IUVA Draft Guideline IUVA-G03A-2005

International Ultraviolet Association

Guideline for Design and Installation of UVGI In-Duct Air Disinfection Systems

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International Ultraviolet Association

NOTE: The International Ultraviolet Association (IUVA) Draft Guidelines for UVGI Air Treatment Systems are international voluntary consensus guidelines developed under the auspices of the IUVA. This consensus represents a substantial agreement reached by parties in Academia and Industry with direct or indirect interests in air treatment with UVGI and related technologies. This consensus signifies concurrence of the majority of the individuals, organizations, and businesses involved in the drafting of this guideline but does not necessarily represent a unanimous opinion and the contents are subject to continual review, expansion, and revision. Compliance with this guideline is voluntary. Consensus is obtained by review of IUVA members and input from various agencies, professional societies, and the public.

This guideline does not supersede nor invalidate any local or governmental standards or the requirements of responsible authorities and the applicable documents should be consulted and adhered to where applicable. Relevant federal and professional guidelines and standards have been identified in the Bibliography and these should be consulted for further information.

The IUVA Chair should be contacted for participation in the development and review process of subsequent revisions, or in regards to interpretation, constructive criticism, and permission to reprint portions of the guideline. This document is being released to the public in the current draft form for review and comment for a period of approximately one year. Comments may be sent to drkowalski@psu.edu.

IUVA does not advocate the use of any particular manufacturer's equipment or services and the use of specific equipment in the tables and figures should not be construed as such. It is impermissible for vendors to use any part of this document to imply product preferences.

DISCLAIMER: The International Ultraviolet Association has developed and promulgated this guideline for the benefit of the public and private sectors based on the best available information and technology and accepted industry practices. IUVA cannot guarantee that installation, operation, maintenance, or testing of the systems specified herein will be nonhazardous or without risk.

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1.0 Introduction

Ultraviolet germicidal irradiation (UVGI) systems are used for air and surface disinfection. This document is one of a series of guidelines and standards issued by IUVA to foster the development of effective and reliable air treatment systems intended to control or improve the aerobiological quality of indoor environments.

1.1 Purpose & Scope

This guideline is written to assist the design and installation of air treatment systems in existing buildings, specifically those based on ultraviolet disinfection technologies. This guideline addresses ultraviolet germicidal irradiation (UVGI) air and surface disinfection systems used to disinfect indoor air in buildings, facilities, transportation vehicles, and other enclosed indoor environments. The primary focus of this document is air treatment systems retrofitted in existing commercial office buildings, schools, health care facilities, and residential and other buildings. This document addresses Class D (in-duct air disinfection) UVGI systems. See IUVA-G01A-2005, “General Guideline for UVGI Air and Surface Disinfection Systems,” for definitions of the system Classes.

NOTE: *This draft guideline is issued to IUVA members and associates for comments as of March 30, 2006. The current contents are incomplete and do not necessarily represent any consensus viewpoints and it is not to be released to non-members without IUVA permission. Upon completion of the review and comment process the subcommittee will issue a draft of this guideline for public comment. Comments are due by 5-10-2005 and should be sent to drkowalski@psu.edu.*

2.0 UVGI In-duct System Installation Guidelines

This section provides some basic guidelines on installing UVGI systems. These guidelines are not exclusive and not intended to limit the design process since many alternatives may be available to the designer depending on the nature of the ventilation system or building under consideration. For information on sizing UVGI systems and on maintenance see IUVA-G01A-2005, “General Guideline for UVGI Air and Surface Disinfection Systems.” For information on testing UVGI systems see IUVA-S01A-2005, “Standard for the Testing and Commissioning of UVGI In-Duct Air Treatment Systems.”

2.1 Location of UV Lamps

For air disinfection applications, it is necessary to locate UV lamps in an area where sufficient exposure time occurs and in which design velocities are not greatly exceeded. In general, a minimum exposure time of 0.25 seconds, combined with an air velocity of 500 fpm, implies that a space of at least 2 feet is necessary for UV lamp installation. For surface or cooling coil UV systems this minimum does not apply. Lamps must also be located downstream of the filters. Lamps may be located around the cooling coils, if possible, as this provides that added benefit of cooling coil disinfection. Placing lamps too close to heating coils is not recommended as the excessive local heat and radiative heat transfer may burn out the lamps or the ballasts (if internal) prematurely.

Location of the UV lamps is, in general, the prerogative of the designers or engineers and will not necessarily have a major impact on the UV exposure, although it should be reviewed and evaluated. Preferred or possible locations in a typical ventilation system can include any and all of the following:

1. Downstream of the filter bank
2. Upstream of the cooling coils
3. Downstream of the cooling coils
4. Upstream of the heating coils
5. In the supply ductwork
6. In the fan housing (if downstream of filters)
7. In the mixing plenum
8. Between prefilters and final filter

Figure 2.1 illustrates one example of the spacing and location requirements for a UVGI system located in an air handling unit. The two feet of spacing upstream and downstream of the cooling coils will provide a total travel length of four feet, and at 500 fpm the exposure time will be 0.25 seconds. Alternate locations are possible such as placing the lamps in a four foot space upstream or downstream, or location of the UVGI system in the ductwork or mixing plenum. The lamp positions in Figure 2.1 represent a figurative example and do not necessarily represent any preferred locations, as many lamp locations and orientations are possible that will produce acceptable results.

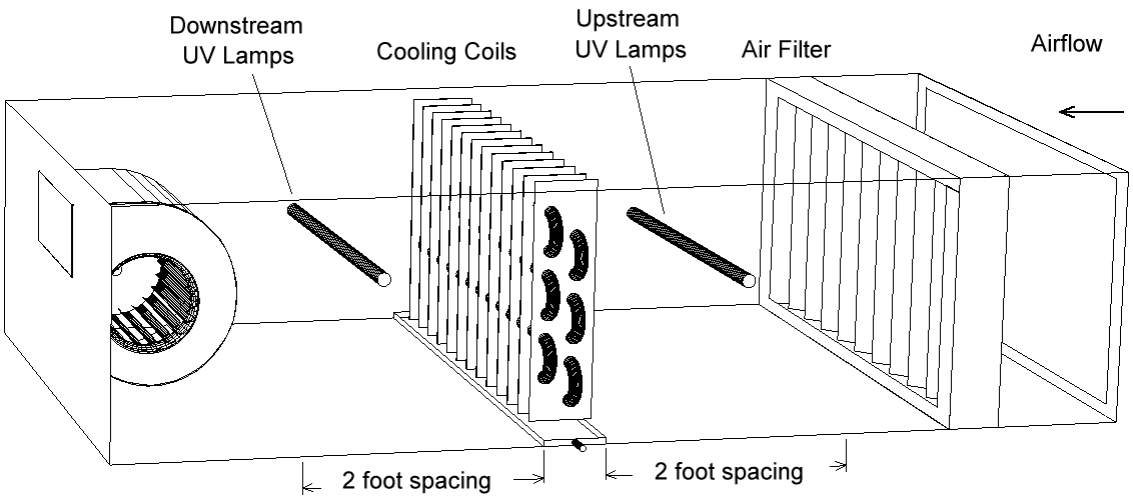

Figure 2.1: Location and spacing for UVGI system in an air handling unit.

2.2 Location of UV Lamp Ballasts

UV lamp ballasts should preferably be located external to the ventilation system although this is not currently a strict requirement due to so many systems that have integral lamp ballasts that must be located wherever the lamp is located. One of the problems with lamp ballasts being located inside air handling units is that they may be exposed to temperature and humidity extremes.

If lamp ballasts are located in an internal lamp housing, the housing should be of drip-proof construction or other approved housing method. If lamp ballasts are located external to the air handling unit or ductwork, the wiring must be run through conduit such that there is no exposed wiring inside the air handling unit. Exposed wiring may be subject to deterioration inside and air handling unit and may also be exposed to UV irradiation, which may cause photodegradation over time and thus pose a fire hazard.

2.3 Operating Conditions

Both the UV lamp and the ballast should be located such that the ambient operating conditions (i.e. temperature and relative humidity) are within the component design or operating limits. Refer to manufacturer's information for design operating conditions. In general, both UVGI and filters are designed to operate at an air velocity of 500 fpm, although some lamps may be suitable for operation at higher velocities. Variations in air velocity (i.e. +/- 100 fpm) may be acceptable depending on the manufacturer's lamp but such variations should be evaluated to include or assess the impact on UV output. See IUVA-G01A-2005, "General Guideline for UVGI Air and Surface Disinfection Systems," for

information on derating UV lamp output when operating outside design conditions.

2.3.1 Normal Indoor Conditions

Normal indoor operating conditions are unlikely to be detrimental to either UV lamps or ballasts. Typically, indoor conditions will remain in the range of 70-75^{o}F and 50-70% RH, neither of which is likely to adversely affect UV lamps or ballasts.

2.3.2 Normal Air Handling Unit Conditions

Ballasts are typically rated, by UL or other organization, for a maximum ambient operating temperature of either 40^{o}C or 50^{o}C (104^{o}F or 122^{o}F). Although this certainly covers normal indoor and outdoor upper temperature limits, it is possible that interior air handling unit temperatures near the heating coils could exceed either of these temperatures, especially when the ballast is exposed to direct radiant heat transfer from the coils.

UV lamps are typically designed for operation in air velocities of between 400-500 fpm and air temperatures between limits of about 40^{o}F-110^{o}F. Both air velocity and air temperature can affect the UV output of the lamps and the manufacturer usually provides curves of UV output vs. air temperature and air velocity. These later curves, if available, should be used in the lamp selection and sizing process to assure that UV output meets design requirements even under the most adverse conditions. Even UV lamps that adjust to the ambient conditions may have some decrease in output and the manufacturer should be consulted for information on their performance. In general, the designer should size the lamp (i.e. the lamp total wattage) based on the worst case cooling effects (i.e. highest air velocity & highest or lowest air temperature).

2.3.3 Outside Air Conditions

UV lamps are generally placed in locations downstream or preheaters and filters, and are unlikely to be exposed to outside air temperatures. If UV lamps are, in fact, located in plenums where temperatures will approach outside air high and low extremes, then the lamps will likely fall outside of their operating range. The typical minimum operating temperature for most UV lamps is about 45-50^{o}F. No credit can be taken for a lamp when it operates below it minimum, or above its maximum, operating temperature. In other words, it should be assumed the lamp has zero UV output under such conditions. Furthermore, operating a lamp under outdoor temperature extremes may cause damage or otherwise limit performance or lifespan.

2.3.4 Heating Coils

Location of UV lamps in proximity to heating coils may result in lamp overheating, or ballast overheating if ballasts are integral. Although heating coils may be designed to heat the air to some normal indoor temperature, the local air temperature at the coils may exceed normal temperatures. Furthermore, the location of lamps or ballasts near heating coils, and especially above heating coils, may result in thermal radiation heat transfer that could overheat and destroy the lamps or ballasts. In addition, the preheating of air handling units by operating the coils prior to initiating airflow, a practice not uncommon in northern states, may result in a stratified layer of hot air inside the air handling unit which could destroy lamps and ballasts.

If lamps are located near heating coils as shown in Figure 2.2, they may be exposed to infrared heating, which may cause aging or may degrade the ballast. Ballasts located internal to the AHU should be rated for a minimum of 135^{o}F). However, ballasts located too close to heating or preheating coils may see higher temperatures due to thermal radiation and if these ballasts cannot be located externally then ballasts rated for higher temperatures should be considered.

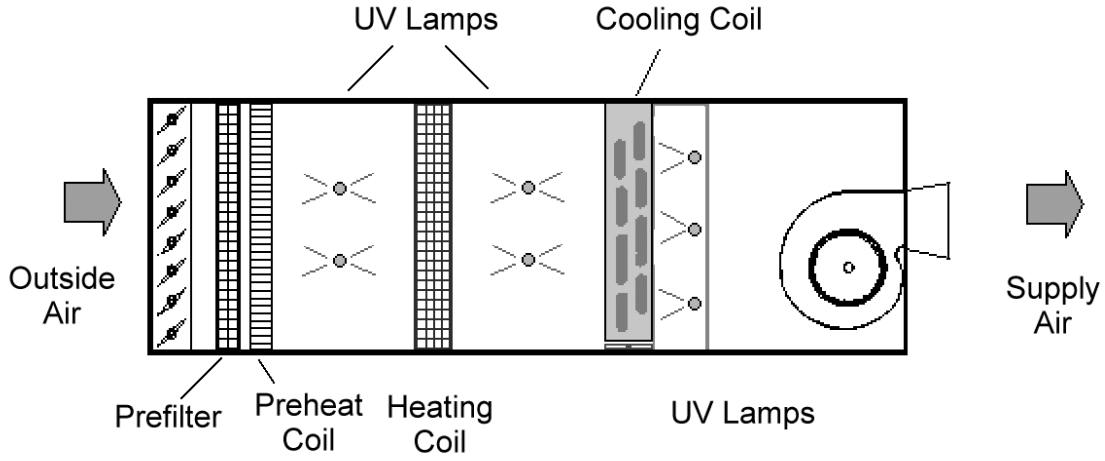

Figure 2.2: Ballasts located internally in an AHU in proximity to heating or preheating coils may see higher than design temperatures due to thermal radiation.

2.3.5 Moisture and Humidity

In general, lamps and ballasts are moisture resistant and can tolerate extremes of relative humidity indefinitely. However, unless they are designated as waterproof lamps, they may not tolerate water intrusion or excessive moisture for extended periods of time. Lamps and ballasts should not be located in areas where water may cause problems due to excessive condensations (i.e. near or below cooling coils) or where water sprays may occur (evaporative coolers). Under conditions where a UV lamp must be placed into a wet environment, it

may be necessary to select a UV lamp that is either moisture resistant or is designed for water immersion applications. Plastic-enclosed drip-proof UV lamps are currently available for airside applications and manufacturers should be consulted for these special needs.

2.4 Wiring and Electrical Connections

All wiring and electrical connections should be handled by trained electricians or certified professionals. All electrical wiring should be in accordance with industry standards or UL/ETL requirements. Wiring inside air handling units should be routed through conduit for safety and fire protection reasons.

2.5 Control Systems

Various control architectures may be used for UVGI systems installed inside air handling units, including full time operation, operation linked to fan operation, and timers or switches to limit operation or shutdown equipment when personnel enter the area.

2.5.1 Full Time Operation

For HVAC systems that operate full-time, the UVGI system can also be operated full time. No special controls, other than an ON/OFF switch, are required for this operating arrangement.

2.5.2 Part Time Operation

In buildings where occupancy is not full time but HVAC operation is, the UV lamps could be disengaged during unoccupied periods, although the actual energy savings from such an arrangement may be minimal. Such a control scheme could be effected by a timer, or even by a manual switch under maintenance personnel control.

2.6 Shutoff Switches

Shutoff switches placed locally near the UV lamp installation are necessary for maintenance purposes so that personnel are not exposed to operating UV lamps. Sometimes circuit breakers are used for this function, especially when power to the lamps comes from the same circuit as power to the fans.

2.6.1 External Switches

Switches mounted external to the air handling unit are suggested as a means of disengaging the UV lamps prior to maintenance or inspection activities. Circuit breakers may also be used to disengage UVGI systems prior to entry. Maintenance procedures should be revised, if a UVGI system is installed, to address the shutdown of UVGI systems.

2.6.2 Access Door Switches

An alternative to an externally mounted switch is a switch placed on the nearest access door such that opening the door disengages the UV lamps. Access doors are often subject to slamming and rough treatment, and such activity may damage switches. It should be ensured that any switches used for this purpose are capable of withstanding rough handling. Ensure switches are of robust construction and can tolerate rough handling.

2.6.3 Motion Detectors

An alternative to an access door switch is the use of a motion detector (i.e. radar or sonic sensor activated) that trips the UV lamps off whenever significant motion (i.e. an opening access door) is detected. Such an approach is a reasonable means of protecting maintenance personnel but may also result in periodic lamp shutdown due to detector activation from other means (i.e. vibrating duct walls, loose insulation, etc.).

2.6.4 High Temperature Cutouts

In addition to shutting down the fans for maintenance personnel, it may also be prudent to shutdown the UV lamps on high temperature. In the unlikely event that the temperature of the lamp assembly exceeds design operating temperature, for whatever reason (i.e. local over-heating), the lamp or ballast may be destroyed. A simple high temperature cutout can save the cost of the much more expensive lamps and ballasts.

2.7 Warning Signs & Safety Training

Warning signs detailing the danger of skin or eye damage due to UV exposure should be placed at all appropriate locations in the vicinity of a UV lamp assembly. In addition, personnel should be informed or trained to understand the hazards associated with UV. An example of a warning sign is shown in Figure 2.3.

Figure 2.3: Typical warning sign for UVGI systems.

2.8 UV Exposure of AHU Components

An inspection should be conducted of the UV lamp installation both before and after to identify any materials that may be subject to UV Photodegradation. Some consideration should be given to changing out or covering up any materials that may degrade under prolonged UV exposure and result in fire hazards or other damage. Plastic coated wires may become brittle over time and break, resulting in potential fire hazards. Wires should be run through conduits to avoid this problem. The presence of any type of plastic materials like plastic fiber filters may result in those materials degrading over time and the potential for fire or other hazards should be addressed.

Not all photodegradation is necessarily a hazard or a danger. Rubber or plastic fan belts are typically thick enough that no UV penetration occurs and Photodegradation is limited to a patina on the surface. Furthermore, if the fan belt should break, it will likely be noticed and replaced in short order. For more specific information on photodegradation see IUVA-G01A-2005, “General Guideline for UVGI Air and Surface Disinfection Systems.”

2.9 Using Reflective Materials

Enhancement of UVGI effectiveness is possible through the use of materials that are highly reflective in the UV spectral range. Polished sheet aluminum is the most common material used in such applications. Aluminum foil insulation is also currently available and is both inexpensive and easy to install. Surrounding the internal surfaces of an air handling unit with reflective materials may increase or multiply the UV irradiance field and will also deliver UV exposure to areas that would otherwise be shadowed. Reflective surfaces may require periodic cleaning although upstream filtration will tend to keep both the UV lamps and the reflective materials clean. See Appendix B in IUVA-G01A-2005, “General Guideline for UVGI Air and Surface Disinfection Systems,” for a list of material reflectivities.

3.0 UVGI Application Notes

This section provides some additional notes and supportive information to assist the installation of UVGI air treatment systems in specific types of facilities.

3.1 Commercial Buildings

Large commercial buildings generally have central air handling units in which UVGI systems can be retrofitted. It is recommended that the outside air be filtered with both a dust filter and a MERV 6-8 filter to control dust, pollen, fungal and bacterial spores, and environmental bacteria. It is recommended that the return air be filtered with a MERV 10-15 filter and that a UVGI system be installed around the cooling coils with an URV 11-15 rating. The latter system should also be designed to provide for cooling coil disinfection if possible. See IUVA-G04A-2005, “Guideline for the Design and Installation of UVGI Cooling Coil Surface Disinfection Systems,” for further information on cooling coil UV systems. Figure 2.4 illustrates the preferred locations and sizes of air treatment system components.

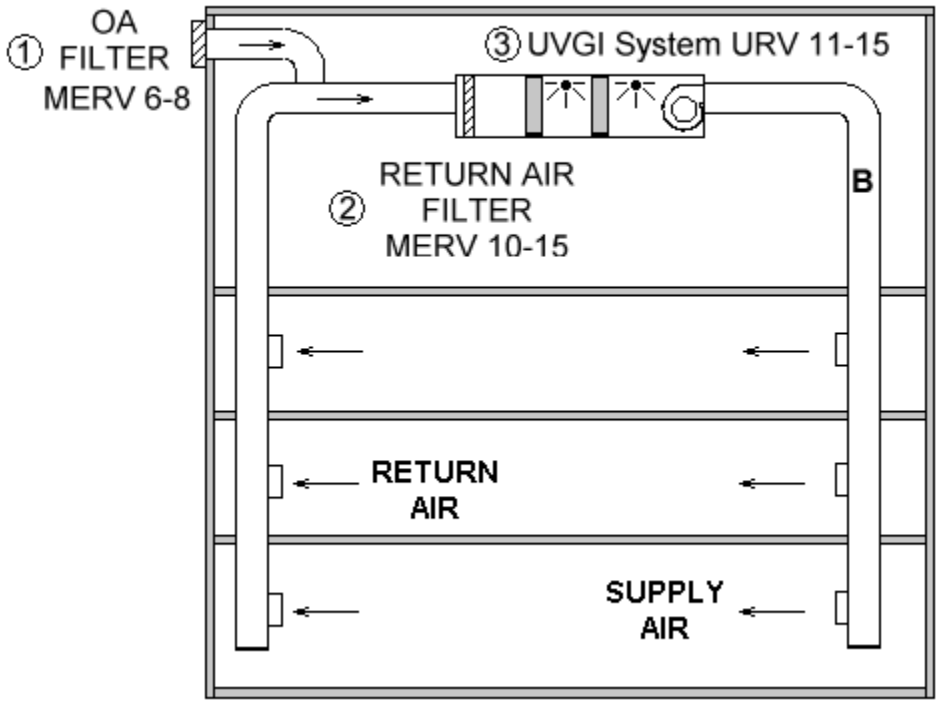

Figure 2.4: Suggested locations and sizes of filters and UVGI system.

In addition to the stated sizes for the air treatment system, it is recommended that the Building Protection Factor (BPF) be estimated to be at least 50% and preferably in the 80-95% range. See IUVA-S07A-2005, “Standard

for the Evaluation and Testing of Building Protection Factors," for information on estimating the BPF.

Any commercial building should meet ASHRAE requirements in Standard 62.2-2001, "Ventilation for acceptable indoor air quality." Minimum requirements are 15% outside air or a minimum of 20 cfm per occupant, or as specified per in the ASHRAE Standard (ASHRAE 2001). Failure to meet ASHRAE minimum standards may impact the effectiveness of any installed air treatment systems.

3.2 Schools

It is particularly important that schools be provided with air treatment due to the number of potential airborne diseases that may be exchanged in classrooms, and due to the susceptibility of children and the problem of student hygiene. Recommendations for system placement and size are identical to those shown for commercial buildings (see Figure 2.4). It is recommended that the outside air be filtered with both a dust filter and a MERV 6-8 filter to control dust, pollen, fungal and bacterial spores, and environmental bacteria. It is recommended that the return air be filtered with a MERV 10-15 filter and that a UVGI system be installed around the cooling coils with an URV 11-15 rating.

Although schools may have central air handling units in which UVGI systems can be installed, it has often been the practice to place upper room UVGI systems directly inside individual classrooms. For information on upper room UVGI systems see the References (First et al 1999, NIOSH 2005). Local recirculation units can also be used in place of central air handling unit air treatment. For more information on sizing and selecting recirculation air treatment systems see IUVA-G05A-2005, "Guideline for the Design and Installation of UVGI Unitary Recirculation Air Disinfection Systems."

School building should meet ASHRAE requirements in Standard 62.2-2001, "Ventilation for acceptable indoor air quality." Minimum requirements are 15% outside air or a minimum of 20 cfm per occupant. Failure to meet ASHRAE minimum standards may impact the effectiveness of air treatment systems.

3.3 Residential Homes and Apartments

Residential homes with central HVAC systems can have UVGI systems installed in the air handling unit or ductwork. Retrofit kits for such applications are currently available and mechanical contractors can also be hired to install these UVGI systems. Often the space available in these small ventilation systems is so limited that insufficient travel time will limit the effectiveness of such systems. In such cases it may be more fruitful to add a recirculation UVGI system to one or more rooms of the house.

Naturally ventilated homes have limited options for air treatment other than the addition of recirculation units. Recirculation units should provide approximately 1 cfm per square foot in the area in which they serve and should

provide about 1-6 ACH. Requirements for filter and UVGI system ratings are the same as for commercial buildings. Filters should preferably be in the MERV 10-15 range and UVGI systems in the URV 11-15 range. For outside air filtration, filters could be added to windows or attic vents to reduce entry of pollen and spores. Some window filters are currently available for such applications. It is recommended that outside air filters be rated at least MERV 6-8.

Apartments with central air handling units can have UVGI systems installed centrally. Alternatively, and if the owners have no interest in air treatment, apartment dwellers can use local recirculation units to obtain air treatment.

3.4 Health Care Facilities

UVGI systems have a variety of applications in health care facilities, including ventilation systems for general areas, isolation rooms, and neonatal wards, burn wards, TB wards, AIDS patients, operating rooms, laboratories, and equipment disinfection. The specific application will dictate the type of UVGI system appropriate for the facility. For the general area ventilation system, recommendations for system placement and size are similar to those shown for commercial buildings (see Figure 2.4). The outside air, air exchange rates, and air filtration requirements for health care facilities have been specified by ASHRAE (ASHRAE 1999a). These specify filters of specific dust spot efficiencies that are shown in table 2.1 in terms of their approximate MERV filter ratings.

Table 2.1: Filter Ratings for Health Care Facilities

Area	1st Filter	2nd Filter	3rd Filter
Operating Rooms (OR)	MERV 7	MERV 13-14	HEPA
Procedure Rooms Treatment Rooms Intensive Care Units (ICU)	MERV 7	MERV 13-14	-
Laboratories	MERV 13	-	-
Administrative Areas	MERV 7	-	-

NOTE: Approximate per ASHRAE Handbook of Applications and ASHRAE Standard 52.2-1999.

In addition to filtration, it is recommended that a UVGI system be installed around the cooling coils with an URV 11-15 rating. Location of the system should be in accordance with the locations recommended for commercial office buildings (see Figure 2.4). Additional information on air treatment for Health Care facilities is available in the References (ASHRAE 1999a, ASHRAE 2003, Kowalski 2005, NIOSH 2005).

Local wards and operating rooms can benefit from local recirculation units sized to produce at least 6 ACH. For more information on sizing and selecting recirculation air treatment systems see IUVA-G05A-2005, “Guideline for the

Design and Installation of UVGI Unitary Recirculation Air Disinfection Systems." Operating rooms may also benefit from upper room UVGI systems, lower room UVGI systems, and overhead surgical site exposure systems. For information on upper room UVGI systems see the References (First et al 1999, NIOSH 2005).

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Appendix A: Checklist for UVGI System Design and Installation

Project		
Input Data	**Design Parameters**	**Enter values**
	UVGI Classification Code	
	Airflow, cfm	
	Air Velocity, fpm	
	Duct Width, cm	
	Duct Height, cm	
	Duct Length, cm	
	Travel Time, seconds	
	Air Temperature, Minimum/Maximum, C(F)	
	Relative Humidity, Minimum/Maximum, %	
	Total UV wattage, W	
	Is lamp burned in?	Y or N
	Lamp burn-in time, hours	
	Enter IESNA Lamp rating, $\mu W/cm^2$ at 1 meter	
	Are Filters included?	Y or N
	Enter Filter rating (MERV)	
	Enter lamp minimum & maximum operating temperatures.	
	Enter ballast maximum operating temperature	
	Are ballasts certified by UL, ETL or other lab?	Y or N
Analytical	Estimated URV of UVGI System (if applicable)	
	Was a zone model used to evaluate performance?	Y or N
	If so, provide the BPF for Scenario A	
	BPF for Scenario B	
	BPF for Scenario C	
	Were lamps corrected for cooling effects?	Y or N
	Enter cooling effect correction factor	
	Were lamps corrected for end-of-life decrease?	Y or N
	Enter correction factor for end-of-life decrease.	
Installation	**Installation Parameters**	
	Lamp location (see Section 6.1)	
	Is lamp downstream of heating coils	Y or N
	Distance downstream of heating coils	
	Thermal cutout switches included	Y or N
	Access door or manual switches included	Y or N
	Warning signs placed locally?	Y or N
	Training for maintenance personnel	Y or N
	Any UV leakage observed in vicinity of AHU?	Y or N
	Any UV leakage in nearest supply registers?	Y or N
	Is ballast located inside or outside air handling unit?	Y or N
	Is wiring, if any, inside the air handling unit?	Y or N
	If wiring is internal, is it routed through conduit per UL?	Y or N
	Do UV lamps disengage on fan shutdown?	Y or N
	Has area been inspected for possible photodegradation of materials?	Y or N
Maintenance	Maintenance Parameters	
	Inspection frequency	
	Filter replacement frequency	
	UV Lamp life or replacement frequency	
	Lamp irradiance testing frequency, if any.	