

ADVANCED HVAC SYSTEMS FOR IMPROVING INDOOR ENVIRONMENTAL QUALITY AND ENERGY PERFORMANCE OF CALIFORNIA K-12 SCHOOLS

Applications Guide for Off-the-Shelf
Equipment for UVC Use

CONSULTANT REPORT

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Table of Contents

Objectives 1

Summary 1

Introduction 1

What kinds of UVC systems can be used?..... 2

How important is indoor air quality? 2

What are the maintenance issues with UVC? 2

How can UVC save energy?..... 3

What are the safety issues? 3

What does it cost?..... 4

What field experience do we have with UVC for coil cleaning? 4

Current California Energy Commission Study of Indoor Air Quality in Schools..... 5

How important is coil fouling? 6

How should UVC systems be sized, located and operated? 7

What situations could benefit from use of UVC for coil cleaning? 7

Climate Issues 8

Environmental Issues 8

Facility/HVAC Issues..... 8

Equipment Selection..... 9

UVC Manufacturers..... 10

UVC Lamps..... 11

Ballasts..... 12

Recommendations 12

References 14

Applications Guidelines for Off-the-Shelf UVC Equipment for Coil Cleaning

Objectives

These guidelines provide a primer on ultraviolet lighting systems for coil cleaning for school facility decision makers, equipment specifiers and manufacturers. An introductory overview leads to a discussion of benefits and application considerations that shows when to consider installation of ultraviolet lighting systems. A discussion of equipment information, product offerings and recommendations is designed to assist school officials and specifiers in making a preliminary assessment of the equipment that could meet their needs. Information is also provided that might help manufacturers see how their product offerings might be viewed by other market participants.

Summary

These guidelines begin with an overview of indoor air quality, maintenance, and energy issues in K-12 schools, and how ultraviolet lighting systems can help address these issues. Case studies are presented that illustrate how ultraviolet lighting has worked in schools and other buildings around the country. System sizing, location and operation are discussed. The conditions favoring use of ultraviolet radiation for coil cleaning are then outlined. Equipment selection considerations, including manufacturer selection information, and product options are presented for ultraviolet lighting systems and for lamps, and ballasts.

Introduction

Information on ultraviolet lighting for coil cleaning can be found on the California Energy Commission website¹ and in a recently published article in *Engineered Systems* magazine.² Briefly, ultraviolet radiation in the “C” wavelength range (UVC) has been used to irradiate dirty air handling system components to deactivate microorganisms on the coils and drain pans of these systems. The UVC is designed to rapidly clean the surfaces and to subsequently penetrate between the coil fins to clean within the coils. The objective in removing the microbiological contamination in cleaning the coils is to reduce the pressure drop and enhance the air-side heat transfer, improving the system energy efficiency. Another benefit that has been claimed is improved indoor air quality, resulting from reduced entrainment of microbes into air passing over the coil before it enters the room.

The benefits of ultraviolet lighting for coil cleaning are (in a retrofit situation) achieved by returning coil performance to the as-built condition or (in a new building situation) by maintaining the coil in a continuously clean condition. As addressed in the article in *Engineered Systems* magazine,² it is not clear from available data whether coils get dirty enough in the California environment to make cleaning a cost-effective proposition. There is however anecdotal data that indicates that using ultraviolet light in the “C” spectrum (UVC) to clean coils that have been heavily fouled by coils in environments that promote heavy microbial growth can be beneficial. There is also well-designed research that has provided evidence in office buildings that this surface cleaning carries over into the workspace with reduced airborne microorganisms and improvements in health and attendance.

What kinds of UVC systems can be used?

There are three main types of UVC systems that are generally used in buildings: in-duct, upper-room, and air handler systems. In-duct systems provide a high level of ultraviolet radiation sufficient to kill microorganisms in the air flowing past the lamps. Upper room units are installed in occupied rooms above the heads of the occupants, shielded from their view, relying upon personnel movement and heat sources to create currents that cause air flow through the units. They are most often used in rooms with low air turnover. Air handler systems are placed near the cooling coil and drain pan in the delivery plenum and are designed to provide ultraviolet radiation that deactivates microorganisms that would otherwise foul the surfaces of the air handling unit. This irradiation of stationary surfaces has long UVC exposure times and therefore lower intensity requirements than the other types of UVC systems that are trying to disinfect a moving air stream.

UVC systems use low-pressure lamps that are designed to provide radiation at the 253.7nm wavelength that is most effective in deactivating microorganisms. The lamps use mercury vapor, operating on the same principles as a fluorescent lamp but differing in not containing phosphors that convert UV to visible light. Another difference is that UVC lamps are made of quartz or soda barium glass which transmits UVC, rather than common glass which does not.

These guidelines deal primarily with issues related to placement of UVC systems in air handling units in the proximity of the cooling coil.

How important is indoor air quality?

Evidence strongly suggests that poor environments in schools, primarily due to the effects of indoor pollutants, adversely influence the health, performance and attendance of students and teachers. This evidence links high concentrations of several air pollutants to reduced school attendance. There is also persuasive evidence that microbiological pollutants are associated with increases in asthma effects and respiratory infections, both of which are related to lower school performance and attendance.³ UVC lights offer a potentially effective means of both reducing energy use and delivering fresh air to improve classroom air quality.

UVC lamps are designed to clean both the coil and drain pan surfaces in a few hours or a few days⁴ and to progressively penetrate between the coil rows and fins with time. Indoor air quality may be improved since the coils that are continuously cleaned by UVC are thus no longer an incubation site for microorganisms. Air flowing through the coils is therefore not contaminated, resulting in cleaner air being delivered to the classroom.

What are the maintenance issues with UVC?

An effective traditional coil cleaning program cleans the coils three to four times per year. Use of UVC lamps can eliminate the need for these costly, tedious cleaning treatments that create system downtime and use chemicals, biocides or pressure washing. Mechanical or chemical washing may also damage coils. Maintenance benefits may accrue from use of UVC lights to keep coils continuously clean, avoiding these laborious coil cleaning actions that will otherwise be required to return coils to a clean condition. UVC lamps should be inspected to see if they are dirty and then cleaned on a regular basis, as needed. Some installations have a view port to permit visual observation of the

Applications Guidelines for Off-the-Shelf UVC Equipment for Coil Cleaning

lamps, without entering the air handling unit. The frequency of cleaning of the UVC lamps depends on the level of filtration and whether the lamps are upstream or downstream of the filter. Some practitioners suggest that if lamps are installed downstream of an effective filter, the lamps will not need to be cleaned at all before they need to be replaced. To clean the lamps, they can be wiped with a soft lint-free cloth (when the lamps are “off”) moistened with isopropyl alcohol or glass cleaner, to assure that the lamps are operating at optimal efficiency. Lamps lose their efficacy with age and are generally replaced annually or whenever the output falls below 70% of the initial output. Some practitioners of UVC systems recommend manual cleaning of the coils prior to installation and operation of the UVC lamps. This allows the UVC lamps to keep the coil in a continuously clean condition without fear of dispersing deactivated mold and other microorganisms that might otherwise be present if the UVC lamps were used to deactivate microorganisms on a dirty coil and drain pan. Another option that may work for school buildings is to initially operate the UVC system when the building will be unoccupied for a sufficient period such as the summer vacation break to deactivate the organisms and “flush” them from the building prior to occupancy.

How can UVC save energy?

Energy benefits may be provided by ultraviolet lighting that cleans cooling coils, by reducing pressure drop, improving heat transfer and increasing system capacity, resulting in overall cooling energy savings. Lamps are generally operated continuously to achieve the most effective cooling system cleaning and indoor air quality improvement. The resulting lamp energy use must be less than the cooling system energy savings for overall savings to accrue. In a typical installation the installed lamp power could be as low as less than 1% of HVAC system power for large systems and as high as 5% or greater for smaller systems. The savings produced by the lamps need to exceed these levels to achieve net energy savings for the installation.

What are the safety issues?

Excessive exposure to UVC causes temporary redness and inflammation of the conjunctiva of the eye. Both should resolve within 24 to 48 hours. The cornea is very sensitive to UVC but UVC does not penetrate the cornea, therefore adverse lens or retinal effects are not experienced except for people who have had cataract surgery to remove their lens or cornea.⁵ View ports designed to see if the UVC lamps are operating properly or need to be cleaned should be constructed of glass or Lexan since UV does not penetrate either of these materials.

The Illuminating Engineering Society of North America (IESNA) cited the following exposure limits set by the American Medical Association:

Table 1: UVC Human Exposure Limits	
Exposure Duration	Exposure Limit
Continuous	0.1 $\mu\text{W}/\text{cm}^2$
7 hours/day	0.5 $\mu\text{W}/\text{cm}^2$
10 minutes	22 $\mu\text{W}/\text{cm}^2$
2.5 minutes	90 $\mu\text{W}/\text{cm}^2$

Applications Guidelines for Off-the-Shelf UVC Equipment for Coil Cleaning

The American Conference of Governmental Industrial Hygienists (ACGIH) recommends threshold limit values (TLV) for UVC exposure in an 8 hour period of 6.0 mJ/cm^2 , equivalent to an irradiance of $.2 \text{ } \mu\text{W/cm}^2$ for an eight hour period and $.4 \text{ } \mu\text{W/cm}^2$ for a 4 hour period. Above this level, erythema (skin redness) and photokeratitis (external eye inflammation) occurs. UV exposure and leakage needs to be minimized. (A tell-tale blue glow provides a clue to UV leakage.)

UVC lamps should be designed to avoid emitting radiation below at the 200nm wavelength that produces ozone. Lamps contain mercury and should be treated with care, as with fluorescent lamps used for illumination, if the lamps are broken or are discarded.

Plastic-coated wiring can become brittle when exposed to UV and can create a fire hazard. Glues that hold filter pleats together or to hold the filter to the frame can be degraded by UV. The exposure of UV to these materials must be avoided.

While these hazards are real and care should be taken to avoid unsafe practices, experienced manufacturers and installers are well aware of the safety issues accompanying the use of UVC in occupied buildings and have designed fixtures, safety interlocks, and installation, servicing and operating procedures to avoid any potentially adverse affects that could occur.

What does it cost?

The initial cost of the lamps and related control equipment and the annual/periodic replacement costs of the lamps are additional costs accrued with the UVC systems. This should be compared to the maintenance costs that will otherwise result from regular chemical, biocidal or pressure cleaning.

Incremental energy use of the lamps must also be considered. Practitioners of these systems have asserted that the additional cost of UVC systems is more than offset by the elimination of costly air handler system cleaning, and incremental coil energy use reduction and that short paybacks are generally achieved.

Quantification of the value of reduced absenteeism, and greater learning performance can greatly multiply these benefits. In the end, it may often be the promise provided by using UVC to improve indoor environments and to consequently enhance student and teacher health and productivity that turns the decision in favor of this technology.

What field data has been published on UVC for coil cleaning?

UVC has been used effectively in many commercial buildings including a number of K-12 schools. Examples of the benefits of UVC installation in schools are provided below: An article on UVC classroom installation in the Capistrano Unified School District in California, claimed reduction in indoor air contaminants (skin cell fragments of 66% and pollen of 50%) and “every 15 to 20 minutes the air in that classroom will be purified resulting in a major improvement over previous conditions.”⁶

The LaPorte Independent School District in Texas installed UVC lamps in a building that had been infected with fungal growth that had been treated with costly cleaning,

Applications Guidelines for Off-the-Shelf UVC Equipment for Coil Cleaning

inspections, and chemical sprays. The UVC installation eliminated the need for these costly, time consuming treatments and provided the ancillary benefit of almost a 10% reduction in energy use compared to a similar facility that had less hours of operation.⁷

The Stepping Stones Center educational and therapeutic facility in Cincinnati, Ohio, used UVC lights to effectively remove mold from an otherwise unusable building.⁸

Examples of UVC use in other types of commercial buildings include the following:

Florida hospital in Orlando, Florida installed UVC lamps in a 27 year old air handling unit and within weeks of the installation, air velocity over the coil more than doubled and pressure drop was reduced by over 60%, saving at least 15% of HVAC energy costs.⁹

Application of UVC in the coil/drain pan area of the HVAC system in an office building in Montreal found a 99% reduction in AHU surface microorganisms, a 25 to 30% reduction in airborne bacteria, a 20% drop in worker absenteeism and a 40% drop in respiratory problems.¹⁰

Central and South West Corporation of Dallas Texas, installed 170 UVC lamps in the air handlers in their nearly 500,000 ft² building in 1998, providing an approximately 28% reduction in air-conditioning system energy use and coils that are free of mold and organic buildup without any use of chemical cleaning or biocidal treatment.^{11,12}

Current California Energy Commission Study of Indoor Air Quality in Schools

In a study sponsored by the California Energy Commission,¹³ UVC lamp systems were installed in 36 packaged air conditioning units in three school districts across California. Their performance was compared to 18 control units in those school districts over a six week period starting in August 2005. Both packaged rooftop and wall mount type air conditioning units were included in the study. Units that were less than four years old were excluded from the study. The three districts that were included in the study all had year-round schedules. Microbial samples were taken from the surfaces of the cooling coils for each of the units prior to the installation and operation of the UVC lamp systems and also at the end of the test period. Each sample was subjected to fungal and bacterial testing.

Results showed that the UVC lamps notably reduced the levels of microbial counts in the evaporator coils in the air conditioning units. (Total fungal and gram positive bacteria reductions from 65 to 100% of colony forming units were found.) Airflow and efficiency measurements were also made on the units and showed a positive trend (1 to 2% improvement in air flow) in reducing pressure drop, and improving air flow but this trend was not statistically significant for the sample size and conditions evaluated.

These study results were somewhat surprising leading to an investigation of the importance of coil fouling, how this is affected by environmental conditions and the influence of coil cleanliness on system performance. This information follows below along with a description of the pros and cons of alternative coil cleaning techniques.

How Important is Coil Fouling?

Coil fouling is defined as an increase in pressure drop above 100% compared to a new coil. Reduced air flows from coil fouling can cause typical efficiency degradation of less than 5%¹⁴ but can be much greater for marginal or extreme conditions where the units are operating on a steep part of the fan curve or have low refrigerant charge. An analysis of air conditioner coils¹⁵ showed that they were relatively insensitive to low and moderate amounts of air flow reduction due to fouling. When air flow was reduced by 35%, the coil had just a 6% drop in EER with the majority (4.6% of the 6%) occurring in last two years of the coil's twenty year life projection.

Both of these studies indicate that substantial fouling is needed to produce modest (~5%) degradation in efficiency. The level of fouling needed to provide the opportunity to save significant amounts of energy as cited in the Texas and Florida studies^{7, 9, 11, 12} is likely to be indicative of humid, warm conditions that have produced considerable microbial growth that may have gone untreated for some time.

Pros and Cons of Coil Cleaning Technologies

The following compares the perceived advantages and disadvantages of traditional coil cleaning methods that use chemicals, biocides or pressure washing to the attributes of UVC lights for coil cleaning. Both types of technologies lack well-documented quantitative studies of coil degradation and the subsequent benefit of cleaning methods and systems.

UVC Technology

Pros – Surface cleaning is quick and effective. Continuous cleanliness is maintained, sustaining cleanliness benefits. Maintenance (lamp cleaning and replacement) is quick and simple.

Cons – It is unclear how UVC light penetrates well below the surface envelope of the coil to disinfect and clean deep within the coil. UVC only addresses biofouling and does not affect other contaminants. Cleaning could take weeks or months to reach maximum effectiveness. The initial cleaning period may need to be coordinated with breaks/school shutdown periods to avoid transmittal of dead/deactivated organisms into the occupied space.

Traditional Coil Cleaning Technologies

Pros – The coil is cleaned to the full extent that is manually possible immediately after treatment. HVAC technicians are familiar with these technologies, infrastructure exists for their deployment.

Cons – Pressure washing could drive contaminants deeper into the coils. Chemicals and biocides need to be carefully removed to avoid subsequent air contamination. Cleaning can require facility shutdown, disassembly of equipment. The coil cleanliness degrades steadily immediately after initial treatment.

How should the lamps be sized, located and operated?

Lamps operate most effectively in still air at 25°C. Temperatures both above and below 25°C result in reduced lamp performance. Lamps are most effective when they are new and clean and lose their efficacy with age and lack of cleanliness. The effect of humidity has little effect on lamp output but germicidal efficacy appears to decrease with increasing relative humidity.¹⁶

Since lamps lose their efficacy with age and operating conditions often differ from optimal, lamps need to be oversized so they can provide effective performance for a reasonable duration in a real world environment of dust, humidity and cooling air flow. Manufacturers will take this into account in providing and locating lamps and reflectors to provide the appropriate lamp intensity for the installation of interest.

Lamps should be operated continuously to prevent growth of microorganisms.

For coil surface cleaning, lamp placement should provide good coverage of the coil face. The travel path of the UV rays should be directly through the gaps between the coil fins. The placement and sizing of the lamps depends on the types of microorganism in the system, the dimensions of the installation and the desired level of disinfection. Many design approaches are available for sizing UVC systems¹⁷ including catalogs, tables, rules of thumb and analytical methods. The analytical methods include point source models; line source models; integrated point source models; view factor models; and dimensionless models. Some of these models can take into account secular and diffuse reflectivity, and light baffles. In general the manufacturer will take the responsibility of sizing the product to meet the conditions required by the application.

One manufacturer suggests that 24 inches of high intensity UVC tube length be used for every 4 ft² of coil face area and that the ideal distance between the fixture and the coil is half the distance between rows or half the height of a one row coil if it is less than 24 inches.

The International Ultraviolet Association is developing guidelines for UVGI air and surface disinfection systems¹⁸ that includes recommendations on UV lamp sizing to include cooling effects, heating effects, aging, dust accumulation, burn-in, as well as information on safety issues and operation and maintenance of UVC systems. Guidelines for design and installation of surface disinfection systems in new buildings¹⁹ recommend coil selection that avoids corrugated fins and limits fin spacing to 8-12 fins per inch to facilitate penetration of the UV rays into the coil. Combining surface disinfection systems and air disinfection systems is recommended for maximum effectiveness. The latest information from the most current version of these guidelines should be used in sizing UVC systems and selecting components for coil cleaning.

What situations would most benefit from UVC lamps for coil cleaning?

The following paragraphs provide a few pointers on climate, environmental and facility/HVAC system issues that could make UVC lamps for coil cleaning a desirable option for a K-12 school facility in California:

Applications Guidelines for Off-the-Shelf UVC Equipment for Coil Cleaning

Climate Issues

- Consider coil-cleaning technologies if high humidity, high temperature and the presence of microbial sources could cause coil biofouling and resultant reduced air flow, lower heat transfer and consequent reduction in cooling capacity could create comfort and energy use issues.
- Most California climates have relatively benign dry climates with regard to microbial growth
- Coastal Southern California areas have high relative humidity compared to the rest of the state
- Agricultural areas such as Imperial Valley and the San Joaquin Valley with normally high summer temperatures but low humidity may have elevated humidity levels due to extensive irrigation in these areas that could be of some concern
- Composting vegetation and disturbed soil from farming or construction can be significant sources of microbes

Environmental Issues

- Microbial loads are excessive as evidenced by sampling in existing District schools
- Coil fouling has been experienced in existing schools in the District and is a problem that must be addressed in those schools and in new schools in the District.
- Indoor air quality problems including high absenteeism, low test scores and other indoor air quality complaints (musty, “dirty socks” odor) have heightened the Districts awareness of the need to look at UVC as a solution to these problems
- In schools or classrooms where the students may have immune systems that have been compromised and every effort should be employed to provide a healthy, productive teaching environment.

Facility/HVAC System Issues

- UVC can keep coils continuously clean, and may be a viable substitute for traditional coil cleaning methods that use chemicals, biocides or pressure washing that often require facility shutdown and only provide intermittent cleaning
- UVC requires minimal lamp maintenance particularly when the lamps are placed downstream of the filter, thus making them good candidates for areas that are difficult to service because they are in high traffic areas or they are difficult to access because of their remoteness or configuration. In any case the units will need some servicing to assure lamp cleanliness and to replace the lamps as recommended by the manufacturer.
- If humidifiers are used that produce saturated conditions in the proximity of the coil and drain pan this will enhance the growth of mold and bacteria. These situations should be candidates for UVC lamps to clean the coils.
- Returning coils to near their as-built condition or keeping coils clean from the start of their installation and operation can offset the need for adding additional HVAC system capacity, saving facility improvement capital as well as reducing operating costs.

Applications Guidelines for Off-the-Shelf UVC Equipment for Coil Cleaning

- Lamps need to be placed where there is ample space in the air-handling unit, a good line of sight to the coil, and the opportunity to avoid exposing materials that are sensitive to degradation from UVC light.
- Placing lamps downstream of the cooling coil usually provides a direct line of sight to the drain pan affording an opportunity to disinfect that source of moisture and microbial growth.
- For coil cleaning the travel path of the UV rays should be directed through the gap between the coil fins.
- Filtration should be used in conjunction with any UVC system.

Equipment Selection

There are several approaches to achieving coil cleaning with UVC lights. One approach, the one that seems to be most widely used, is to place the lamps on the downstream side of the coil where there is a good line of sight to this wettest side of the coil, and to both the coil and the drain pan. This places the lamp on the occupant side of the coil so some manufacturers of this configuration take extra care in providing shielding of UVC energy from users (and vulnerable plastic wiring, shellacked motor windings and other components) with shields and reflectors. The reflectors concentrate the UVC energy on the coil and drain pan surfaces. Lamps placed on the downstream side of the filter require minimal inspection for dirt buildup and resulting cleaning, perhaps quarterly or less. By contrast, others may use high output lamps and may not shield them, providing some disinfection of the air stream over and by the UVC lamps.

Other put their lamps on the upstream side of the coil but this creates line of sight problems to the drain pan. If the objective is improved coil performance this may not be an issue. Proximity of the filter to upstream side of the coil may make the installation of a UVC fixture difficult there but with sufficient space this type of installation could provide effective coil cleaning. The Adhesives used in some filters may be damaged by UVC so this is a consideration as well. Since air filters are frequently changed this provides the potential for mishandling and breakage of the lamps. Lamps installed upstream of the filters need to be inspected, and may need to be cleaned, every month.

As mentioned above, it is important that enough space is available to provide proximity of the lamp and good line of sight to the surfaces to be cleaned to assure high enough UVC irradiance to provide the desired germicidal disinfection. UVC lamps and fixtures are made to be installed in all types of HVAC system configurations. For some units this may be difficult due to lack of space and access. Unit ventilators and wall mounted units are particularly compact and therefore may present particular problems in this regard.

Another difference between products is the branding of the components. Most UVC system manufacturers use components such as lamps and ballasts with models available to the user from recognized commercial manufacturers of these components. This permits the user to shop for replacement components and to obtain a competitive price and attractive delivery terms. Purchasing from a manufacturer that puts its own brand on the component may provide some assurance of quality and adherence to the terms of the guarantee/warranty. On the other hand branding could limit the replacement choices available to the user resulting in a higher price and less attractive delivery schedule than would occur if products were used that had commercially available alternatives.

Applications Guidelines for Off-the-Shelf UVC Equipment for Coil Cleaning

UVC Manufacturers

Once having decided that UVC should be considered for an installation, it is recommended that the decision maker talk to several manufacturers of UVC lights to:

- Listen to claims about their product and decide whether those claims seem reasonable in the context of the information presented in these guidelines and the decision makers expectations for the product
- Ask for product layout and design assistance
- Ask for quotes, delivery and installation schedules
- Ask for performance guarantees, and warranties (lamps are generally warranted for 1 year, ballasts for 5 years and fixtures for as high as 3 years)
- Request a performance verification plan to assure that the units operate as claimed
- Ask for installation, operation and maintenance guidelines
- Ask for references in K-12 schools with similar climate and configuration

A compilation of major manufacturers and their websites is given below in Table 2. The web sites can be used to scan product offerings and related information and to locate a manufacturer's representative in the geographical area of the project being planned.

Table 2: Manufacturers of UVC Air and Surface Treatment Systems	
Company	Web Site
Allanson Environmental Systems	www.swordfishuv.com
American Air and Water	www.americanairandwater.com
American Ultraviolet	www.americanultraviolet.com
Atlantic Ultraviolet (Aerologic)	www.ultraviolet.com
Catalyx Technologies	www.catalyx.com
Dust Free	www.dustfree.com
Environmental Dynamics and Design	www.eddipure.com/air_quality.htm
Hanovia Ltd	www.hanovia.com
Living Ultra Healthy	www.premiumairproducts.com
Lumalier	www.lumalier.com
Natural Lighting	www.naturallighting.com
NQ Environmental	www.nqinc.com
Peterson Air Purifiers	www.breatheCLEAN.com
Sanuvox Technologies	www.sanuvox.com
Sentry Ultraviolet	www.sentryuv.com
SterilAire	www.sterilaire.com
Triatomic Environmental	www.freshaireuv.com
Ultravation	www.ultravation.com
UVDI	www.altruv.com
UV Resources	www.UVResources.com
Ultraviolet Systems	www.ultravioletsystems.com
Vigilair Systems (formerly FP Technologies)	www.vigilairsystems.com

Applications Guidelines for Off-the-Shelf UVC Equipment for Coil Cleaning

If the decision maker decides to purchase the system from a manufacturer and their representative, the transaction is likely to be turnkey, with the manufacturer and their representative sizing the components; providing the lamps/tubes, fixtures/housings, reflectors, ballasts, sleeves, wiring, and view ports; delivering them to the site; installing them and trouble-shooting their startup; and checking back, to assure that the units are performing as promised. If a decision maker decides to put together their own units they will have the daunting task of performing all of these functions. This will likely entail designing and building fixtures, wiring and safety switches/interlocks and view ports for each UVC system installed. If all the HVAC systems are similar then one design may suffice for all units. The major purchased components will be the UVC lamps or tubes and the ballasts/power supplies that drive the lamps.

UVC Lamps

The low pressure mercury lamps that are usually used in UVC systems for coil cleaning produce a spectrum that peaks near 253.7 nm. High output lamps have three to four times the UVC output for a given lamp length than conventional lamps. Lamps come in several configurations in order to suit particular situations. The most common type of UV lamp is the cylindrical lamp, having connectors at both ends. Biaxial lamps use two cylindrical lamps in parallel with the connector at one end. U-tube lamps are similar to biaxial lamps and use a single connector at the base end, except they have a continuously curved bend at the outer end.

Some of the major manufacturers of UVC lamps are listed in Table 3 along with their web sites. They typically offer a range of lamps sizes and configurations. For example First Light offers a variety of shapes in 5 sizes of lamps in ranging from 12 watts to 48 watts in input power and 2.8 watts to 13.5 watts in output UVC power. All are rated for 9000 hours.

General Electric offers 5 sizes of biaxial lamps ranging from 5 watts to 55 watts in input power and 1 watt to 17 watts in output UVC power. All are rated for 8000 hours. They also offer 4 cylindrical lamps ranging from 4 watts to 55 watts in input power and .8 watt to 18 watts in output UVC power with ratings of 6000 hours for the smaller lamps and 8000 hours for the 39 watt and 55 watt lamps.

Heraeus offers cylindrical, biaxial and u-shaped lamps in sizes ranging from 5 watts to 300 watts in input power.

Philips has a large array of product offerings in different configurations and sizes ranging from 5 watts to 115 watts with ratings of 5000 hours for some of the specialty lamps, 8000 hours for the PL-L and PL-S lines and 9000 hours for other lamps.

Table 3: Manufacturers of UVC Lamps

Company	Web Site
First Light	www.firstlightusa.com/germicid.htm
General Electric	www.geconsumerproducts.com/pressroom/press_releases/lighting/specialty_lighting/uvgermicidal.htm
Heraeus Noblelight	www.heraeusnoblelight.com

Applications Guidelines for Off-the-Shelf UVC Equipment for Coil Cleaning

Osram Sylvania	www.sylvania.com
Philips	www.uvdisinfection.philips.com
Ushio	www.ushio.com/categ_uvgermicidal.htm

Ballasts

The lamp ballast performs both a starting function (in ionizing the gas in the UVC lamp) and a current limiting function. A high initial voltage provides the starting arc and the ballast then limits the current to maintain lamp longevity. Both magnetic ballast and electronic ballast are employed but electronic ballasts are recommended for their energy efficiency and reliability. The specifier should assure that the ballasts meet safety and operational features/specifications such as follows:

- Total harmonic distortion of less than 10% when operated at normal line voltage
- Power factor greater than 96% for large installations
- Output frequency above 42kHz to minimize interference with infrared control systems and to eliminate visible flicker
- Meet ANSI C82.11, Lamp Ballasts- High Frequency Fluorescent Lamp Ballasts
- Meet UL listing requirements and be rated for use in air handling spaces
- Five year warranty
- Meet applicable energy efficiency standards and FCC Title 24 requirements
- Ballasts should be labeled for use with a particular UVC lamp.

Since the ballast is likely to be provided as part of a package delivered by the UVC system manufacturer, these specifications should serve as a check list for the specifier and school facility personnel for assuring that the delivered components meet these requirements. Some of the major manufacturers of ballasts for UVC lamps are listed in Table 4 along with their web sites.

Table 4: Manufacturers of Ballasts for UVC Lamps	
Company	Web Site
Advance Transformer (PureVOLT)	www.advancetransformer.com
Amtek	www.amtekballast.com
Magnetek	www.magnetek.com
Philips	www.uvdisinfection.philips.com
Robertson Transformer	www.robertsonww.com
Sunpark	www.sunpkco.com
Universal	www.universalballast.com
UV Electric	www.uvelectric.com

Recommendations

Ultraviolet lighting systems to clean coils should be considered for situations where biofouling and consequent reduction in indoor air quality are likely to be linked as important issues. The conditions that promote coil fouling, moisture/humidity, and microbial sources may only be present in selected areas and situations in California but for those conditions, UVC systems could be valuable tools. Keeping the coils clean can

Applications Guidelines for Off-the-Shelf UVC Equipment for Coil Cleaning

reduce pressure drop and enhance heat transfer in coils that might otherwise be contaminated by growth of microorganisms and could therefore eliminate a source of contamination of the air flowing through the coil into the classroom. These guidelines provide information that can be used by school facility decision makers and their architects and engineers to decide whether UVC systems might help their situation and to provide pointers on how to select the right manufacturer, systems and components.

Applications Guidelines for Off-the-Shelf UVC Equipment for Coil Cleaning

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