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ES ENGINEERED SYSTEMS

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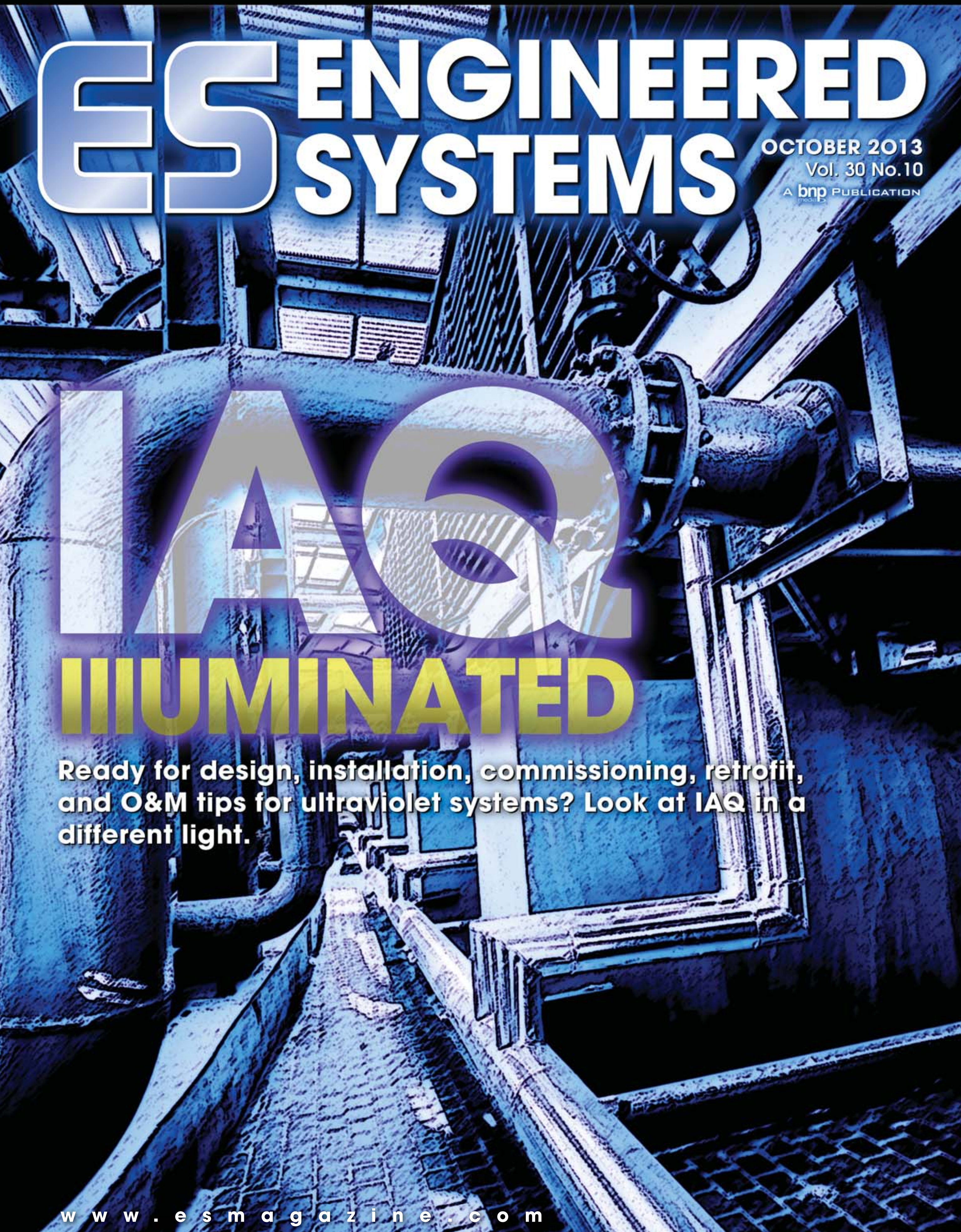
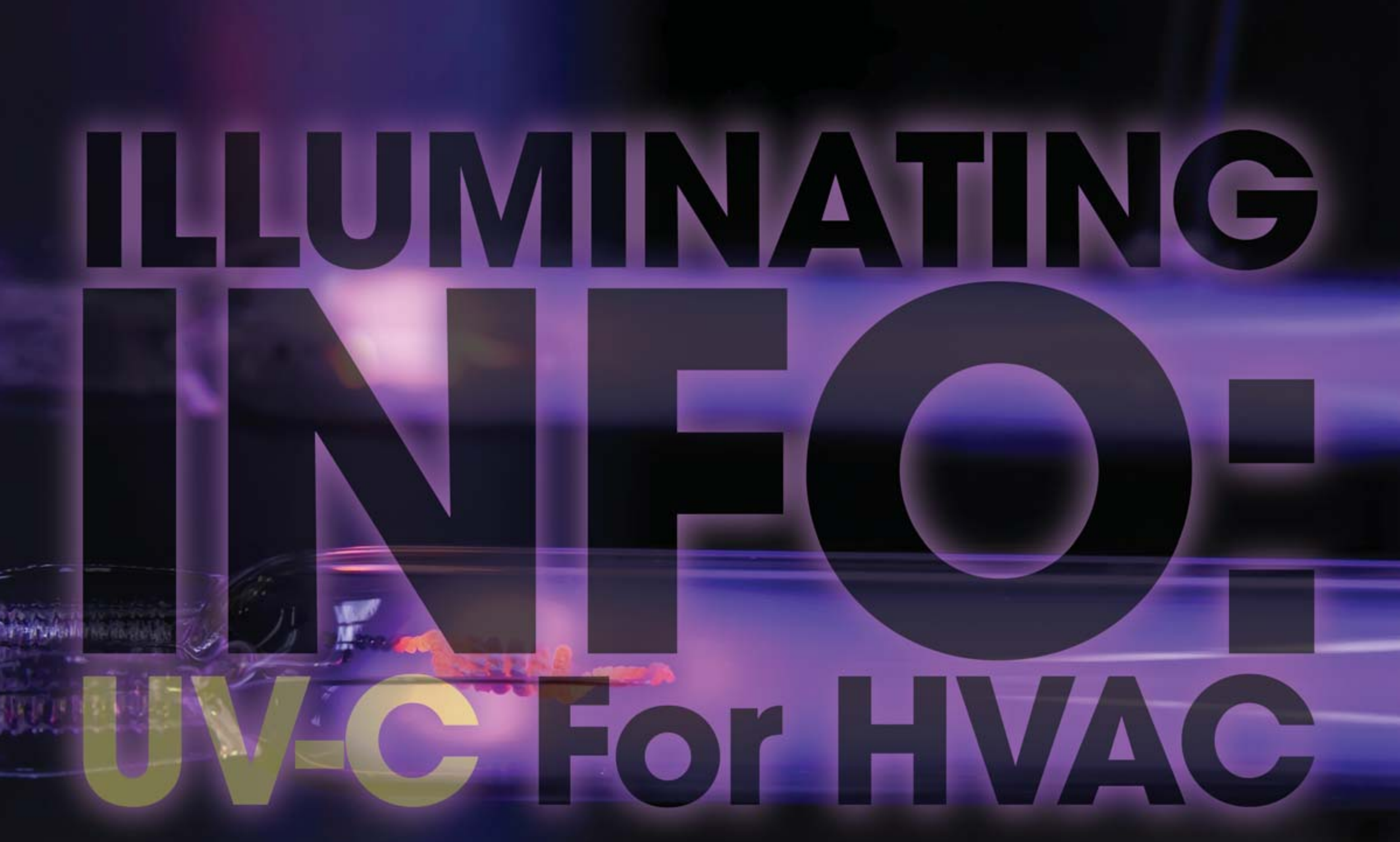


IAQ Illuminated

Ready for design, installation, commissioning, retrofit, and O&M tips for ultraviolet systems? Look at IAQ in a different light.



ILLUMINATING INFO: UV-C For HVAC

Looking for lifecycle guidance or more extensive info for your stationary applications? An industry IAQ veteran weighs in about the design, installation, commissioning, retrofit, and O&M of ultraviolet systems for commercial HVAC equipment.

By Forrest Fencl

Feedback from potential users of UV in HVAC equipment suggests that many are confused about its use. Despite UV's relative simplicity compared to equipment such as chillers and boilers, not all HVAC professionals are proficient on how to size and specify UV-C systems, how to design their installation, how to install UV-C systems, or how to plan for lamp replacements.

All of this is to be expected. While UV-C systems are not new, the UV-C industry has undergone formalization in recent years, beginning primarily with ASHRAE adding a UV-C section to the Systems and Equipment Handbook. Also, manufacturers have simplified their offerings to make selection, installation, and service much easier. This article takes advantage of these advancements to provide guidance about the complete lifecycle of UV-C systems — sizing, selection, installation, commissioning, operations, service, and disposal/recycling.

UV-C systems today are primarily focused on stationary or "surface" applications, e.g., coil irradiation with airstreams as a secondary benefit. Because coil applications are dominant, this article will focus on these types of installations. This article breaks the lifecycle into four parts:

1. System sizing and installation design
2. Commissioning guidance
3. Retrofitting UV-C systems
4. Maintenance

PART 1: SYSTEM SIZING AND INSTALLATION DESIGN

Designing a UV-C system can be simple once the basics are known, such as the rationale for a UV-C system, how to estimate the lifecycle cost (first cost and operating cost), sizing, and installation design.

The most authoritative resource for design guidance is the *2011 ASHRAE Handbook: Applications.* Section 60.8 summarizes decades of research papers, technical articles, and application experience.

The problem. The handbook describes how HVAC systems can "promote the growth of bacteria and mold-containing biofilms on damp or wet surfaces such as cooling coils, drain pans, plenum walls, humidifiers, fans, energy recovery wheels, and filters," and links these conditions to reduced airflow and heat exchange efficiency. Exposing HVAC surfaces to UV-C light prevents the buildup of contaminants and, in retrofits, eradicates contaminants that have built up over time.

Alternatives. The handbook describes how chemically and mechanically removing deposits and growth from the surfaces of HVAC equipment "can be costly, difficult to perform, and dangerous to maintenance staff and building occupants." Engineers and

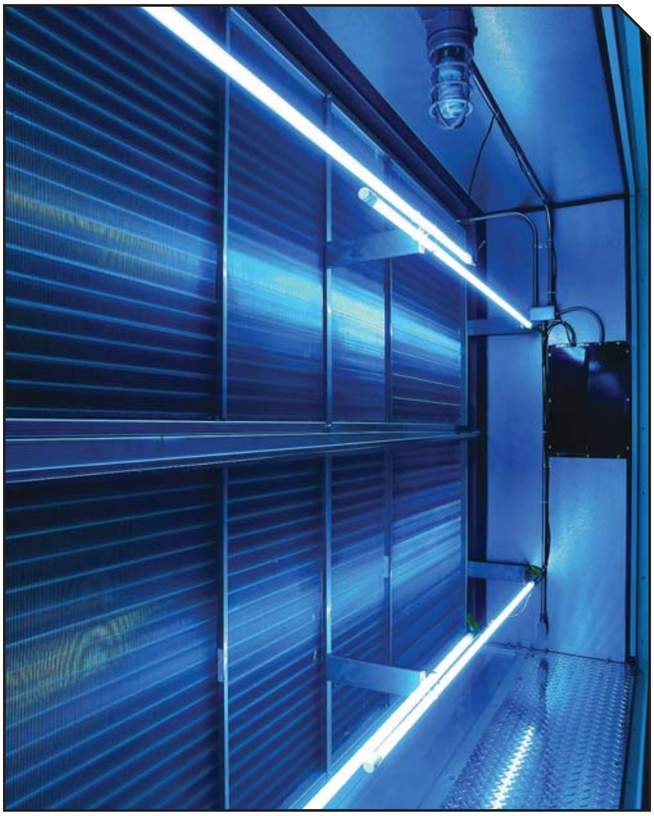


FIGURE 1. Overlapping lamps enables installation of uniform lengths, which makes re-lamping easier. (Image courtesy of UV Resources.)

building owners should read this section carefully.

Design guidance. Perhaps the most important guidance in the handbook is the specification for UV-C irradiance levels that should strike coil surfaces: 50-100 µW/cm2. A more understandable and convenient way to provide the recommended amount of UV is to use lamp watts, which can be found printed on all major suppliers' lamps. ASHRAE's recommendation of 100 µW/cm2 works out to be slightly under 7.5 lamp watts per sq ft of coil surface area.

UV lamps are available in multiple lengths ranging from 24 in to 60 in (60-145W). Lamps are typically overlapped in the plenum to reduce the number of sizes used (Figure 1). Doing this, the designer can often use one lamp length, which will minimize both first and replacement costs. A 27,000-cfm system could have a coil size of about 6 ft high by 9 ft wide that might use four 60-in, 145W lamps, or 10.7 lamp watts per sq ft.

Lifecycle cost. Many users report that their cost for an installed system featuring high output lamps was less than $0.15 per cfm. As discussed in the section above, this might cost ($0.15 x 27,000 cfm) less than $4,000. The operating cost for a system that is on 24/7 is then easy to estimate: Annual energy cost = Installed Wattage (kW) x Utility Rate ($/kWh) x 8,760 hours. This system at $0.10/kWh rate comes out to (0.580 x 0.10 x 8,760) about $508/year or less than 1% of the power to operate the air conditioning system.

Field reports indicate that the first cost of a UV-C system is approximately the same as one properly performed coil-cleaning procedure, especially if system shutdowns, off-hours work, associated overtime, and/or contractor labor costs are considered. The cost is usually more than offset by system sustainability or energy use and little or no maintenance, as ASHRAE points out.

UV-C lamps are typically replaced all at once as part of a routine annual fluorescent lamp change-out schedule. They can also be recycled with fluorescent lamps.

Location. UV-C systems are most often installed downstream of the cooling coil in the direction of airflow. This is favored because the air there approaches saturation, meaning that within this plenum, there could be raw water, damp insulation, and other conditions that are known to lead to the growth of mold and some forms of bacteria. Also, coil drain pans are often extended in this location to catch raw water carry-over from the cooling coil.

Lamp installation details. Lamps are mounted horizontally, usually 12 in from coil surfaces. A connection to 120/240/277Vac power fed through a toggle switch outside of the plenum and door interlock cut-off switches are the basic installation criteria. Check manufacturer's Installation/Operation/Maintenance (IOM) details for how to hold the lamps in place for easy lamp installation and replacement.

Controls and safety. UV-C systems should be designed with door interlocks such that when air handlers are opened, the UV-C lights are turned off automatically (See Figure 2). Warning labels should be placed on air-handler doors. Additional equipment that can be installed is lamp/ballast monitors, alarms, and radiometers. Lamp/ballast monitors are typical today, and alarms and radiometers are used in infectious disease applications where the highest output must be maintained on a continuous basis.

PART 2: COMMISSIONING TIPS (CHECKING DESIGN SPECIFICATIONS AND INSTALLATION QUALITY)

The following tips should be followed for any UV-C install in new and retrofit applications. This section covers pre-functional checks and tests, functional checks and tests, and training/documentation.

PRE-FUNCTIONAL

Installation. Obtain a list of materials specified, ordered and received, and verify that they are correct. Verify that the installation

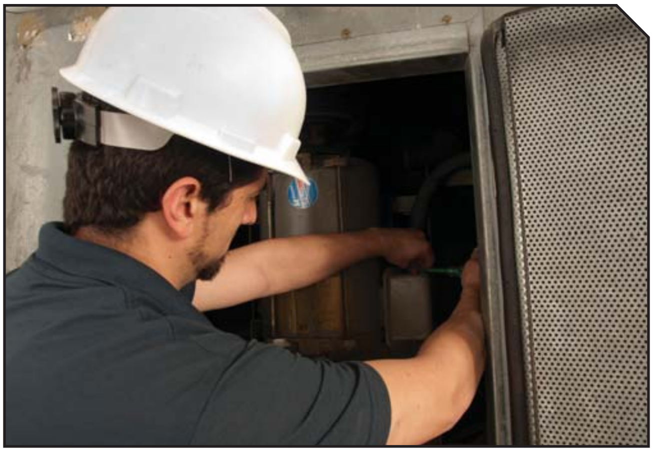


FIGURE 2. HVAC equipment with installed UV-C lamps should have an interlock switch that turns off the UV-C lamps when the door is opened. (Image courtesy of UV Resources.)

FIGURE 3. Note the person checking the installation is wearing protective eyewear, and that the safety interlock for turning off the lights when the access door is open has been overridden. (Image courtesy of UV Resources.)

meets construction details and the manufacturer's IOM manual for the equipment. Document the condition of equipment as installed.

Start up. Using the manufacturers IOM, note any pre-operation requirements. Verify that manufacturer's startup procedures are performed and document the performance. Verify the calibration of devices, including the operation of the toggle switch, door interlock safety cut-off switch(s), and that all lamps can be turned on, and that they are functioning.

Controls. Review installation of sensors such as radiometers, current switches, and output signals to the building management system (BMS). Document calibration of sensors and devices and document proper operation of remote monitoring of equipment at the BMS, if applicable.

FUNCTIONAL

Automatic equipment operation. Witness automatic startup and shutdown from the plenum wall switch as well as the door switches. Verify that equipment sequence of operations is correct.

Automatic system operation. Witness automatic startup and shutdown of integrated systems at the BMS, if applicable. Verify that system sequence operation is correct.

Alarms and safeties. Verify that systems alarms are active if applicable. Verify sequence of operation under alarm condition. Verify equipment safeties are active.

TRAINING AND DOCUMENTATION

Training. Verify that adequate safety training is provided to building maintenance personnel for entering an active UV-C installation (See Figure 3). Witness portions of the training, and identify any additional resources for use after training ends, such as lamp replacement and disposal. Also ensure that staff has been trained on safety measures, including UV-C exposure, lamp breakage, function of the alarms and safety interlocks, and how to tell if they are not functioning properly. Also, ensure that protective eyewear and clothing is discussed and available to staff.

Report of commissioning. Document commissioning activities. Document issues resolved during the commissioning process. Identify a plan to resolve any issues remaining after installation and commissioning.

Systems manual. Document operations and maintenance manuals for equipment included in the commissioning process. Create a useable sequence of operations of systems. Document the design intent for use during renovation or retrocommissioning. Document safety features and requirements, along with the availability and location of protective clothing and eyewear.

PART 3: RETROFIT GUIDANCE

UV-C has been more prevalent in new-construction specifications and projects; however, UV-C installs have gained popularity in retrofit projects, especially in hospitals. Three reasons seem to be driving the increase: 1) Better indoor air quality; 2) increased airflow, and 3) energy savings.

UV-C systems will clean dirty coils, even deeply inside the coil. And once clean, UV-C keeps the coil clean continuously.

Typically, retrofits adding UV are comprised of fixtures, lamps, and door interlock switches, plus an electrical connection. Options can include a radiometer, or more popular today, a lamp-monitoring kit that provides local and remote monitoring. As to framing to hold the fixtures inside coil plenums, most users build their own, using preformed materials available at hardware stores.

As with new construction, UV-C system design is similar in process and costs ($0.15/cfm). While economic benefits from improved indoor air quality exist, they can be difficult or subjective to quantify. Therefore, energy savings drive most retrofit payback analyses.

The more accurate and therefore favored way to determine payback, or ROI, is by measuring the before and after capacity of an air conditioning system and putting the measurements into the following equation: BTU's = cfm x 4.5 x (h1 – h2), where: h1 – h2 = enthalpy difference (British thermal units per degree wet-bulb).

The following parameters are necessary to determine capacity:

- Coil traverse – note: if fan is VAV, set at 60Hz for each test
- Coil entering and leaving wet bulb temperatures (h1 – h2)

For fan horsepower savings:

- Coil pressure drop (expressly across the cooling coil)

FIGURE 4. UV-C lamp (top) and fluorescent lamp (bottom) of the same form factor, which could be made on same lamp machine. The UV-C lamp has a fused quartz envelope that is clear in order to let UV-C light through unfiltered. The fluorescent lamp glass envelope is lined internally with phosphor, which glows when charged. (Image courtesy of UV Resources.)

Optional:

- Chilled water entering and leaving temperature and volume
- Coolant temperature differentials (at the coil – for CW units)
- Fan rpm
- Fan motor amp draw

By taking these measurements, the user will be able to determine their actual capacity, both before the installation of UV, and after. It is not uncommon to see improvements of 10% to 50% (or more). Help can be had through most UV-C manufacturers in performing these measurements and obtaining ROI spreadsheets for actual payback calculations.

For ultimate precision, the following should be considered to maximize before/after consistency:

1. Note all damper positions and unusual damper systems that might affect pressure drop readings (i.e. economizer cycle). Dampers can move for various reasons, but their movement can effect airflow and pressure drop readings.
2. If the AC system is VAV, override the controller so that the unit is at 100% capacity (60Hz) during each test period to provide exact before and after comparisons of cfm. This will assure that fan rpm is the same each time readings are performed.
3. Note whether the system includes a return air fan. A return air fan will affect total airflow and therefore pressure drop across the coil. It must perform the same during the before and after measurements. If it includes a VFD be sure it is also at 60Hz.

UV-C RESOURCES

Additional articles by the author — "The Hidden Value of UV-C" and "Maintaining A/C-System Performance With UV-C" — have appeared in various publications and will provide background information to engineers, contractors, commissioning providers, and facility staff. Find them all on the UV Resources website at *http://tinyurl.com/mjvlxay.*

4. Coil cleaning costs (material & labor), actual or estimated.
5. Drain pan cleaning and treatment costs (material & labor).
6. Electrical cost in dollars per kWh.
7. Demand charge in dollars per hours of system cooling per year (actual or estimated).
8. How is unit operation and operation hours controlled? Make sure it is consistent.

PART 4: OPERATING AND MAINTENANCE RECOMMENDATIONS

Most all lamp manufacturers list a UV-C lamps "useful life" as 9,000 hours. At 9,000 hours the lamp output begins to fall to 85% or less of the original output. Because the blue hue produced by the lamp is not indicative of the invisible UV-C energy output, lamp manufacturers are not willing to guarantee useful UV-C output for longer than 9,000 hours.

The lamp closest to a UV lamp in construction and function is the fluorescent lamp as both are low pressure UV-C lamps (See Figure 4). Therefore, both can be treated similarly whether purchasing, storing, replacing, or disposing. The minor construction differences are the glass envelope and internal coatings. In the fluorescent lamp, ordinary glass is used and it is internally coated with phosphors, which gives fluorescent lamps their characteristic glow (visible light).

Can UV-C lamps be run longer than 9,000 hours? Yes, but field operators report that running lamps longer will produce lamp outages one lamp at a time. This requires maintenance personnel to inspect UV-C installations routinely to know what and how many to replace. This is poor management of staff time. Furthermore, replacing lamps only as they burn out requires a significant amount of lamps be kept as spares should lamps start to fail in larger numbers. Most users report that they have set up an annual replacement schedule or linked it to their fluorescent lamp replacement schedule.

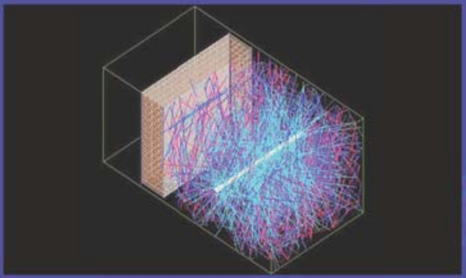
An annual lamp schedule has the following benefits:

1. It provides time to get a full replacement competitively quoted and fulfilled.
2. The inventory or replacement lamps are reduced to a recommended quantity of 5% of the installed lamp quantity to hedge against breakage or premature failure.
3. It eliminates the time, labor, and cost of trying to monitor the lights on a more frequent basis, especially toward the 9,000-hr window.
4. It minimizes system downtime and provides maximum UV-C output to keep the kill of airborne microorganisms as high as possible. **ES**

The president of UV Resources, Forrest Fencl, is the holder or co-holder of 15 patents and the author or co-author of numerous papers and articles and several ASHRAE Handbook chapters related to ultraviolet air and surface treatment. He is a Life member of ASHRAE, an ASHRAE Fellow, formerly an ASHRAE Distinguished Lecturer, and a member of the International Ultraviolet Association (IUVA) and the Illuminating Engineering Society (IESNA).

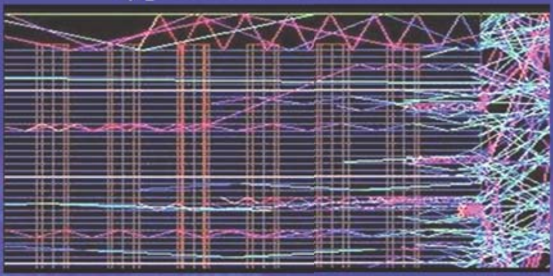
UV Installation

UV Distribution Example



For. . .
Greater airflow
Colder air
Increased efficiency
UV is the best option!

Typical UV Reflection*



* Coil Plan View

Before and after pictures show fouled coils returned to as-built capacity.

- Lowers pressure drop
- Increases airflow
- Provides colder air
- Restores efficiency
- Stops microbial growth
- Rids A/C of slime and odor
- Eliminates coil cleaning

Why UV Resources?

- Up to 5-year warranties on fixturing
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- EncapsuLamp™ technology available
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