Introduction

Information on ultraviolet lighting for coil cleaning can be found in a recently published article in *Engineered Systems* magazine and this article written by Roy Underwood with Sentry Ultraviolet, Inc. 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, it is not clear from available data whether coils get dirty enough in the environment to make cleaning a cost-effective proposition in some states. There is however anecdotal data that indicates that using ultraviolet light in the "C" spectrum (UVC) to clean coils that have been heavily fouled 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, all but Sentry UV's and it is patented location and to be placed on the coil and drain pan in the delivery plenum and is designed to bathe the coil continuously to provide ultraviolet radiation that deactivates microorganisms that would otherwise foul the surfaces of the air handling coil and drip pan. 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. Sentry's system does both. By being placed inside on the coils surface it handles both the coil surface the incoming air. The air at this point is moving at its slowest speed (CFM) due to being forced through the coil. This means longer dwell (UV dose).

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 blocks the UV allows visible light through. 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 handing units in the proximity of the cooling coil, because all other UVC system have to be placed outside the coil and some in the duct above the coil or in coming air duct.

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.[2] 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 days[3] 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. Sentry has also patented a new device that retrofits onto existing sewage vents. This is the other source of indoor pollutants. Every commercial building the US has a fresh air vents.

These vents have to open my law at lease once an hour. Some commercial buildings run them more often. In the fall and winter months when the air is heaviest gasses and pathogens are pulled/sucked into the buildings causing what is called the sick building syndrome. See the Sentry web site for more details. www.sentryuv.com

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 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.[4] 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 $\mu W/cm^2$
7 hours/day	0.5 $\mu W/cm^2$
10 minutes	22 $\mu W/cm^2$
2.5 minutes	90 $\mu W/cm^2$

UVC lamps should be designed to avoid emitting radiation below the 200nm wavelength that produces ozone. Lamps contain mercury and should therefore be treated with care if the lamps are broken and must be disposed of properly at a hazardous waste facility.

Plastic-coated wiring can be 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 cold 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. However, when 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 that 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, for example, student and teacher health and productivity that turns the decision in favor of this technology.

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 coils[15] 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 the 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.

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. Since Sentry's system is located on the coil surface it is encapsulated inside a quartz sleeve preventing any kind of moisture problem.

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 systems[17] 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. This is due to the fact Sentry holds a patent on the coil surface and that means others have to try to reflect their light on to the coil surface for other locations.

One manufacturer suggests that 24 inches of high intensity UVC tube length be used for every 4 ft^2 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 systems[18] 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 buildings[19] 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.

This brief overview given to you by Sentry Ultraviolet, Inc hopefully has help you better understand how UV works and the benefits of installing and using UV, a very green method, to maintain a cleaner and healthier indoor environment. Please ask for additional information by leaving us all your contact information and someone from Sentry will contact you. As a manufacturer of UV for several applications Sentry is proud to be an innovator of applying UV for new and better application. Thank you for taking the time to read this and we look forward to hearing from.