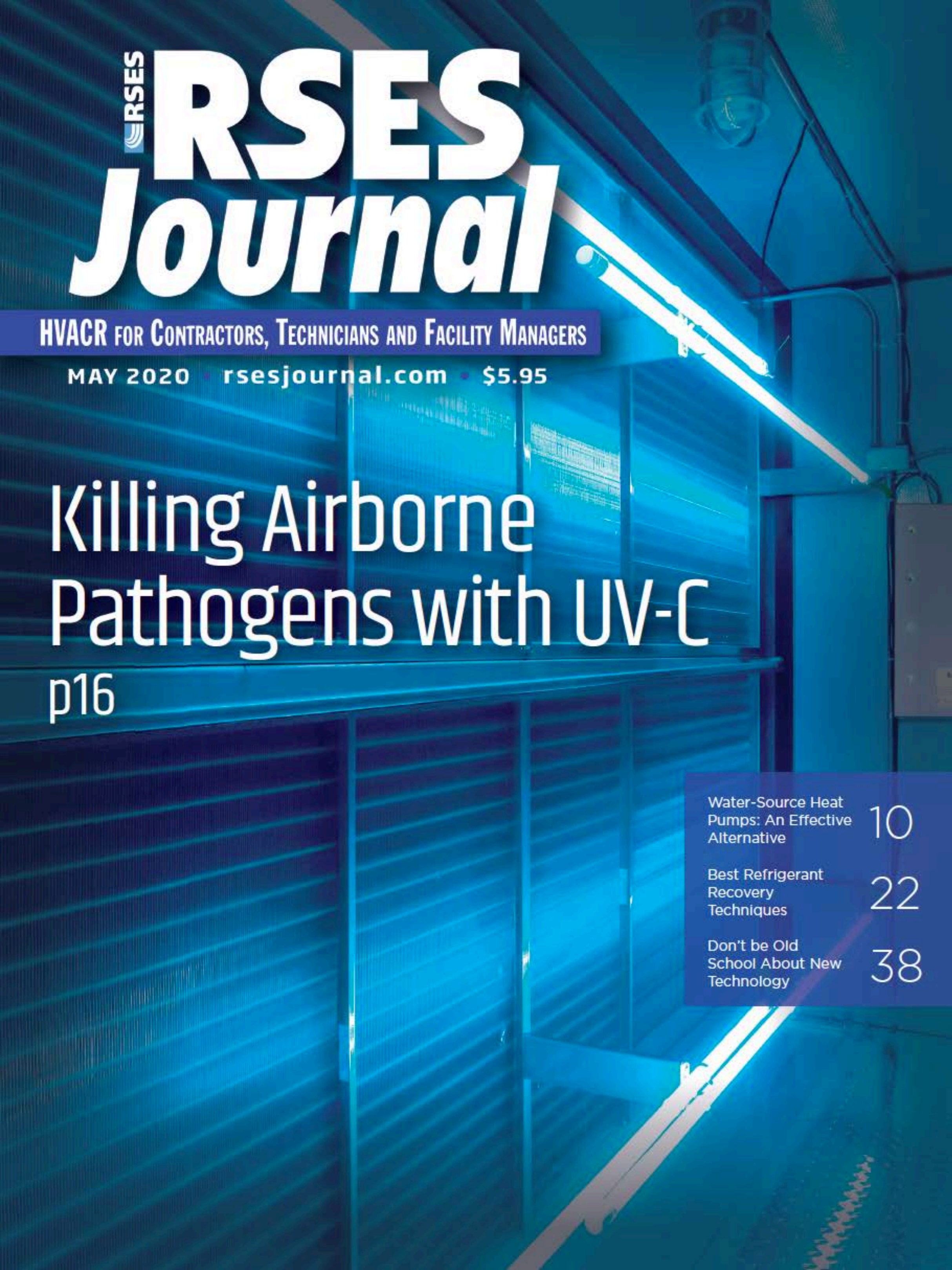

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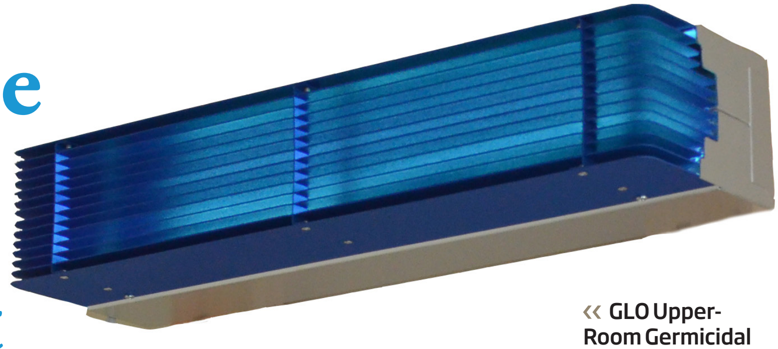
Killing Airborne Pathogens with UV-C
p16

Killing Airborne Pathogens *with* Ultraviolet Germicidal Irradiation



« GLO Upper-Room Germicidal Fixture.

Limit the spread of contagious diseases and bacteria where people congregate.

BY DANIEL JONES

Like other infectious disease outbreaks, the COVID-19 pandemic has renewed the search for ways to reduce contagious airborne pathogens. Although everyone is using the shorthand, "Coronavirus," to discuss the current outbreak, coronaviruses are actually a category of viruses that range from the common cold to more severe diseases, such as the 2003 Severe Acute Respiratory Syndrome (SARS) and the 2012 Middle East Respiratory Syndrome (MERS).[1] Although Ultraviolet Germicidal Irradiation (UVGI or UV-C) is effective in killing other varieties of coronaviruses, such as SARS and MERS, scientists do not yet know about the impact of UV-C on COVID-19.

Scientists are learning more about this virus every day and authorities currently believe that COVID-19 is stable for several hours to days in aerosols and on surfaces.[2] In late March, the Centers for Disease Control and Prevention (CDC) said that genetic traces of the COVID-19 virus were found on surfaces of the Princess Cruise ship 17 days after passengers disembarked.[3]

Killing Airborne Pathogens

Certainly, using the germicidal UV-C waveform (253.7 nm) for disinfection is not a new application. In 1877, researchers in the journal Nature described how sunlight prohibited the growth of microorganisms. Since the 1940s, many hospitals have relied upon germicidal UV-C energy to control airborne infectious diseases, but use waned with the arrival and proliferation of antibiotics.

In the 1990s, demand for the technology returned following a resurgence of drug-resistant infectious microorganisms, as germicidal UV-C technology kills airborne pathogens regardless of their antibiotic-resistance. In other words, there is no way for microbes to develop a resistance to germicidal UV-C, and there are no harmful side effects as a result of its proper use.

It is important to note that science has not found any microorganism that can withstand the destructive effects of the UV-C germicidal wavelength, including superbugs and other antibiotic-resistant germs. All bacteria and viruses tested to date (many hundreds over the years, including other coronaviruses) respond to UV disinfection—as noted above, some are more susceptible, but all tested so far do respond at the appropriate doses.[4] ASHRAE, too, has recognized that the UV-C wavelength inactivates virtually all microorganisms living on HVACR surfaces with a kill ratio of 90% or higher, depending on UV-C intensity and length of exposure.[5]

In fact, the CDC's Healthcare Infection Control Practices Advisory Committee found that ultraviolet energy helps to control disease transmission: "As a supplemental air-cleaning measure, UVGI is effective in reducing the transmission of airborne bacterial and viral infections in hospitals, military housing and classrooms."[6]

Three Methods of Applying UV-C Energy

Following are three primary means of applying UV-C for air and HVAC surface protection against infectious agents.

The first method, **Upper-Room/Air systems** work by interrupting the transmission of airborne infectious diseases in high traffic communal areas. Immunocompromised and contagious individuals in emergency room waiting areas, urgent care facilities, doctors' offices or senior living centers increase the potential for community spread by positioning potentially undiagnosed/untreated patients near others. The Upper-Room UV-C fixtures utilize the natural rise-and-fall of convection or mechanical air currents to lift airborne infectious agents into the upper room where they are exposed to UV-C irradiation and killed.

A standard waiting room with a UV fixture.

Science has not found any microorganism that can withstand the destructive effects of the UV-C germicidal wavelength, including superbugs and other antibiotic-resistant germs.

Operating 24/7/365, Upper-Room germicidal fixtures can inactivate microbes in under a second, including measles, mumps, TB, and cold viruses. These fixtures are wall-mounted above 7-ft. and use baffles to direct the UV-C energy upward and outward ensuring that no UV-C energy enters the occupied portion of the room. Kill ratios of up to 99.9% on a first-pass basis have been modeled and concentrations are further reduced by each subsequent pass of recirculated air ("multiple dosing"). The goal, relative to coverage, is to maintain UV-C irradiance levels at a minimum of 50 microwatts per square centimeter ($\mu W/cm^2$).

The second method uses **HVAC air-stream-disinfection systems**. UV-C air disinfection systems are installed in-duct in air-handling units or air distribution systems to inactivate microorganisms and disinfect moving airstreams "on-the-fly." UV-C exposure and the resulting dosage is determined by the quantity of germicidal energy absorbed by a pathogen over a specific period of time, i.e., disinfection is a function of the time and UV-C intensity a microbe is exposed to UV-C energy, and that microbes' specific susceptibility to UV-C. While that may sound "easy," there are many operational conditions that will change this equation.

These factors include the target pathogen and its susceptibility to UV-C; the amount of airflow (volume and velocity); the air temperature and RH; the length of exposure time (duct length); and the duct material reflectivity. Each of these factors will determine the amount of UV-C energy necessary in any given application.

One of the most important considerations is the amount of UV-C energy necessary to kill a specific pathogen. The UV-C dosage/fluence rates required to inactivate specific RNA and DNA viruses are identified in various scholarly research,[7] and these may be used with predictive-modeling to forecast how much UV-C would be necessary to kill individual bacteria, viruses, or spores. For example, viruses like influenza, measles, SARS, and smallpox tend to be more susceptible to UV-C inactivation in an air-stream.

UV lamps can also be included in patient exam rooms for added protection.

GERMICIDAL UV-C INACTIVATION OF MICROORGANISMS BY GROUP

VIRUSES	VEGETATIVE BACTERIA	MYCOBACTERIA	BACTERIAL SPORES	FUNGAL SPORES
• Influenza viruses • Measles • SARS • Smallpox	• Staphylococcus aureus • Streptococcus pyogenes • Escherichia coli • Pseudomonas aeruginosa • Serratia marcescens	• Mycobacterium tuberculosis • Mycobacterium bovis • Mycobacterium leprae	• Bacillus anthracis • Bacillus cereus • Bacillus subtilis	• Aspergillus versicolor • Penicillium chrysogenum • Stachybotrys chartarum

MOST SUSCEPTIBLE → LEAST SUSCEPTIBLE

Data Source: ASHRAE Handbook—HVAC Applications Ch. 60

For an application to keep cooling coils free from mold and bacteria, lamps might be installed on the downstream side of a coil surface, spaced every 30-in. to 40-in. of coil height, this equates to roughly 7.5 lamp watts per square foot, i.e, enough UV-C energy to get the job done. In this example, the target (coil) is stationary, the exposure time to UV-C is 24/7/365, so the UV-C intensity can be lower.

The fixture shown here is disinfecting the childcare center at Schenectady County Community College in upstate New York.

However, for a moving air-stream, UV-C intensity must be increased due to the limited residence time that the target pathogen(s) will be exposed to the UV-C energy. Greater UV-C fluence can be achieved by using more or higher output lamps—both of which increase the total number of lamp watts, normally expressed as microwatts per square centimeter ($\mu W/cm^2$). "Fluence" is defined in terms of UV "incident" on a tiny sphere from all directions.[8] Product design and application also have a part to play in this equation. For example, by using a "fixtureless" UV-C system, 360-degree irradiation can be achieved, which allows more UV-C energy to saturate the entire plenum, thus increasing UV-C fluence. UV-C fluence can also increase based on UV-C's reflectivity off of the plenum surfaces. That is, the amount of UV-C energy bouncing off of the top, bottom and sides of a plenum can "remain in play" versus being absorbed by the surfaces. Different metals have different reflectance multipliers that can significantly increase UV-C fluence levels (see the UV-C Multiplier Chart). Another option to increase UV-C fluence is as simple as decreasing lamp-row-spacing, from, say the surface irradiation standard, 36-in. centerlines to 12-in. or less.

Predictive-modeling based on scientific studies of each pathogen's susceptibility to UV-C can assist in specifying the recommended dosage rates required to kill individual bacteria, viruses, or spores. Studies have demonstrated that viruses (e.g., influenza, measles, SARS and smallpox) are more susceptible to UV-C inactivation than, say, bacteria.

The third method installs Coil-irradiation systems within HVAC air-handling units and duct runs. As air conditioning equipment ages, its ability to maintain designed coil leaving-air temperatures and humidity levels decline. Predominantly, the culprit is reduced coil heat-transfer efficiency, or the ability of the AHU's cooling coil to remove heat and water from the air. Evidence shows this decline in performance can occur within five years of startup due to the buildup of biofilm on coil surfaces. Of course, there are energy and other cost penalties associated with coil fouling, such as fans and chilled water systems consuming more energy to compensate for lost coil capacity.

A system installed for coil irradiation can also have a secondary benefit of eliminating up to 30% of airborne pathogens on a first-pass basis (and these concentrations are further reduced by each subsequent pass or "multiple dosing").

Metal	UV-C Multiplier
Stainless Steel	1.40
Galvanized steel	1.50
Aluminum	1.75

ASHRAE's Handbook also recommends that the UV-C irradiance levels should strike coil surfaces at 50-100 μW/cm^2. A more understandable and convenient way to achieve the recommended dosage of UV is to use lamp watts, which is printed directly onto all major lamp brands. ASHRAE's recommendation of 100 μW/cm^2 works out to be slightly under 7.5 lamp watts per square foot of coil surface area.

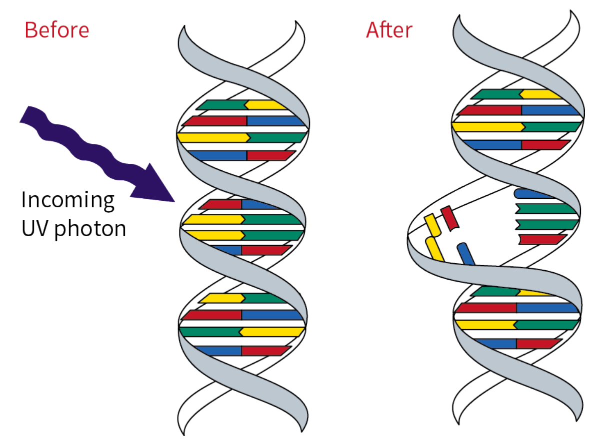
How Engineers and Contractors Can Help

While the use of UV-C to irradiate cooling coils is more commonplace, mechanical engineers and contractors need to educate and remind facility managers and building owners about the fact that Ultraviolet Germicidal Irradiation is an established means of killing airborne pathogens and mitigating the spread of infectious diseases.

Although scientists are learning more about the COVID-19 virus every day, authorities currently believe that coronaviruses can be transmitted via air and direct contact. Researchers have found the COVID-19 virus can live in the air for several hours, up to 24 hours on cardboard and up to two to three days on plastic and stainless steel.[9] Moreover, because of the extended incubation period for some of these diseases, people can spread the virus before anyone knows they are contagious and, more importantly, before anyone can take precautions. Therefore, it is incumbent on facility engineers to use preventive infection-control measures such as UV-C to mitigate the potential spread of airborne diseases.

ASHRAE states that the UV-C wavelength can kill 90% or more of all microorganisms living on HVAC air ducts and evaporator coils.

ASHRAE states that the UV-C wavelength can kill 90% or more of all microorganisms living on HVAC air ducts and evaporator coils, depending on UV-C intensity, length of exposure (a.k.a. residence time), UV lamp placement and lamp life cycle. Operating 24/7/365, Upper-Room germicidal fixtures can inactivate microbes in under a second, including measles, mumps, TB and cold viruses. In fact, ASHRAE's position document on airborne infectious diseases identifies just three proven methods of controlling airborne infection: ventilation, particle filtration, and germicidal UV-C energy. UV-C is such a promising technology that ASHRAE placed its highest research priority on both Upper-Room/Air UV-C and in-duct/ air-handler UV-C technology.



The 253.7 nm germicidal C-band wavelength inactivates virtually all microorganisms living on HVAC/R surfaces with a kill ratio of 90% or higher, depending on UV-C intensity, length of exposure, lamp placement and lamp life cycle.

There is a growing use of UV-C energy in hospitals to control airborne infectious diseases.

Conclusion

Although Germicidal UV-C systems have been used for nearly 80 years, their application in infection-control settings has waxed and waned. Given the growing desire to prevent the transmission of infectious diseases in hospitals, schools, airports, etc., facility professionals can utilize germicidal ultraviolet technologies to greatly reduce concentrations of pathogens in a highly reliable and cost-effective fashion.

Within patient rooms, waiting rooms and other congregational areas, Upper-Room UV-C units will kill airborne microorganisms that inherently circulate into the UV-C irradiation zone. UV-C lamps can be installed within HVAC systems downstream of cooling coils to keep coils clean and to provide supplemental kill ratios in airstreams and on filter surfaces. Recent guidance from ASHRAE and published technical articles in HVAC trades provide healthcare engineers and facility staff with the resources needed to size, select, install, operate and maintain UV-C systems.

The president and co-founder of UV Resources, Daniel Jones is an ASHRAE Member and a corresponding member of the ASHRAE Technical Committee 2.9 and ASHRAE SPC-185.2, devoted to Ultraviolet Air and Surface Treatment. He may be reached at daniel.jones@uvresources.com.

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