NADCA White Paper on Ultraviolet Lighting Applications in HVAC Systems

The HVAC Inspection, Maintenance and Restoration Association

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Introduction

Awareness of indoor air quality has increased substantially in recent years, and the systems that supply air to our living and working spaces are critical to the maintenance of a healthy indoor environment. As the global industry's leading advocate and trusted resource for reliable information, the National Air Duct Cleaners Association (NADCA) is uniquely qualified to provide guidance for consumers and the industry on the best practices for inspecting, cleaning and restoring HVAC systems.

It is generally agreed that source removal of contaminants remains the single best method for cleaning and decontaminating HVAC systems. One of the tools used to improve air quality from HVAC systems is the use of ultraviolet lighting within the system, intended to decrease the level of airborne pathogens and allergens going through the HVAC system and thus into the indoor air environment. Currently a broad range of information exists regarding the use and efficacy of ultraviolet lighting. In working with all parties associated with indoor air quality, NADCA recognizes the need to provide direction in this area.

Although the following information reflects the current state of the art for the use of ultraviolet lighting in HVAC systems, readers should recognize that new developments regularly occur and should familiarize themselves with the most current information when determining the appropriate steps to take.

Disclaimer

NADCA recognizes that differences in opinion will exist as to how to manage the use of ultraviolet lighting in HVAC systems. NADCA also recognizes that industry professionals will decide whether or not the application of ultraviolet lighting is appropriate for a given HVAC system, based on the unique circumstances surrounding that system. Ultimately, the decision of whether or not to apply ultraviolet lighting to an HVAC system rests with the owner of the system.

Ultraviolet lighting does not clean HVAC systems and should not be used as a substitute for HVAC cleaning.

This document was written in the United States of America and is intended primarily for use in that country. This material may also prove useful for industry professionals and others operating outside the USA. All users of this document are encouraged to refer to applicable federal, state/provincial, and local authorities having jurisdiction over the subjects addressed within this document.

Definition of Ultraviolet Lighting

A rainbow is made when light shines through droplets of water and breaks into its various colors. The light just beyond the violet end of the spectrum is not visible to the naked eye and is called ultraviolet ("beyond violet"), known commonly as UV light.

There are three types of UV light: A, B, and C, each representing a different section of the UV light spectrum. Type C, known as UVC, is the form used for germicidal activity. Although 10% of the sun's radiation is composed of UV light, virtually all of the sun's UVC rays are blocked by the Earth's ozone layer, so most UVC exposure is created by artificial means.

Typical Use

When UVC light is used for germicidal purposes, it is referred to as UVGI, ultraviolet germicidal irradiation.

UVGI "deactivates" or kills microorganisms, including viruses, bacteria, molds, and other fungi by disrupting their DNA. "Deactivated" means the organism is not necessarily killed but can no longer reproduce. Some deactivate after microseconds of exposure while others require much longer exposure. However, the effectiveness of UVGI depends on a number of factors, including:

1. Intensity of lamp(s).
2. Length of time of exposure.
3. An organism's ability to withstand UVGI.
4. The presence of particulate that may protect the organism from exposure by providing shadows or a shielding effect.
5. Increased humidity which may protect the organism.
6. Location of the UVC lamp(s).
7. Ambient temperature.
8. Number of lamps.
9. Reflectivity of surrounding surfaces.

Among other things, UVC is used for:

- Upper-room air disinfection (lighting designed for the top of a room)
- Surface disinfection
- HVAC air disinfection
- Cooling coil disinfection
- Water treatments
- Curing plastics and other materials
- Printing
- Chemical processing

Application method in HVAC systems

Bioaerosols are airborne particles that contain living organisms or were released from living organisms. They exist in the air around us and in the air that passes through HVAC systems. Inactivating them reduces the risk of occupant illness, allergic response, and infection from microbes. The use of UVGI to reduce microorganisms on the surfaces and bioaerosols in the airstreams of HVAC systems dates back to about 1900.

UVGI in HVAC systems has been studied and reviewed extensively by many scholars internationally, by professional organizations such ASHRAE – the leaders in the HVAC engineering field, and by government agencies.

UVGI lamps are categorized by the internal pressure of the gas in the lamp. Low-pressure lamps are, by far, the most commonly used in HVAC systems. Medium-pressure lamps are typically used where critical levels of disinfection are required.

On hard surfaces, like evaporator coils and drain pans, where UVGI exposure is constant and within adequate proximity, the kill rate for organisms contacted is up to 99.9%. However, deactivating bioaerosols is a more complex activity.

A common question asked is, “How effective is UVGI at killing (deactivating) bioaerosols in the airstreams of HVAC systems?” The answer is, “The technology can be effective, but many variables can impact its effectiveness.”

For example, a single UVC lamp randomly placed in an HVAC system would not be nearly as effective as multiple lamps of the same intensity installed at strategic locations. To get maximum benefit from UVGI, the installer should be well-trained in proper placement of lamps and the proper intensity and number of lamps needed for optimal deactivation of bioaerosols.

A key report from the Air-Conditioning and Refrigeration Technology Institute (ARTI), the global association of the manufacturers of HVAC and water heating equipment, states, “Be extremely cautious regarding claims about UVGI systems’ high levels of inactivation of pathogenic bioaerosols…. It would be irresponsible to claim a high inactivation rate for a pathogenic bioaerosol without substantial testing. Even with substantial testing, design failures may occur.”[1]

Studies of UVGI in commercial HVAC systems are not common. However, one study of office systems reports a 25-30% reduction in airborne bacteria when UVGI was used on HVAC drip pans and cooling coils. [2] Comparable results would require approximating the conditions of the study, including the number of lamps used, lamp intensity, lamp placement, and the initial condition of the drip pans and cooling coils.

Organisms vary dramatically in how quickly they deactivate from UVGI. Bacteria deactivate faster than fungi spores by an approximate factor of 200:1.[3] Some bacteria and mold spores are resistant to UVGI. The rates (length of exposure and wattage) required for deactivating specific species of microorganisms are available in various reference materials on UVGI.

Low-pressure UVC lamps operate best at 72° - 105° F, less effectively below 72°, and are not operable below 32° F. When placed in the airstream of an HVAC system, the operating temperature of the lamp will be altered through cooling or heating or through heat transfer because of air flow, potentially impacting the effectiveness of the lamp. Additionally, humidity can impact optimum operating temperature. While the impact can be significant, above 32° F UVC lamps still maintain a degree of effectiveness in HVAC systems, depending on ambient air conditions.

Medium-pressure lamps are more effective at lower temperatures than low-pressure lamps. However, they have shorter life spans, consume more energy and are rarely used in HVAC systems except for specialized commercial applications.

UVGI can be amplified by using certain reflective materials in the near vicinity, thus increasing its effectiveness against bioaerosols.

UVC lamps have a limited lifespan and their effectiveness reduces over time. In HVAC systems, they typically need replacement after one to three years, depending on the manufacturer’s specifications.

Any installation of a UVC lamp in an HVAC system should include a method of visually inspecting it periodically. Dirty lamps will result in reduced effectiveness, and the rate at which a lamp will become dirty depends on the cleanliness of the air that passes by the lamp. If the lamp has become dirty, it should be cleaned with a lint-free cloth and commercial glass cleaner or alcohol. Never inspect or

clean a lamp while it is turned on. If it is burned out or failing, it should be replaced.

All access panels or doors near UVC lamps where UV radiation may penetrate or be reflected should have clearly visible warning labels on the outside in appropriate languages.

Since improper placement of UVC lamps can result in poor efficiency and hazards, it is recommended that anyone installing UVC lamps in HVAC systems be fully educated on the matter and related issues. Detailed instructions can be found in the *ASHRAE Handbook – HVAC Systems and Equipment*, Chapter 17: Ultraviolet Lamp Systems.

Hazards

Material Decomposition

Organic material is that which was derived from living organisms, such as rubber, petroleum products and many components of adhesives. UVGI can seriously degrade organic materials over time in an HVAC system, including filters, sealants, gaskets, and wiring insulation, resulting in air leaks, fire hazards, and/or a loss of system performance. This is a major consideration when choosing if and where to install UVC lamps in such a system. Vulnerable materials should be shielded or substituted. If in doubt, consult the manufacturer of the potentially vulnerable material.

Filters, for example, vary greatly in their resistance to UVGI. Some made of inorganic fibers may hold up well, while others using organic fibers, binders or adhesives may disintegrate. Consult your filter dealer and, if needed, the UVC lamp manufacturer for guidance. Ensure the client is informed if specific types of filters are required in the system due to UVC lamp proximity.

The rate of UVGI deterioration for many materials was reviewed by ASHRAE in their research project RP-1509 and may be found in their final report by Kaufman.[4] See also Kowalski (2009) for additional information on UV photodegradation.[5]

ASHRAE recommends, “Although UV-C photodegradation is of concern, with the selection of the proper material or metallic shielding of other components, the problem is significantly reduced and components can be expected to meet product design life. As a simple, practical approach, it is wise to shield all organic material components within about 5 feet of the UV lamp.”[6]

Human Exposure

UVC exposure can be dangerous and should be taken seriously. Workers should not be subject to direct UV exposure. Lamps should be powered off, following lockout/tagout procedures, when being serviced. Per the ASHRAE Handbook, "if exposure is unavoidable, personnel should wear protective clothing (no exposed skin), protective eyewear, and gloves. Most eyewear, including prescription glasses, are sufficient to protect eyes from UV, but not all offer complete coverage; standard-issue protective goggles may be the best alternative."

Most of us are familiar with warnings of sunburn from too much UVA or UVB exposure. Direct UVC exposure – as used in HVAC systems - is hazardous, particularly to the skin and eyes. Ocular damage consists of inflammation of the eye with discomfort, *sometimes severe*, appearing within 6-12 hours after exposure and usually resolving within 24-48 hours. Skin damage from excess exposure is similar to sunburn. The ASHRAE Handbook reports that "acute overexposure to UVC band radiation is incapacitating, but generally regresses after several days, leaving no permanent damage."[7]

Mercury Exposure

UVC lamps are a type of bulb referred to as a compact fluorescent lamp (CFL). CFLs contain a small amount of toxic mercury so if a bulb breaks, care should be taken to reduce exposure.

Procedures for broken lamp cleanup can be found in the *ASHRAE Handbook – HVAC Systems and Equipment*, Chapter 17: Ultraviolet Lamp Systems:

If a lamp breaks, all workers must exit the HVAC equipment. Panels or doors should be left open and any additional lamp chamber access points should also be opened. Do not turn air-handling unit fans back on. After a period of 15 minutes, workers may reenter the HVAC equipment to begin bulb clean-up.

If a lamp breaks in a worker's hand, the worker should not exit the HVAC equipment with the broken bulb. Carefully set the broken bulb down, then exit the equipment. When possible, try not to set the broken lamp in any standing condensate water. Follow standard ventilation and reentry procedures.

Cleanup requires special care because of mercury drop proliferation, and should be performed by trained workers. As a minimum, workers should wear cut-resistant gloves, as well as safety glasses to protect eyes from glass fragments. Large bulb pieces should be carefully picked up and placed in an impervious bag. HEPA vacuum

the remaining particles, or use other means to avoid dust generation.[8]
Additionally, according to scientists from the Lawrence Berkeley National Laboratory of the U.S. Dept. of Energy, following the cleanup steps below results in about as much mercury exposure as a bite of tuna:

1. "Ventilate the area where the lamp is broken with outside air,
2. "Promptly clean up and remove any visible debris to a ventilated (preferably outdoor) area,
3. "Vacuuming forces mercury into the air and should be avoided if possible. (Any vacuuming should be limited to one or two minutes, and the vacuumed space should be vacated, while ventilating, for one to two hours. In addition, the vacuum cleaner should be emptied, then used and stored in ventilated areas until it has been used several more times.)

"If they have already broken the lamp and vacuumed it up and are worried, you can tell them that they have been exposed to about as much mercury as they would get from eating the FDA recommended amount of fish per week. They can reduce any potential risk to a prenatal infant by limiting their fish intake over the next couple of weeks."[9]

Ozone Generation

Ozone can be generated by UV lamps depending on the wavelength of the light generated. Ozone is produced at a wavelength of 185 nanometers. To avoid ozone production, use UVC lamps with a wavelength of 254 nanometers.

Best practices

It is generally agreed that source removal of contaminants remains the single best method for cleaning and decontaminating HVAC systems.

The application of UVGI in HVAC systems can be an effective means to reduce airborne pathogens but *only* if lamps are properly and strategically installed in sufficient number and/or intensity and are properly maintained.

If installed in HVAC systems without proper training, UVC lamps can be largely ineffective and can create hazards or material decomposition that negatively impact the functioning of the system and put occupants and installers at risk.

It is recommended that installers be well educated on the materials from the manufacturer and in the *ASHRAE Handbook – HVAC Systems and Equipment*, Chapter 17: Ultraviolet Lamp Systems.

It is also recommended that proper safety precautions be taken to protect workers and occupants from unnecessary UVGI exposure and the effects of lamp breakage should it occur.

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