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Ecolibrium

ANNUAL AIRAH AWARDS SPECIAL

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Different wavelengths

Can ultraviolet light help limit the spread of COVID-19? Ecolibrium assembled a panel with diverse opinions to discuss UV-c technology in HVAC systems. Our panel members are **Andrew Watson, Patrick Chambers, Affil.AIRAH, Dion M Froes, M. AIRAH, Daniel McCaffrey M.AIRAH**, and **Scott Summerville, M. AIRAH.**

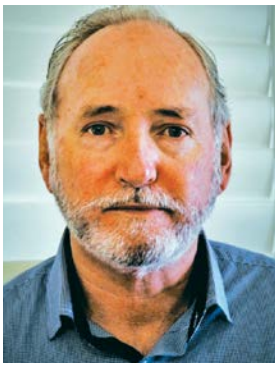
Danny Chan reports.

This roundtable is part one of a two-part series.

Andrew Watson, CBE director

Patrick Chambers, Affil.AIRAH, Stantec associate mechanical project engineer

Dion M Froes, M.AIRAH, chair and general manager of ecoHVAC



Daniel McCaffrey, M.AIRAH, AFPRO Australia

Scott Summerville, M.AIRAH, managing director of Opira and of Air Restore, and a director of Labstar

Mounting concerns surrounding the airborne transmission of SARS-CoV-2 have contributed to a renewed interest in ultraviolet germicidal irradiation (UVGI). UVGI is an established means of disinfection that can be used to effectively inactivate airborne microbes that transmit tuberculosis, measles and SARS-CoV-1, a close relative of the novel coronavirus.

Since the pandemic, this century-old technology, known alternatively as GUV or UV-c, has received the kind of attention usually reserved for a novel method or device.

Some within the built environment industry have also been mulling over the deployment of germicidal UV HVAC systems as an additional measure to curb infection risks.

UNDERAPPRECIATED OR UNTESTED?

Applications include placing UV-c lamp devices and systems in air-handling systems and in room settings for air and surface disinfection; and installing upper-room devices to control bioaerosols – for example, suspended bacteria and viruses contained in droplet nuclei. The solutions can take various forms, from on-coil HVAC UV air-handling systems to in-duct UV-c fixtures, to operating room UV packages.

Depending on who you ask, the disinfection solution is either under-appreciated or yet to be tested in terms of safety and real-world applications.

The shorter wavelength of the UV-c (between 280nm to 200nm) has been touted as having the most germicidal effect, due to its narrow band in the light spectrum covering what is known as the optimal wavelength (265nm) for inactivating microorganisms. Some believe its non-touch, non-chemical and low-maintenance attributes make it the choice weapon against viruses in high-risk indoor settings. Then there are those who would question its role as a front-line device, pointing out the dangers of direct exposure to humans or its premature use in continuous air disinfection.

A CLEAN START

Most would agree that germicidal UV has years of proven efficacy in medical sanitation and sterile work facilities. These are sectors where it has found some acceptance as a supplemental – not standalone – cleaning measure since the mid-20th century.

The HVAC stakeholders we spoke to for this Q&A article were chosen for their varied expertise in UVGI products and involvement in the infection control and indoor air quality of medical and clean room environments.

Not only are the "clean" stakes much higher in these facilities, but they will also likely set the benchmark for implementation of UV-c technology in Australian buildings – which is still in its infancy.

Commercial buildings are considered a vital line of defence in fighting the spread of coronavirus.

Q: Are there cost-benefits of incorporating germicidal ultraviolet light (UV-c) technology in HVAC systems?

Dion Froes: In the Australian market, the "cost-benefits" equation is really only valid when UV-c is used in an "on-coil" situation and the UV-c lamps are incorporated in the AHU/FCU to ensure the coil remains clean. ROI is typically 12 months, which is when the normal coil clean would be performed.

Keeping coils clean with UV-c not only reduces (possibly eliminates) the need for manual coil cleaning, but also preserves the efficiency of the AHU as designed by preventing clogged and thermally inefficient coils, thus the blower doesn't have to work harder to move air through the coil, extending useful system life. It must be noted that UV-c does not replace filtration.

Patrick Chambers: The true cost-benefits of UV-c need to consider the economics of indoor air quality. The application of UV-c in HVAC systems can provide benefits relating to enhanced air quality (by virtue of reduced pathogens and colony-forming units), and to minimise the maintenance burden associated with microbial build-up inside HVAC systems. The latter example has clear and measurable fiscal benefits, and we have seen examples in the healthcare sector where clients have indicated that maintenance costs relating to coil cleaning and ductwork cleaning have dropped significantly due to the installation of on-coil UV-c technology.

In the instance of providing enhanced air quality, this is very difficult to measure, as generally speaking, the economics of clean air inside buildings is multi-faceted and an evolving space of research.

Andrew Watson: There may be an energy benefit in the lowered cost of running the UV-c versus pushing air through a filter. However, the full cost of a UV-c may vary according to the application.

The decision would need to be made whether it is a "front-line device" (primary contamination control) or as an "add on" or "nice to have". If it is a front-line device you would need to add the cost of testing on installation, alarm device in case of unit failure and yearly tube replacement and re-testing. However, if it is a front-line device, why wouldn't you just use a HEPA filter?

> If it is a front-line device, why wouldn't you just use a HEPA filter?

A HEPA filter is a common device that can be tested to a NATA-accredited procedure on installation and regular recertification. If installed in a well-designed system, it should provide high level (almost absolute) protection for 10 to 15 years.

Daniel McCaffrey: Purchase/installation/maintenance/replacement costs would need to be compared with disinfection protocols already in play with legacy systems.

Scott Summerville: A lot more studies need to be conducted on the costs and benefits. There will be plenty of similar data coming out over the next few years as we are seeing a greater uptake in UV-c in in-duct systems due to the coronavirus.

Looking at hospital-acquired infections where Victoria had hundreds and more than a thousand in isolation at times and the growing evidence of aerosol transmissions, it also seems negligent not to spend the money on this type of air disinfection. If in-duct air disinfection can save one life or prevent an ICU bed being occupied for a week, you would think that the benefits far outweigh the costs.

In relation to the coil disinfection systems, these are now quite commonplace and gaining more acceptance due to higher uptake, particularly in the healthcare space. We are finding these projects are predominantly being pushed by hospital maintenance staff with a five-plus year experience looking after plants with UV-c systems. They see first-hand that the coils don't require cleaning, and understand there is a benefit from reduced pressure drop and better heat transfer.

Q: Why isn't it more commonly done?

DF: Unfortunately, within the Australian market, projects are normally tendered aggressively and "lowest cost solutions" are normally considered. The initial capital cost of UV-c is removed to make the bid more "cost-effective" without taking the benefits of UV-c into account.

It is not uncommon to see specification text stating "provision for UV-c lamps" within the AHU, but this can be interpreted as "only make provision for", but not actually installed.

PC: The mainstreaming of any technology is inherently multifaceted, particularly so for emerging products in the construction industry. Generally speaking, the industry is very risk-averse, and so the application of new technologies unfortunately takes time to gain market confidence and manifest into normal industry practice.

In addition, another intrinsic issue relates to the increased capital costs, for which developers often do not see the returns.

We have only found UV-c technology to be a mainstream requirement in public hospitals, where the asset owners do see returns due to reduced maintenance costs over the life of the product.

I would like to think that with the increased focus on the importance of clean air inside buildings, and increased awareness of the merits of UV technology, that it starts to become a private-sector request.

DM: New technology does take time to be properly assessed and justified by end-users.

Q: What are the differences in terms of efficacy and cost-benefits between coil-mounted versus duct-mounted UV fixtures?

DF: While both the on-coil UV-c and in-duct UV-c use the same lamps and technology, they are implemented very differently.

The main purpose of on-coil is to treat the coils with UV-c to ensure that they remain clean. Air passing over these lamps will be treated, but the UV-c exposure the airflow will receive would be minimal.

An in-duct UV-c system is normally selected to ensure that all the airflow is treated and within a suitable time period. Ideally in-duct should be selected for single-pass UV-c sterilisation. This can be achieved within an AHU as well, but a correct selection of the UVC system would need to be carried out by the UV-c manufacturer.

PC: Coil-mounted applications typically involve the installation of UV ballasts within the AHU, with the intention of keeping the inside of the AHU and coils clean. We have seen particular effectiveness of this application of the technology. For best results, we recommend ensuring the ballasts are complete with reflectors, which focus the light on to the coil.

We also recommend where possible installation on the wet side of the cooling coil, as it is within the damp environment where microbiological growth flourishes. In retrofit situations, consideration needs to be given for impact to non-UV-stabilised AHU internals, and appropriate automatic switch-off when doors open. I also highly recommend fitting of a viewing port hole.

Duct-mounted UV fixtures are less common – but increasing in popularity due to coronavirus concerns – and are installed longitudinally within ductwork, parallel with direction of airflow. If being used to target infectious pathogens and aerosols, we recommend installation within return air ductwork, as outside air should itself be free of infectious aerosols.

DM: The correct application of AHU placed UV-c/UVGI will address biological/viral matter on heat transfer coils but will not clean them – that is a function of air filters – however, UV-c/UVGI will "disinfect"' any dust penetration of air filters, that settles on the surface of the coils that is in "direct sight" of the UV-c/UVGI source. Surfaces lying in "shadows" of the UV-c/UVGI source are not addressed. This will potentially occur within the fabric of air filters, in heat transfer coils and within the internals of ductwork, so it cannot be regarded as a single-step measure to eliminate the risk of viral or organic matter transmission, via the air handling system.

SS: With a coil you don't need anywhere near the amount required for ultraviolet light fixtures. The coil is in a fixed position and is not going anywhere. Therefore, the UV can just keep treating anything on the coil or any particle that lands on it. Moulds are a lot harder to kill than viruses. Moulds such as *Aspergillus Niger*, which are common on cooling coils, are difficult to kill but the exposure time is great because the coil is in a fixed position.

Coil UV systems are not effective at removing airborne viruses, bacteria and moulds because the tubes are located perpendicular to the air-flow and therefore the dwell time is not sufficient to break the DNA and prevent replication. Certainly, one could argue that if the coil is a major source of biological contaminants, which we know it is, then treating this source will also prevent the spread of these contaminants throughout the building. This does not guarantee that mould-growth issues in a building will not occur, as it is line-of-sight technology. If you have moisture and high humidity and a food source you will get mould growth in the building.

In-duct UV systems need to be sized to ensure the target organism will be treated. And the engineering needs to consider air speed across the tubes and number of ACH rates for the HVAC system. It can be engineered so that certain biological contaminants can be killed with a "log six kill" on the first pass for many common viruses such as TB, measles, coronavirus, etc. This technology would be considered far too expensive for treating moulds alone.

The cost benefit needs to consider what you are actually trying to kill and whether it is in air or on a surface.

Q: What are the determining factors for HVAC businesses to embrace UV technology in a big way?

DF: UV-c technology has been around for many years and extensively used and accepted within the North American market. The Australian market has adopted the technology but unfortunately not yet to the extent of the US market.

With COVID-19 presenting itself, suddenly UV-c has become this "new" wonderful technology that can assist in eliminating viruses and bacteria. The issue is UV-c has many variants, and I believe is not regulated within Australia, so it allows any supplier to stretch the truth. The IUVA (International Ultraviolet Association) is a good source of independent information and should be considered.

PC: Mainstream application needs to be preceded by consumer demand. Once there is a market demand for the technology, engineers will specify the products. The key to getting consumer confidence in the technology is more research by independent bodies, and acknowledgement from industry professional institutions.

DM: HVAC businesses require confidence that any equipment offered can have a demonstrable capital benefit to both their client and their business.

SS: The factors include:

- Happy clients, as there will be less temperature complaints when mould builds up on coils affecting airflow and heat transfer, and less IAQ and odour complaints related to contaminated coils
- Happier staff, as they don't need to keep high-pressure cleaning blocked coils, which is a very messy and dirty job
- Realisation of the life-saving benefits of in-duct systems
- Commercial business clients looking for solutions so that

people feel safe in their buildings. They should see appropriately designed UV technologies as an opportunity for business growth in very uncertain times.

Q: How likely is mainstream UV adoption?

DF: It certainly is being more and more widely accepted. As more and more end-users are utilising the technology, they are seeing the benefits very quickly.

PC: I believe the industry is in the midst of a transformative period in which the entrenched methods of maintaining air quality in buildings such that it is "safe" for occupants, is being challenged by a different paradigm: that we should be maintaining air quality in buildings such that it is "healthy" for occupants. This is happening slowly, but the outcome will be higher monetary value placed on air quality, which I would think will drive the adoption of technologies such as UV.

DM: This technology does have mainstream technical acceptance from industry advisory groups such as ASHRAE, REHVA, CIBSE, Eurovent, AREMA and AIRAH. It will be a matter of proven benefit and case studies/examples of cost/efficacy benefits of careful selection of equipment to application that leads to mainstream acceptance.

Q: Is the UV-c incorporated HVAC system good or bad news for HVAC maintenance and servicing?

DF: UVC on-coil is good news, as it keeps the coil clean. However, UVC lamps have a lifespan and will need to be replaced. The lamp life does vary between manufacturers, but still needs to be replaced. The issue is the lamp will continue to light up with blue light, even when it is no longer generating UV-c.

PC: Good news for asset owners – potentially bad news for HVAC hygiene contractors! In our experience, particularly with on-coil applications, microbiological growth within air handling units significantly reduced after the installation of UV-c technology.

AW: Based on the level of maintenance I see at many critical installations such as hospitals – particularly with specific devices such as humidifiers – I would expect that even if an effective and qualifiable device could be made available, its effectiveness would be cut short by poor maintenance. This, however, should not be used as an excuse not to pursue the technology.

DM: HVAC businesses require confidence that any equipment offered can have a demonstrable capital benefit to both their client and their business. A judgement that the adoption and promotion of this technology, within their portfolios, will be good news for their business is based on that assessment. Those that choose not to will unlikely be affected, as the technology is not likely to be detrimental to their core business operations.

Q: UV is being used to decontaminate surfaces in hospitals and public transport systems. Can the technology be relied upon to provide continuous air disinfection?

DF: There are several different options available on the market; however, one must remember that prolonged, direct exposure to UV-c light can cause temporary skin redness and eye irritation, but it does not cause skin cancer or cataracts. Continuous air disinfection can best be described by upper-air irradiation, which has been successfully used worldwide for decades controlling the spread of airborne tuberculosis, and these technologies are available.

PC: Jury is out on this one. Generally speaking, it is known that UV exposure can be harmful to biological cells, causing skin/eye irritation and potentially melanoma. Any continuous air disinfection strategy needs to be mindful of exposure to humans and animals alike. There is, however, emerging research regarding certain wavelengths of UV light (specifically 222nm) which in laboratory experiments are showing not to be harmful to mammalian skin. Such a technology could potentially be used for continuous air disinfection. However, my personal opinion is given the risks associated with this, this specific application of the technology requires considerably more research and development.

AW: Considering the current technology, no. Upper air irradiation devices would not see the level of contamination found at 1m above the floor and below, which is where most of the contamination resides. For moveable devices, you need to get proper right angle or near-right-angle exposure on a surface for the device to be properly effective.

As a secondary or tertiary device, it probably does little harm.
As a "front line device", I am sceptical of the claims that many of these devices are making, and would hesitate to use these devices for critical installations.

DM: It will be a matter of proven benefit and case studies/examples of cost/efficacy benefits of careful selection of equipment to application.

SS: Treating surfaces and air are very different when using UV-c. Surfaces can be treated but the technology is limited by line of sight and it is also hazardous, so it cannot be used to treat surfaces while people are present.

As the wavelength of 254nm is very dangerous, the technology requires additional safeguards such as door switches, safety lockouts and occupancy sensor to ensure zero human interaction.

In relation to continuous air disinfection, the answer is yes but the particle has to pass through the UV-c light source. If it does not, then it will not be disinfected. While UV-c disinfects air, it cannot be used to stop person-to-person transmission.

Everything needs diligent engineering. More effort should be put into systems and procedures that keep infected people out of public buildings. Of course, this not possible for hospitals.

Q: How does light intensity and exposure time affect UV-c application?

DF: The key to UV-c is the wavelength, the lamp intensity and the time. Time x Intensity = dose, but the industry now prefers the term "fluence" (UV dose). Germicidal UV-c should produce a peak output at a wavelength of 253.7nm. Calculating UV-c "dose or fluence" is a factor of time x intensity. It depends on the "log reduction" or "kill factor" required, as well as on the intensity required.

Depending on what we are tying to sterilise, clean or disinfect, there will be a length of time of UV-c exposure. For example, if you wanted to ensure sufficient UV-c exposure to "kill" or deactivate the COVID-19 virus within a duct system, a reputable UV-c manufacturer should be able to calculate the intensity required for the duct size, airflows, and air temperature to ensure 3-log (99.9%) within a single pass.

PC: The simplest way to think about it is via dimensional analysis. It requires a certain amount of energy (joules) to break a molecular bond and disrupt a pathogen. Intensity is a function of power (Watts) per unit area (m^2), which when multiplied by time (s) and an exposed surface (m^2) results in Watts-seconds, which is a joule. Simply put: "intensity" x "area of exposure" x "time" equates to how effectively UV can neutralise pathogens. If you increase any of these parameters, you will increase the performance.

This is why it is also equally important to consider wavelength of the UV ballast, as different wavelengths start with a different photon intensity/energy, based on Planck's equation.

SS: For continuous air disinfection it is important to understand that every contaminant has certain UV susceptibility and it takes different amounts of time and energy to damage DNA or break chemical bonds.
The success of any UV installation depends on the UV dose applied on an organism over a certain period of time. Dr Wladyslaw Kowalski published a UVGI handbook, UVGI Air and Surface Disinfection, where he specified UV susceptibility of most known organisms.

UV-c photons at 254nm wavelength carry 470 kj/mol of energy. This so-called germicidal UV is capable of damaging DNA of a living organism if applied for a correct period of time.

Knowing the target organism and its UV susceptibility, we can calculate the dose of UV and time required to damage its DNA to inhibit reproduction. If the exposure time is insufficient, DNA of the organism will not get damaged and the organism will continue reproduction.

If we are talking about HVAC in-duct air disinfection we need to take into account air duct height and width, or diameter, air velocity and what organism we want to inactivate, whether it is SARS CoV-2, influenza A, TB or anything else.

For maximum exposure, UV lamps should be installed parallel to the airflow. This will give us the best chance of delivering a right dose of UV. As the air passes over the lamps the contaminants will get more exposure time. The length of the lamps will be determined by air velocity, duct size and target organism.

It is important to understand that coil-cleaning UV doesn't disinfect the air. What we need to understand here is that coil-cleaning UV is installed in front of or behind the cooling coil perpendicular to the airflow and is designed to disinfect a surface that doesn't move. As the air passes over the lamps at 2.5m/s there is not enough exposure time for UV dose to be delivered, and most of the contaminants will pass through with no to minimal damage.

Would you like to know more?

Look for Part 2 of this feature in early 2021.