info@entegritypartners.com

White Paper February 3, 2021

New Applications for Operating Room Air-cleaning Solutions: Open Office

John Wixson, BSC CP[a], Ryan T. Evans, PE, BSME, MBA, LEED AP BD+C[b], Jeff Gattis[c],
Jon Pahl, LEED AP BD+C[d]

[a] *Entegrity Consulting, Lenexa, KS*
[b] *Entegrity Energy Partners, LLC, Lenexa, KS*
[c] *Nabholz Construction, Lenexa, KS*
[d] *Nabholz Construction, Lenexa, KS*

Key Words:
Indoor air cleaning
Airborne pathogens
Air quality
Workplace-acquired infections
Sick building syndrome

Background: Controlling infectious agents in an office environment requires more than disinfection or multiple air changes. We must consider infectious agents as well as other airborne contaminants that can lead to spread (allergens).
Methods: We took an air particle control technology designed for hospital operating rooms and adapted it to an office environment. Over the course of several days, we utilized air particle counter measurements to study the effects on the environment.
Results: The air cleaning technology reduced the particle count by as much as 90%. Its observed effectiveness was < 3 hours.
Discussion: Utilizing this technology in an office environment can dramatically reduce indoor air contamination, thus lessening the spread of infections. Further, it reduces airborne particulate matter that can lead to the spread of some infectious disease by asymptomatic building occupants.
Conclusions: The technology studied may protect workers from workplace-acquired infections that otherwise could lead to sick building syndrome; it may do so more cost-effectively than other CDC-recommended options.

Table of Contents

Table of Figures

Abstract

Since 2012, a dynamic air cleaning solution designed to dramatically reduce airborne contaminations in hospital operating rooms has been on the market. This technology was proven to not only reduce microbes corresponding to hospital-borne infection, but also reduce allergens and control odors, important side benefits that have implications for new applications. Given the varied human response to COVID-19 — especially when considering asymptomatic carriers of the disease who are unknowingly infected — having an air cleaning solution that does more than disinfect is imperative to mitigating the risk of infectious disease spread.

Our study is of adapting the use of the hospital air cleaning product into an open office setting. We hypothesized that the air cleaning technology would do more than virus control and that by cleaning small airborne particulate (< 1 micron), we might also reduce infection spread from an asymptomatic carrier by limiting allergens in the space.

The technology studied did in fact dramatically reduce airborne particulate and did so more effectively than by increasing outside airflow to the space.

Introduction

We are just beginning to understand the role of airborne transmission from both symptomatic and asymptomatic carriers of viruses. Considering today's pandemic of SARS-CoV-2 (coronavirus; size approximately 0.1 micron), understanding human impacts on viral transmission is paramount. For certain, research shows there is overwhelming evidence that humans generate infectious aerosols[1].

The industry standard for infection risk mitigation is dilution via outdoor air. But the introduction of additional outdoor air carries risk. For most facilities, it can lead to the insertion of more particulate to the space, including allergens, unless heavy filtration is utilized.

The HVAC systems in most buildings were not designed to handle additional large volumes of outdoor air. Without proper system design, poor outdoor air management can lead to loss of humidity control which in turn can lead to poor indoor air quality, the very problem we are trying to address.

Regardless, energy is of concern. The introduction of additional raw outdoor air typically requires a great deal of energy to process into clean, comfortable indoor air.

The HVAC industry needs to develop air cleaning technology that addresses viral airborne transmission, while eliminating these unintended consequences. Our research team seeks to study if current technologies can be adapted for new applications that address today's current needs without the drawbacks of increasing outdoor air.

Technology Operating Room (OR) Performance

SecureAire was designed for the hospital operating room environment. Our research team reviewed case studies and reports for healthcare facilities that reported dramatic drops in airborne particulate and TVOCs[2,3]. In 2019, the researchers found that the air cleaning technology reduced fine and ultrafine particles greater than HEPA filtration in live operating rooms at the Mayo Clinic in Rochester, Minn.[4]

Given the success of this technology in the healthcare environment, it has promising implications for other building types.

Technology New Application

We seek to determine if the SecureAire active particle control system can be adapted from the hospital operating room environment to the office environment without dramatically impacting the HVAC system or energy use. Challenges to alternative HVAC approaches include the addition of restrictive air filtration (e.g., HEPA), increasing air changes, and enlarging system sizes to handle the extra load required due to increased outdoor air.

The team reviewed several non-healthcare case studies to learn how the system was adapted for other building types and spaces. These building types included higher education[5], office[6], institutional[7], and manufacturing[8]. In most cases, the technology was deployed with intent to remove airborne toxins from the indoor environment, but not for infection control as it would be used in a hospital setting. In one case, the technology was deployed to control odors.

Problem Statement

Viruses are extremely small (often less than 1 micron) and can take up to 72 hours to precipitate out of the air stream depending on their size.

HEPA filtration is good, but it does not address the potential impact to these small particles being suspended in the air for hours or days. Hospitals use extremely high air change rates of 15 to 20 air changes per hour (ACH) to force the particles to move. At two to four ACH, today's office HVAC is not designed for this and there would be a huge energy penalty if we were to follow an operating room example.

A simple way to think of this transport mechanism phenomenon is a large weather balloon in a five mile per hour crosswind. In this scenario, the weather balloon acts as a large sail and travels at roughly 5 MPH. Conversely, a small balloon the size of a nickel would travel at a slower rate because its surface comes into contact with much less air.

Therefore, an air cleaning system that sends out active particles (i.e., bipolar ionization) has been shown to have a remarkably better chance of filtering out viruses and other particulate once they have been clumped together to reach a critical size where they can move with the airflow. SARS-CoV-2, commonly known as coronavirus, is one such small particulate that takes hours before it precipitates out of the air. At 0.1µm (0.1 micron), it is too small to effectively move with the flow of air. **See Figure 1** for particle sizes.

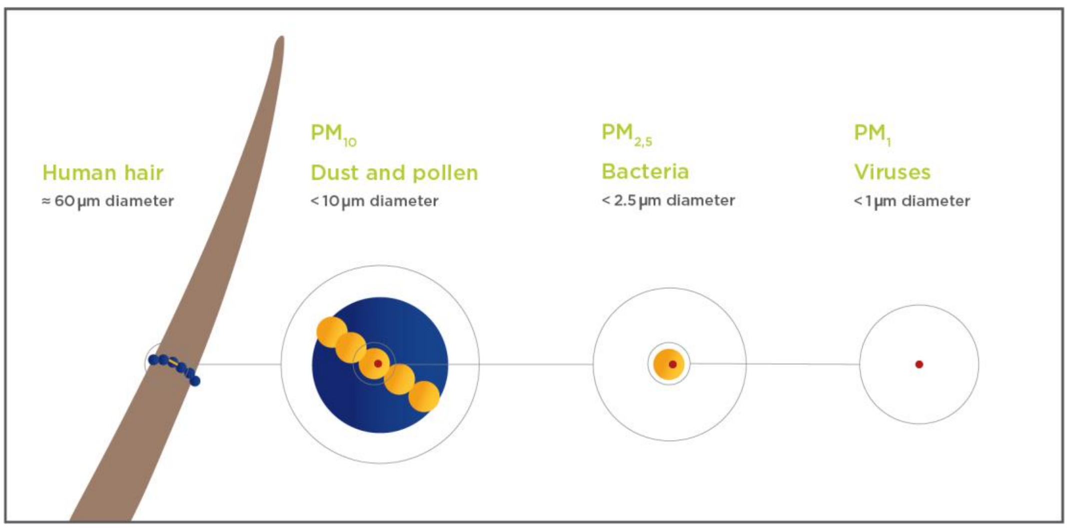

Figure 1: Common size of airborne particulate

This study seeks to determine if SecureAire can be effectively adapted to an open office environment to reduce airborne contaminants such as viruses and allergens, thereby mitigating viral transmission in the shared spaces.

Office Layout

The building is comprised of 12,000 square feet of office space with 9,000 square feet of construction shop immediately to the north. The shop is attached to the office by a fire-rated, sealed demising wall. The office plan is typical with an open office design: training center, multiple conference rooms, a small batch of walled offices, open kitchen, exercise room, and restrooms (**See Figure 2**). The construction is typical tilt-up concrete walls with double-pane, insulated windows. From an infiltration perspective, construction is tight. The floor-to-deck height is 18 feet creating a voluminous space (approximately 216,000 cubic feet). The roof construction is a high-albedo, flat membrane. Four packaged rooftop units serve the office. Two are single zone, constant volume; the others are single zone, but equipped with zone dampers and bypasses, therefore making them variable volume and temperature (VVT) systems.

Figure 2: Office Layout: *Locations and rough sizes of air cleaning equipment denoted in red.*

<u>Impacts of Existing HVAC System</u>

We found the inclusion of VVT controls for rooftop units 1 & 2 a bit surprising. VVT systems are rarely designed today, giving way to variable air volume (VAV) systems or load-matching systems that adjust both fan and compressor speed.

Nevertheless, VVT systems still operate at constant volume, which allowed the research team to have stable airflow rates for testing.

Nevertheless, philosophically VAV system speed is seen as a proxy for occupancy, especially in interior spaces. For example, a packed conference room will have a call for cooling, leading to increased airflow in that space. Eventually, we may need to study the impact of VAV on air cleaning performance (see Future Considerations).

Equipment Considerations & Design

We consider air changes to be a major factor. One of the reasons we picked this technology and the application thereof was to increase the air change rate. The idea behind this is simple: increasing airflow increases the efficacy of the filter media with smaller particulate (< 1 micron).

Filtering at Higher Airflow Rates

This filter media is typically applied in the filter banks of large air handling units in the hospital where code requires air changes at rates much higher than a typical office environment. To increase airflow without redesigning the existing HVAC system size, we simply made standalone fan-filter boxes (**see Figure 3**). This increased the airflow from 14,000 cubic feet per minute (cfm) to 22,000 cfm, which equated to an air change rate of 6.11 (up from 3.89 or a 57% increase). Filtering with higher air changes helps move small particulate, especially if we can grow the particulate size (3-5 microns). It also allows us to run these units continuously, reducing impact to energy use.

Figure 3: Installed SecureAire Recirculating Fan-powered Unit

Proximity Effects

In healthcare applications, we noticed that by applying technology in a certain area (e.g., operating room) that it had benefits to air quality in the spaces immediately adjacent to the areas served by this technology. We hoped to capitalize on this phenomenon in an open office layout whereby actively charged particles can easily navigate open office space, but also adjacent closed-wall spaces such as single occupancy offices and conference rooms.

Final Design

We designed two, 4,000 cfm units and located them at opposite ends of the office space (**see Figure 2**). We deployed calibrated particulate counters at multiple locations in both open office and closed-wall rooms to test the efficacy of the system. The results were similar, verifying proximity effects. The open office particle counter data is provided in this report.

Budget

Due to our research partners and suppliers, we were able to deliver the project at a discount. The following figures are estimates on what the cost will be when developed for market use. Associated Air Products, a partner in the research, aided in procuring the technology. The fan-filter boxes were fabricated by AirFixture, LLC, of Kansas City, Kansas.

Nabholz Construction provided the labor for installation and some small electrical connections. They also relocated one sprinkler head. Once the product development is fine-tuned, we expect the installed units to be available to the market at about $18,000 to $20,000 each. Labor rates and product availability may vary based on market.

Therefore, we expect the cost to be $3 to $3.50 per square foot or $4 to $5 per cfm. For new construction or for retrofits where air handlers already exist, the cost would be considerably less.

Test Results/Performance

To establish a baseline, the research team took tests of both ambient indoor and outdoor conditions. Outdoor concentrations of particle size 0.5 microns per cubic foot range around 2,000,000. We found indoor concentrations to be about 20-25% of that number (400,000 to 500,000 parts) depending on outdoor air damper position. We locked out the economizer mode of the rooftop units during the experiment.

We began full-scale testing of the SecureAire equipment on September 16th, 2020. During the first several days, we saw a dramatic drop in particulate concentrations with several days ranging at or below levels for an ISO 7 clean room (threshold 10,000 particles of 0.5 microns and larger).

The biggest exception was the first day immediately after we began testing (September 17th). On this day, our staff was engaged in painting in the attached shop. The caustic nature of the fumes was immediately noticeable upon entry into the office. By 7:00 am particulate concentrations of 0.5 microns or larger had reached more than 427,000 parts per square foot (**See Figure 4**) or approximately ambient levels prior to air cleaning. We could still perceive the fumes a few hours later.

Interestingly, the air cleaning systems were at work. By mid-afternoon, the concentration had dropped by half and was no longer perceptible through smell. Before 8:00 pm, the air quality had returned to clean room levels.

Although this anomaly in the experiment was unplanned, it did provide some useful information on the speed that the air cleaning systems work. Microbes and allergens in the air cannot easily be detected by the senses, but this instance offered the research team an olfactory indication of particulate concentration under normal office ambient conditions — much like the inclusion of the *mercaptan* chemical in natural gas. The strength of the natural gas smell is an indicator not only of particulate concentration, but of risk to human life. Indeed, SecureAire has been used for odor mitigation in other applications (e.g., NFL locker room). And we believe it has many uses outside of infection control.

Over the next several days we watched as the particulate count ranged between a low of 2,800 parts per square foot to more than 100,000 parts with still many hours falling below the ISO 7 clean room threshold. The average parts per square foot was approximately 50,000 for an 87% to 90% reduction compared to ambient indoor conditions.

We learned from this experiment there were two factors that limited the SecureAire system from being able to consistently clean the space to clean room conditions. The first factor was the proximity of the construction shop to the office. Although these spaces were separated by a fire-rated demising wall, the experiment does indicate that some air is still transferred between spaces. By simply opening the large overhead doors in the shop, one could immediately see the impact to particulate count on the meter in real time. We would need to do pressurization studies to fully understand this phenomenon, but also realize that having a shop connected to an office is not a typical office design.

The second limiting factor was that we designed our SecureAire systems to be standalone, recirculating air units. Because of this, they do not clean the outdoor air from the rooftop units prior to it being introduced to the space. This effectively means that there is also some source of particulate being introduced to the indoor space from outdoors. For this reason, nighttime readings when the outdoor air damper was closed were significantly lower than daytime readings (**See Figures 4 & 5**).

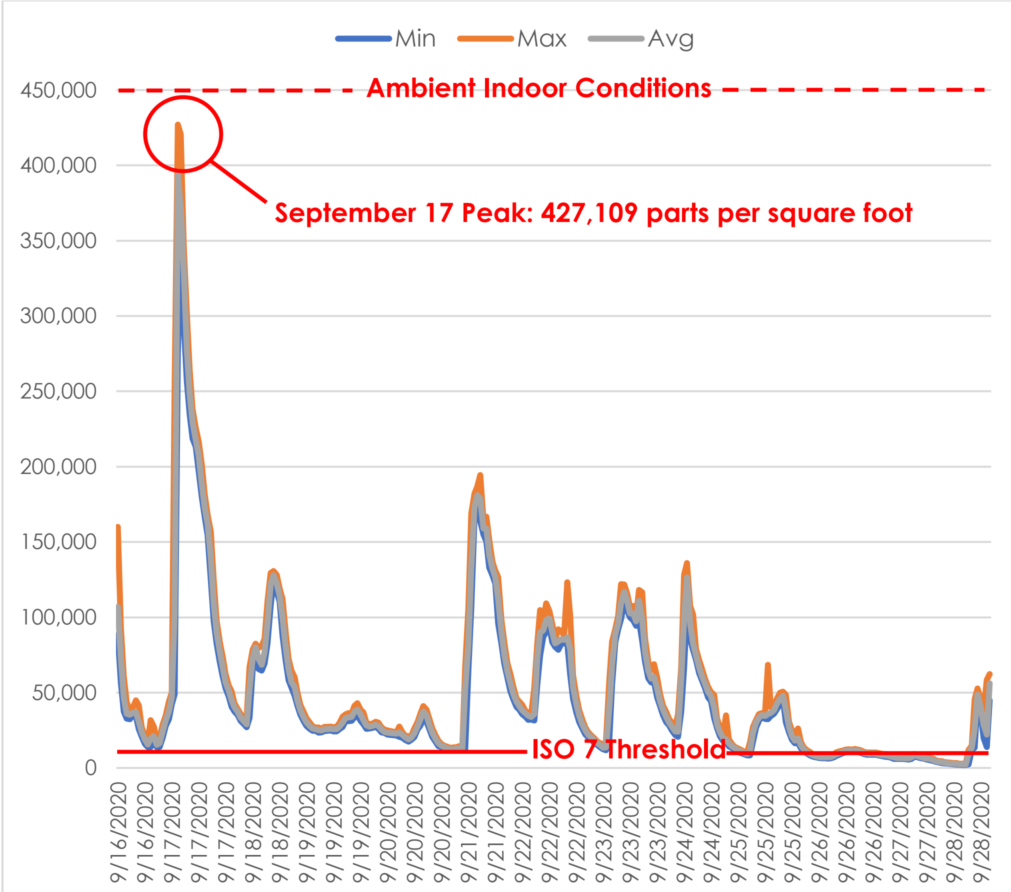

Figure 4: Particulate counts per square foot for particle size > or = 0.5 microns

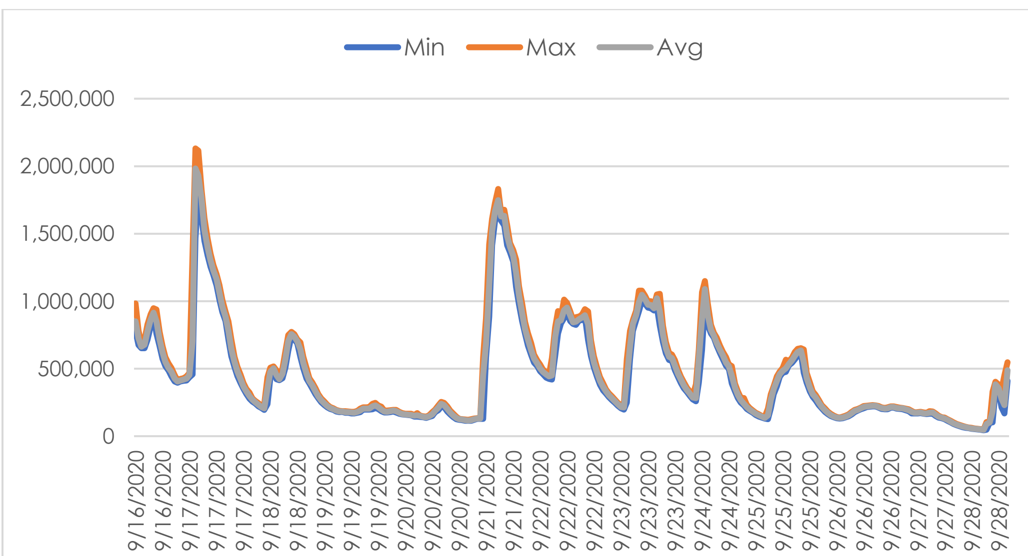

Figure 5: Particulate counts per square foot for particle size > or = 0.3 microns

Beyond Infection Control/Other Benefits

One of the more exciting aspects of air cleaning using ASHRAE's Indoor Air Quality Procedure (IAQP) is its ability to pay for itself over time. This is accomplished by improving indoor air quality while reducing the amount of outdoor air required to safely ventilate the space(s).

In the climate where we conducted the research, each cubic foot of outdoor air delivered on a per minute basis (CFM) results in $3.50 to $7.00 of additional energy cost per year depending on utility rate and run hours. Therefore, if a space could moderately reduce its ventilation requirements by 4,000 CFM, the building owner/operator could save on the order of $20,000 per year. Building operators will realize paybacks in 7-17 months, and even shorter paybacks for new construction. For certain, climate influences paybacks; our climate is severe, considered a mixed-humid climate with hot, humid summers and cold, dry winters. Nevertheless, the opportunity to reduce outdoor air while delivering cleaner, healthier air exists and should be considered.

Air Quality Audit

To better understand the impact of air cleaning to a facility's energy use and bottom line, HVAC and/or energy engineers can be deployed to perform an air quality audit and make recommendations. The audit will likely include some ASHRAE or building code calculations for ventilation but may also include some air quality testing.

Conclusion

We sought to apply the principles of healthcare operating room air cleaning in a new way. This does appear to be suitable for several applications, especially in large open spaces with high occupant densities (i.e., auditoriums, gymnasiums with spectators). It has the ability to help protect building occupants from air contaminants that could be impactful on their health.

Nevertheless, costs for our retrofit solution were significant — at up to $5 per cfm — and there may be better ways to provide similar results with other technologies while driving down costs.

However, these costs are much more manageable when included in new construction or a major renovation. For example, the solution's cost would dramatically drop if deployed in an office tower with one air handler per floor, as a contractor could install the technology in the filter media section of the air handler. Or if the ventilation air is decoupled as a part of a dedicated outside air system (DOAS), the costs would also be significantly less.

Regardless, the technology does exhibit noticeable economics with short paybacks when used in climates requiring significant heating and/or cooling.

Finally, we see many risks to increasing outdoor air at the existing units unless the engineers designed the units to handle larger volumes of ventilation air. Without proper design and control, a building operator could inadvertently impair the system's capability to maintain humidity control and therefore undermine the system's ability to deliver clean, healthy, cost-effective air.

Overall, when implemented correctly, the use of this adapted technology is a solid way to improve building air quality without risk to system performance. We believe these benefits should also positively impact other building types with large volume space and low air changes. Examples include K-12 and higher education, big box retail, manufacturing, and food processing.

The research team thoroughly thanks the owners and principals of Nabholz Construction and Entegrity Consulting for their support of this research; without this the experiment would not have been possible.

Future Considerations

This research project only proves the feasibility of utilizing this technology in an open office environment with a narrow set of HVAC delivery options. To understand how it impacts other office scenarios, more research is needed. Following are several topics that investigators could use to build off this research:

- Recirculation of building air (resulting in higher air changes) vs. inclusion of outdoor air (interception of OA particulate)
- Impacts on walled spaces
- Impact of variable air volume where OA is delivered via main air handler (no DOAS)
- How to reduce costs in a retrofit scenario
- Effects of technology on other building types

References

1. Yan, J., Grantham, M., Pantelic, J., Bueno de Mesquita, PJ, Albert, B., Liu, F., Ehrman, S., Milton, DK, & EMIT Consortium. (2017). Infection virus in exhaled breath of symptomatic seasonal influenza cases from a community college. *Proceedings of the National Academy of Sciences of the United States of America (PNAS)*. 115 (5), pp. 1081-1086. https://www.pnas.org/content/115/5/1081
2. SecureAire Case Study: Lake Tahoe Surgery Center [Zypher Cove, NV]
3. *Beall, R. & Entek Consulting Group. UC Davis Final Report, (2020)*
4. Ereth, MH, Hess, DH, Driscoll, A., Hernandez, M., & Stamatatos, F. (2019). Particle control reduces fine and ultrafine particles greater than HEPA filtration in live operating rooms and kills biological warfare surrogate. *American Journal of Infection Control.* Vol. 48, Issue 7, pp. 777-780. https://www.ajicjournal.org/article/S0196-6553(19)30983-6/pdf
5. SecureAire Case Study: University of California San Francisco (UCSF) [654 Minnesota Street, San Francisco, CA]
6. SecureAire Case Study: IBM Corporation, A LEED IAQ Certification Study [Foster, CA]
7. SecureAire Case Study: The Art Institute of Chicago [Chicago, IL]
8. SecureAire Case Study: CannaCraft: A Leading Colorado Grow Facility (2019)