COMPREHENSIVE VENTILATION MANAGEMENT FOR SAFETY AND SUSTAINABILITY

Defending against even a simple airborne attack may require a complex ventilation safety plan — or at the least, a well thought-out strategy. Sensor capabilities, sensor placement, response speed, and the general ventilation system are some of the factors that play into protecting occupants (and even property) in the case of something worse than an accident.

BY LARRY CLARK, LEED® AP

Advanced ventilation strategies like demand-controlled ventilation (DCV) have gained significant traction over the past several years[1,2]. As with any ventilation approach, indoor environmental quality (IEQ) regarding both safety and comfort are major considerations in the implementation of this type of technology. Although the resulting savings from avoided energy consumption can be significant, depending on the type of building, its geographical location and the type of DCV, (such as multiparameter DCV)[3], the economic considerations must always be incidental to safety.

These strategies, then, are designed to provide safe and code-compliant ventilation (generally to ASHRAE 62.1, although other standards may apply in specialized facilities such as laboratories and vivaria) during the usual and customary operations specific to the facility and when unplanned pollution events occur. These events are likely to occur as a result of accidents caused by human error (e.g., drops or spills) or equipment failure (e.g., leaks or fugitive emissions).

It is generally assumed that these pollution events are truly the result of accidents; that is, they are consequences of unintentional actions by trusted employees or visitors. What these strategies do not generally address is an intentional event, such as an airborne chemical, biological, radiological, or nuclear (CBRN) attack by terrorist or criminal elements. As this article will attempt to explain, those types of threats are best addressed by a somewhat different technological and strategic approach. However, there is no reason to not combine the best of both approaches into a comprehensive system.

TARGETS DEFINED

First, what types of buildings are particularly vulnerable to an intentional terrorist or criminal attack? According to the New York City Police Department[4], some of the characteristics of higher risk buildings include architectural design that is nationally recognizable; a location adjacent to other high-risk buildings; the absence of screening and control of vehicular traffic approaching the building; height (multi-story structures in which most occupants depend on elevators to reach their destinations)[5]; high occupant densities; local, regional, or national economic significance; located atop five or more sets of rail lines or a vehicular tunnel, or adjacent to the footprint of a significant transportation hub servicing five or more sets of rail lines or the entrance to a bridge, so that a successful attack on the critical infrastructure would severely disrupt service.

Assessing the threat to a particular building is not based solely on its physical characteristics. It is also influenced by the nature of activities and materials used within the building. For example, buildings that store or use — or are in close proximity to buildings that store or use —significant quantities of potentially harmful chemical, radiological, and/or biological materials are at increased risk[6].

STRATEGIES

Obviously, any advanced ventilation strategy — one that is to be both effective and energy efficient — requires a relatively sophisticated HVAC system. For example, to implement multiparameter DCV, fixed outside air dampers would need to be replaced with modulating dampers. The building's HVAC system is also often the first line of defense in an intentional airborne attack utilizing chemical, biological, or radiological materials[7].

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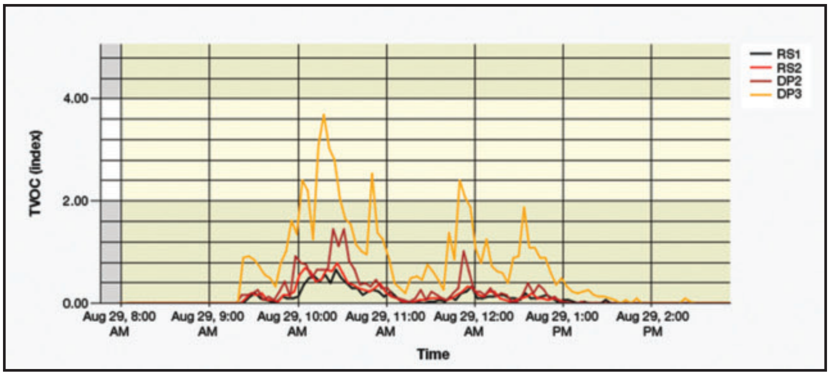

FIGURE 1. Total VOCs in an actual laboratory environment (Courtesy of Aircuity, Inc.)

In the event of an accident, something as innocuous as a volatile organic compounds (VOC) release caused by a minor alcohol spill during the repair of a DNA extractor in a university research lab can affect the IEQ, shown as DP3 in the total VOC graph (Figure 1). With a DCV system capable of sensing VOCs, the fresh air ventilation rate can be increased to a level adequate to clear the space in a reasonable period of time. DCV systems will generally have sensor locations, either discrete sensors or air sampling points, in a majority of the regularly occupied spaces.

In the event of a terrorist attack, the strategy is quite different: to quickly isolate the building's ventilation system from the external airborne threat. This requires a sensor array network, strategically located in the HVAC outside air intake and/or supply and return air ducts, that will detect the airborne toxin or radionuclide in milliseconds and direct the BMS to immediately shut down the air distribution system. It is reasonable to assume that an intentional toxic release will be accomplished quickly, in order to minimize the chance of detection before the maximum damage had been done. In an unprotected building, the toxins can spread through the HVAC distribution system very quickly. If we assume an office building with an average ventilation rate of only 4 ach, then the building's indoor air could be fully compromised in 15 min.

1 hr x 60 min/hr / 4 ach = 1 air change / 15 min

If the ach is increased to 10, which would not be unreasonable in a courtroom, for example, then the toxin could be completely circulated in only 6 min.

1 hr x 60 min/hr / 10 ach = 1 air change /6 min

In Figure 2, we see that immediately shutting down the HVAC system can reduce peak toxin concentrations by >70% when compared to only 1 ach. After two hours, the total indoor exposure is still less than half of what would have occurred during that 1 ach "normal" operation[8].

DEFINING POLLUTANTS

So now that we have identified some candidate buildings and defined a general strategy for the two types of ventilation management, we should examine the characteristics of the hardware (and supporting software) itself. First, of course, are the sensors.

For the multiparameter DCV system, we must initially define the pollutants to be detected. It has long been recognized that CO_2 levels correlate with human metabolic activity and are, therefore, a reliable surrogate for the level of indoor pollution emitted by humans.

In a conventional DCV strategy, CO_2 is used as a proxy for all of the human bioeffluents that may be present in the space. It is, therefore, representative of both the number and activity levels of the occupants and can be used to modulate the outside air ventilation rate to maintain a constant CO_2 concentration differential relative to the outside air CO_2 background level. Since those outside air CO_2 levels are not constant, the ventilation control must be capable of continuously modulating the ventilation rate in the space. Figure 3 illustrates typical outside air CO_2 levels over a 24-hr period. Most good commercial (and laboratory) grade CO_2 sensors employ non-dispersive infrared technology. As with any light source, accuracy varies; however, ±75 ppm is not unusual.

Common non-human pollutants to be detected include total (non-speciated) VOCs, such as those typically found in paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment such as copiers and printers, graphics and craft materials including glues and adhesives, permanent markers, and stored fuels and automotive products; respirable fraction particles in the diameter range of ≤ 2.5 µm (PM 2.5),

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which are constituents of fine-particle aersols and, as such, have long been recognized as a primary transmission mode for infection; and CO, since concentations above 35 ppm can produce symptoms in humans and may be fatal in concentrations of 3,200 ppm (the current OSHA permissible exposure limit (PEL) for CO is 50 ppm[9].

VOC sensors for these applications are generally metal oxide semiconductor (MOS), photoionization detector (PID), or a combination of both. The PID has a higher accuracy and resolution over a smaller calibrated range. Particle monitoring may be accomplished by means of optical (laser) particle counters, and CO detectors commonly employ electrochemical sensors. A common characteristic of all of these DCV sensors is the need for a reasonable degree of accuracy and stability. The recommended interval for accuracy verification — and any required calibration — for DCV sensors is frequently six months[10].

Sensors for protection against targeted airborne attack, on the other hand, must be capable of detecting a broad spectrum of chemical or biological toxins, or radiological hazards, in a very short time period. They must be reliable and robust enough for commercial service, using validated algorithms to ensure a confidence level of >99.5% in eliminating false positive responses. These sensors must also be reversible, with a consistent recovery time after exposure to detected substances, and should be self-calibrating for temperature and signal drift.

In addition to chemical agents (CA) — those chemical substances intended to be used as weapons to kill or cause serious injury to humans, such as Sarin or so-called "mustard gas" — there is a more immediate and obvious threat from the toxic industrial chemicals (TICs) identified by the Centers for Disease Control (and other federal agencies) as being "most likely" to pose an exposure threat.

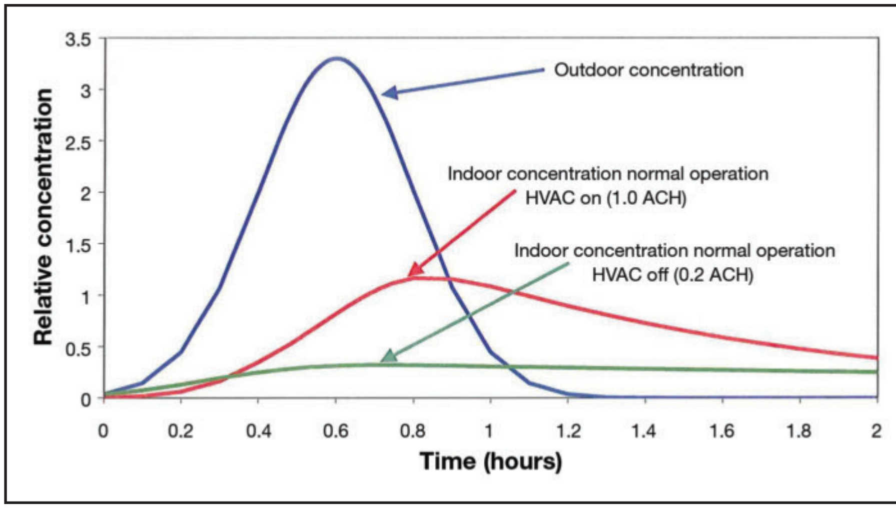

FIGURE 2. Effects of air change rate on indoor air toxin concentrations.

In this application, a typical chemical sensor array must be capable of detecting those substances. These sensor arrays should incorporate N+1 redundant design and may utilize various technologies, including conductive polymer, MOS, bulk acoustic wave (BAW), and surface acoustic wave (SAW)[11]. Toxic chemical attacks against a building could be external or internal. For example, an external threat scenario might involve the dispersion of a common industrial product such as chlorine gas (Cl2) into the fresh air intakes, while an internal threat scenario could be the release of arsine (AsH3), another highly toxic gas that is a simple arsenic compound, in the center of the building.

In order to protect against both of those threats, chemical sensor arrays would need to be located in both the outside air intake and the return air plenum and, upon detecting a threat, would immedi-

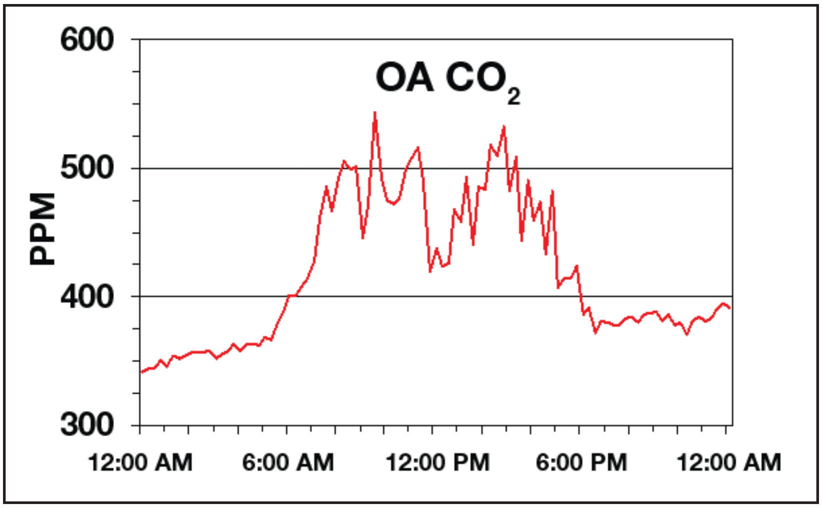

FIGURE 3. Typical outside air CO_2 over a 24-hour period.

ately direct the shutdown of the building's air circulation system and initiate the appropriate emergency response protocol.

Radiological sensors are intended to protect the building's occupants and assets against exposure to airborne radioactive materials. To adequately protect against that type of threat, the sensors should have a mature isotope library (100 to150 isotopes) with both shielded and non-shielded variations (the sensor should eliminate Beta emitters to limit shielding), should be capable of indicating the specific isotope category (e.g., medical or industrial) and should identify the specific mix of isotopes and generate both a spectral header file (for reach back protocol) and a simple life sciences file. Most sensors of this type will be stabilized with a long-lived isotope, such as Potassium-40 (40K), to allow automatic adjustment for background.

A radiological/nuclear threat scenario might involve the detonation of a "dirty" bomb in the central business district of a metropolitan area. According to Phil Anderson, now senior associate (non-resident) with the International Security Program at the Center for Strategic and International Studies, Cesium-137 (137Cs) is the most likely radioactive element in a dirty bomb[12]. It is considered one of the most dangerous radioisotopes to the environment, in terms of long-term effects, with a half-life of approximately 30 years. And it is readily available to terrorist and criminal elements. There are more than two million point sources of Cesium-137 in the U.S., in a variety of medical and industrial applications. In addition to perhaps its best-known use — in the atomic clock known as NIST-F1, the nation's primary time and frequency standard — Cesium-137 is widely used in the treatment of cancer and is used in industrial radiography for the control of welds; in liquid scintillation spectrometers and other instruments; and in industrial irradiators to sterilize medical products, meat, fresh vegetables, and other foodstuffs.

A single cylinder of Cesium-137 material, small enough to fit into a computer case, could have 25 gigabecquerels (GBq) — equivalent to approximately 0.68 curie (Ci) — of radioactivity. In this scenario, as soon as the plume cloud comes into contact with the radiological sensor located in the outside air intake, the building's air circulation would, as in the other scenarios, be immediately shut down and emergency response protocols initiated. This would substantially mitigate the exposure to building occupants of radioactive material and could literally ensure the survival of the building itself.

Clearly, in any ventilation strategy, safety must always be the primary driver. But comfort and sustainability should also be considered. Fortunately, advances in commercially available ventilation technologies — as in the instant example of combining multiparameter DCV, whose economics through avoided energy consumption have been well demonstrated, with state-of-the-art airborne toxin detection — have now made it possible to ensure a safe and sustainable IEQ for buildings. **ES**

Clark is the principal of Sustainable Performance Solutions LLC, a South Florida-based firm providing energy audits, general energy efficiency and sustainability consulting services for nonresidential buildings and advanced ventilation strategies for facilities with critical indoor environmental quality requirements. He previously served as director of corporate business development at Hill York, was actively engaged with its Hygreen Energy Solutions group since its launch in 2008, and continues to assist them on a part-time basis. He is the author of more than a dozen HVAC- and energy-related articles and afrequent presenter and lecturer on metering and sub-metering and advanced ventilation strategies. He is a member of various professional organizations including ASHRAE, IEEE, and USGBC South Florida, and serves on the BOMA Florida Energy Committee.

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