A Safer Germicidal Ultraviolet (UV) Air Disinfection Proposal

Ismail Gobulukoglu, Ph.D., Director of Research and Development (R&D),
Ultraviolet Systems, R&D Laboratory, 4500 South Pinemont Drive,
Houston, Texas, USA; Tel: 713-939-8889; Fax: 713-939-1101; ismailg@uvbiz.com

ABSTRACT

The popularity of ultraviolet air disinfection systems is increasing with advances in lamp technology, and more reliable data about the effectiveness of UV. These advances have resulted in more commercial interest of UV for air treatment systems. One of the problems associated with UV air disinfection systems is the fouling of quartz lamps and sleeves that reduces the disinfection efficiency in traditional UV systems. The decrease in the average UV intensity transmitted to the air due to fouling and the necessary cleaning of the quartz lamps and sleeves adds significant cost to a standard UV system. Additionally, due to the fragile properties of quartz lamps and sleeves, the potential for breakage and subsequent air contamination is always present in HVAC systems. Therefore from a cost, maintenance and safety stand point; it would be best if quartz sleeves and lamps could be protected with non-fouling and non-breaking properties.

INTRODUCTION

Numerous regulatory, process and system design changes have impacted the use and implementation of germicidal ultraviolet (UV) disinfection systems. A wide range of applications has resulted in the use of germicidal UV systems for air disinfection in the United States. Germicidal UV air disinfection systems are receiving increased attention in the HVAC industry, as a non-chemical method that can contribute to the improvement of indoor air quality (IAQ) (4,5,7-13). There has been extensive research on ultraviolet light disinfection technology in air applications (1-3,6) There are several factors that affect ultraviolet light efficiency, such as lamp output, lamp aging, and fouling of contact surfaces.

EQUIPMENT OPERATIONAL FACTORS

Ultraviolet lamp efficiencies decline over time. Therefore, it is important when adopting a minimum intensity threshold for ultraviolet light treatment for the standard to state the output of the lamp at its lowest point according to the manufacturer's suggested effective time of usage. Industry brochures show approximately thirty percent (30%) reduction in light transmission efficiency over a period of 10,000 hours. Operators and maintenance crews need to be adequately trained to service the equipment as recommended by the manufacturer.

FOULING, PLATING AND DAMAGE TO LAMPS AND SLEEVES

Fouling of the unit's quartz surfaces reduces the light energy reaching the air. Typically, high quality fused quartz sleeves have a UV transmittance of more than ninety percent (90%) when new and clean. With time, the surfaces of the quartz sleeves that are in contact with the air in the system start collecting organic and inorganic debris – such as dust particles, etc. – causing a reduction in UV transmission. The amount of fouling on the lamp sleeve will depend on the quality of air (filtered air or non-filtered air), as well as the material of which the quartz sleeve is made. It is therefore very important to maintain the surfaces of the sleeves to ensure that they are clean and free of deposits. In order to keep the maintenance costs low, one can look into other types of material for the replacement of the quartz sleeve. The material should have non–fouling and non–breaking properties with the most UV transmission capability at 254.7 nm. The quartz itself is famous for being very fragile and can break during shipment or cleaning. This poses a potential health hazard to maintenance personnel and those in the downstream airflow. In order to reduce maintenance costs, new materials have been evaluated and patents applied for. A typical in-line germicidal UV air disinfection system with multiple lamps is shown in Figure 1.

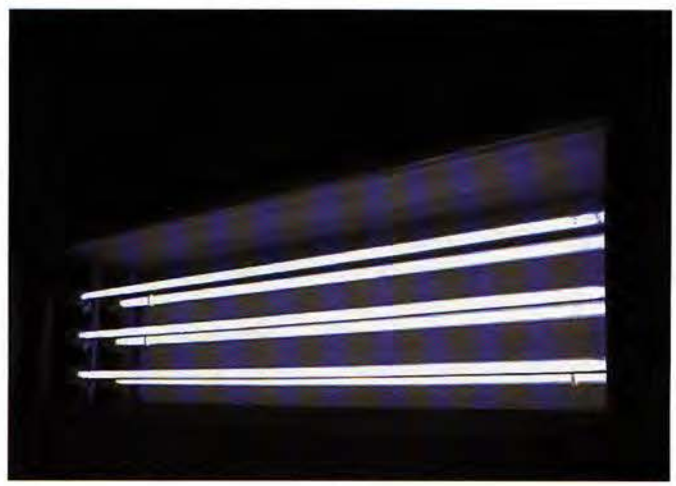

Figure 1. In-line germicidal UV air disinfection system for HVAC ducting with Fluoro-Safe™ sleeve technology.

EXPERIMENTAL

One possible solution to address the problem of quartz breakage is by studying the properties of a specially engineered sleeve (patent pending), called Fluoro-Safe™ (Figure 2). The non-fouling properties of the material that are used to make the sleeves reduces the need for most physical or chemical cleaning and hence, reduces the cost as well as maintenance time for most UV air disinfection units. In case of impact to the lamp, the Fluoro-Safe™ wrap retains the pieces of glass as well as other contents from the lamp within a sealed environment; therefore helping to prevent contamination to the downstream air flow. The test data presented will show the UV transmittance at 253.7 nm for various types and thicknesses of the Fluoro-Safe™ sleeves as well as data on the improvement of the surface reflectivity in a model UV germicidal air disinfection system. It will be shown that any UV energy loss due to the use of the Fluoro-Safe™ material is recovered fully by the right design, thickness of the sleeve material and lamp type. Additionally it will be shown that a reflective material placed on the inner walls of the air disinfection unit where the UV lamps are placed, dramatically increases the UV intensity, therefore, achieving adequate disinfection of the air stream.

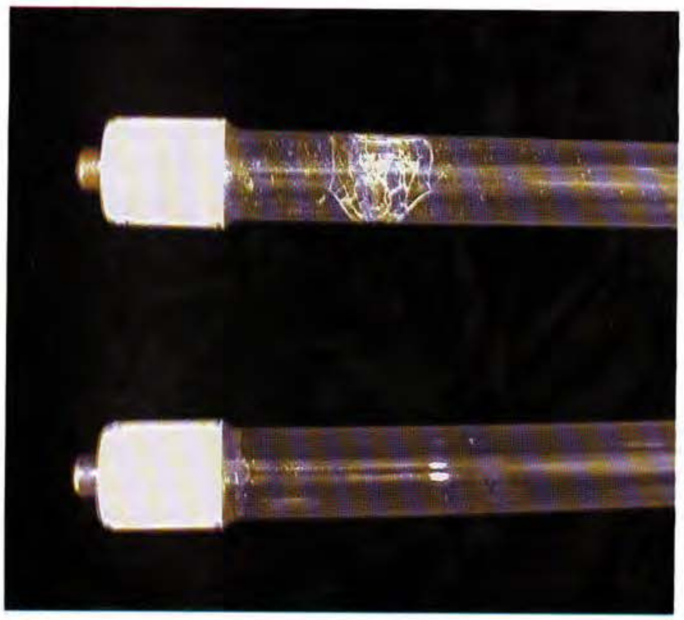

Figure 2 Close-up view of the Fluoro-Safe™ sleeved germicidal UV lamps.

TEST SETUP

Various Fluoro-Safe™ sleeves were used made of different types of materials and thicknesses for a comparison of UV transmittance at 254 nm, see Table 1.

For UV energy recovery, a cube was made of mirror-finished aluminum sheets with dimensions of 5 inches x 5 inches x 5 inches with polished sides facing toward the lamp. There are two openings on both sides of the box to accommodate a lamp and sleeve combination with a diameter of 3 inches. The openings are located in the middle and 0.2 inch above the base. The UV irradiance measurements were made through a 0.7-inch diameter port located in the middle of the top plate of the box, directly above the lamp (see Figure 3). The majority of UV disinfection applications use low pressure mercury arc lamps, producing primarily a wavelength of 253.7 nm. The research presented in this study incorporates low-pressure-high-output (LPHO) lamps with a wavelength of 253.7 nm, and the UV irradiance from LPHO lamps was measured with a Spectroline DRC-100X radiometer equipped with a DIX-254A UV-C sensor calibrated by the manufacturer to standards of the National Institute of Standards and Technology (NIST). Tests were performed on four different types of sleeves. Each test was repeated with a different set of sleeves with the same dimensions in order to check consistency. A LPHO lamp was used for this test, and UV lamp output efficiency comparison between the LO lamp and the LPHO lamp was made. Additionally, breakage testing was performed on the sleeved lamps to observe any visible signs of content spill.

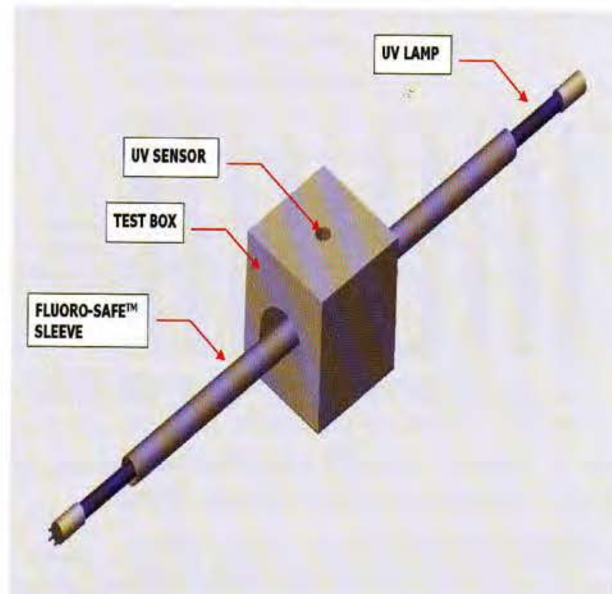

Figure 3. UV Test Box.

RESULTS AND DISCUSSION

All the tests were carried out at room temperature and in air for UV transmittance of the materials mentioned above. Test results are summarized in Figures 4-8. From the results, material D turns out to be the best material in transmitting UV at 253.7 nm, followed by material E, material A, material B, and material C, respectively. The sleeved lamps also were field tested and operated in air for about 2,500 hours with no deterioration of the sleeve. The sleeved lamps were dropped from a height of 3 ft,

Table 1. Fluoro-Safe™ sleeve dimensions

Material Type	A	B	C	D	D	D	E	E	E	Quartz
Inner Diameter (in)	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.875	0.858
Thickness T, (in)	0.02	0.017	0.02	0.02	0.04	0.06	0.02	0.04	0.06	0.057

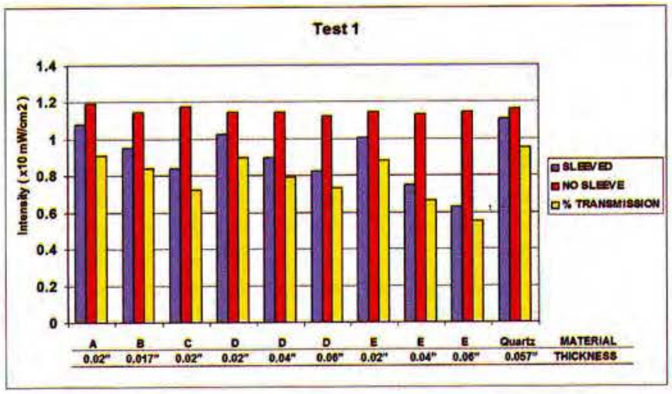

Figure 4. Test # 1, Inner diameter of the sleeves is 0.875 inch.

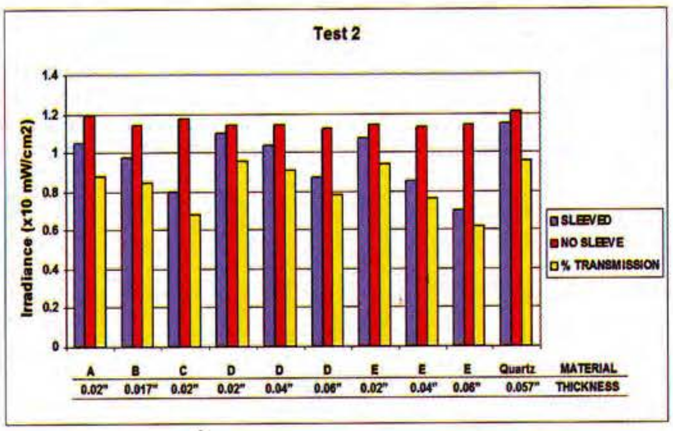

Figure 5. Test # 2 = Test 1 is repeated with another set of sleeves of the same dimension.

and although the lamp broke in three different places, the contents, as well as the broken quartz were contained within the sleeved environment of the lamp and the overall physical dimensions of the lamp were preserved. Also a thirty percent (30%) drop in irradiance measurements was observed after the bottom of the surface was replaced with a wooden piece. It was observed that LPHO lamps gave an output about 2.5 times greater than those of the LP lamps. From the results, one can conclude that the engineered material definitely shows promise in UV air applications.

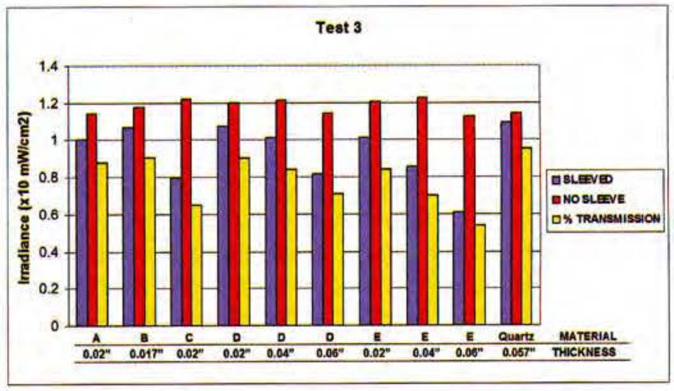

Figure 6. Test # 3 = Test 1 is repeated with another set of sleeves of the same dimension.

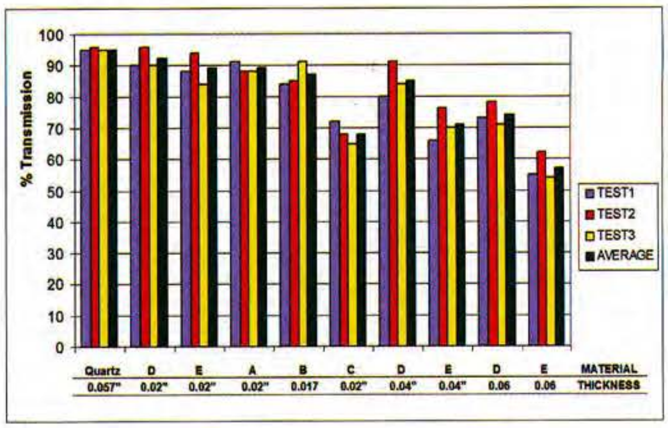

Figure 7. The percent UV transmittance through the skin of various Fluoro-Safe™ sleeves.

INTERNATIONAL ULTRAVIOLET ASSOC.

REFERENCES

1. Defining the Effectiveness of UV Lamps Installed in Circulating Air Ductwork, ARTI 21-CR Research Project 610-40030, Air-Conditioning and Refrigeration Technology Institute, the final report is expected to be available in the third quarter of 2002.
2. The Characterization of Upper-Room Ultraviolet Germicidal Irradiation in Inactivating Airborne Microorganisms, Environmental Health Perspectives, Vol. 110, No. 1, January 2002.

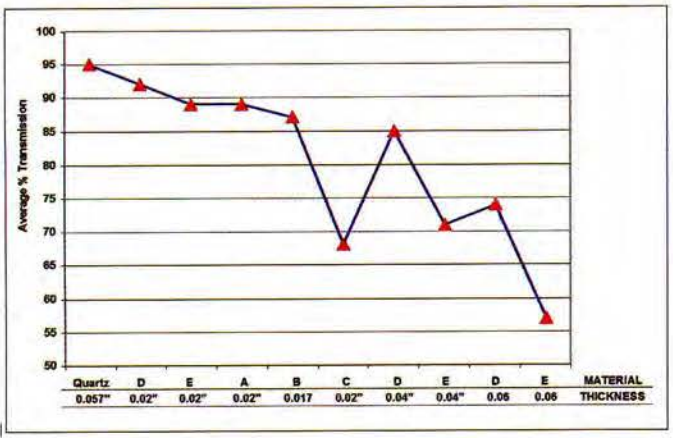

Figure 8. The average percent UV transmittance at 253.7 nm.

3. Airborne-Microbe Filtration in Indoor Environments, HPAC Engineering, P 57, January 2002.
4. FDA Information on Ultraviolet Disinfection Technology, Ultraviolet Systems, May 2002.
5. Draft Guideline for Environmental Infection Control in Healthcare Facilities, Healthcare Infection Control Practices Advisory Committee (HICPAC), Centers for Disease Control and Prevention (CDC), 2001.
6. Design and Optimization of UVGI Air Disinfection Systems, PhD Thesis, Pennsylvania State University, 2001.
7. Guidelines on the Design and Operation of HVAC Systems in Disease Isolation Areas, TG252, U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM), November 2000.
8. Primary Containment for Biohazards: Selection, Installation and Use of Biological Safety Cabinets, 2nd Edition, Center for Disease Control and Prevention (CDC) and National Institute of Health (NIH), September 2000.
9. Ultraviolet light (C band) emitters shall be incorporated downstream of all cooling coils and above all drain pans to control airborne and surface microbial growth and transfer, GSA Facilities Standards for Public Buildings Service, section 5.4, Drains and Drain Pans, P 130, November 2000, PBS-P100.
10. The Interdepartmental Working Group on Tuberculosis, The Prevention and Control of Tuberculosis in the United Kingdom, Department of Health, The Scottish Office and Welsh Office, September 1998.
11. Prevention and Control of Tuberculosis in Correctional Facilities, Morbidity and Mortality Weekly Report (MMWR), Centers for Disease Control and Prevention (CDC), Vol. 45, No. RR-8, June 7, 1996.
12. Guidelines for Preventing the Transmission of Mycobacterium tuberculosis in Health-Care Facilities, 1994, Morbidity and Mortality Weekly Report (MMWR), Centers for Disease Control and Prevention (CDC), Vol. 43, No. RR-13, October 28, 1994.
13. Biological Defense Safety Program, Unclassified, Department of the Army, Pamphlet 385-69, December 31, 1993.