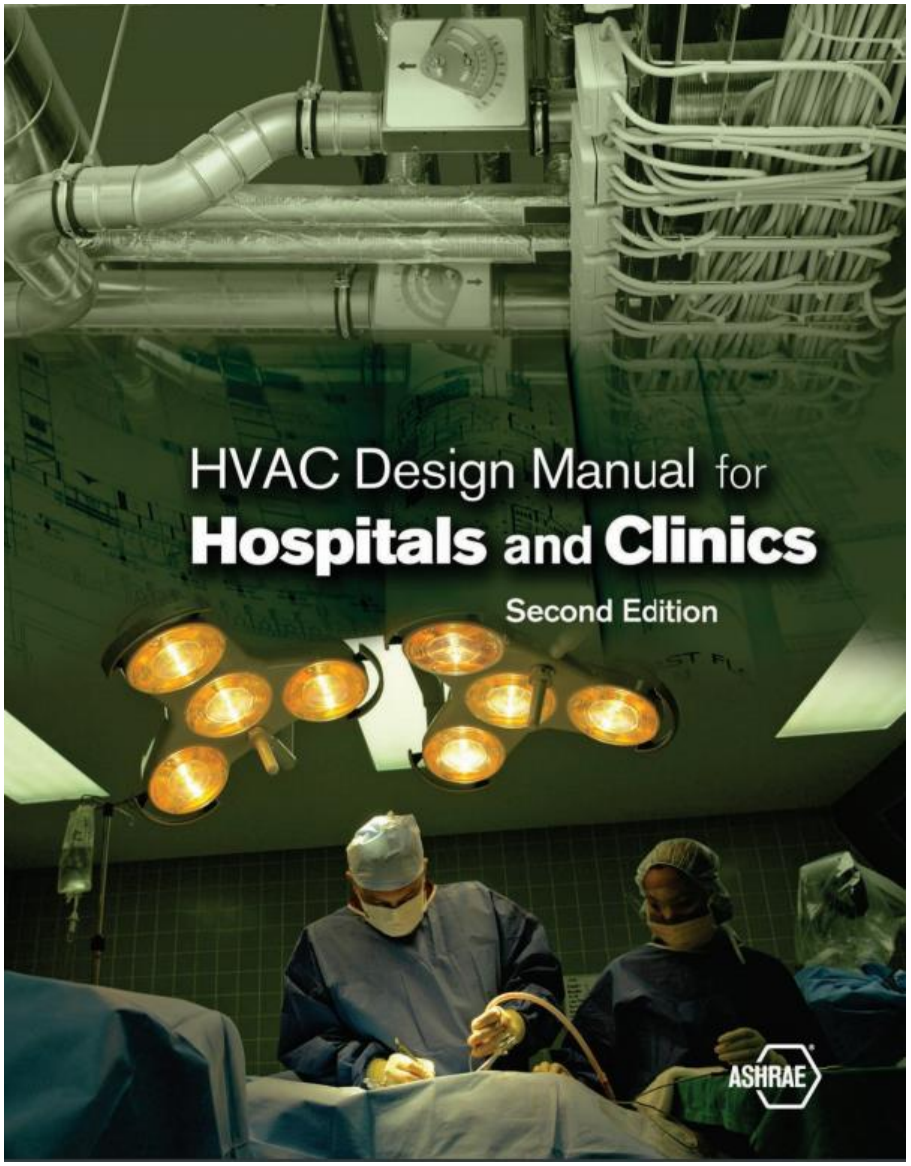
How UV-C Can Reduce HVAC Energy, Maintenance Costs and Improve IAQ

UV-C References

- CDC
- US Department of Health and Human Services
- NIOSH
- GSA Public Buildings Standard (since 2003)
- ASHRAE



Systems Handbook

2016 HVAC Systems and Equipment Handbook

CHAPTER 17

ULTRAVIOLET LAMP SYSTEMS

Application Handbook

2019 HVAC Applications Handbook

CHAPTER 62

ULTRAVIOLET AIR AND SURFACE TREATMENT

Here's What ASHRAE Says…

Chapter 60.8 - ASHRAE 2015 Handbook

- **Chemical and mechanical cleaning can be costly, difficult to perform, and dangerous to maintenance staff and building occupants. Furthermore, the systems performance can begin to degrade again shortly after cleaning as organic and microbial deposits reappear or reactivate.**
- **UV-C is an easy, cost-effective way to prevent the growth of bacteria and mold on system components and keeping surfaces clean continuously rather than "periodically restoring fouled surfaces" – meaning lower maintenance cost and, potentially, better HVAC system performance.**
- **Removing and suppressing the formation of biofilms on coils should reduce airside pressure drop, increase heat transfer coefficient, and reduce fan and refrigeration system energy consumption.**

STANDARD

ANSI/ASHRAE/ACCA Standard 180-2012
(Supersedes ANSI/ASHRAE/ACCA Standard 180-2008)

Standard Practice for Inspection and Maintenance of Commercial Building HVAC Systems

Purpose: The purpose of this standard is to establish minimum HVAC inspection and maintenance requirements that preserve a system's ability to achieve acceptable thermal comfort, energy efficiency, and indoor air quality in *commercial buildings.*

TABLE 5-2 Air Handlers

	Inspection/Maintenance Task	Frequency*
a	Check for particulate accumulation on filters. Clean or replace as necessary to ensure proper operation.	Quarterly
b	Check ultraviolet lamp. Clean or replace as needed to ensure proper operation.	Quarterly

- Table 5-7- Coils and Radiators
- Table 5-15- Fan Coils, Hot Water and Steam Unit Heaters
- Table 5-22- Rooftop Units

Position Documents

ASHRAE Position Document on Airborne Infectious Diseases

Approved by ASHRAE Board of Directors
January 19, 2014

Reaffirmed by Technology Council
January 31, 2017

Expires January 31, 2020

ASHRAE Position Document on Filtration and Air Cleaning

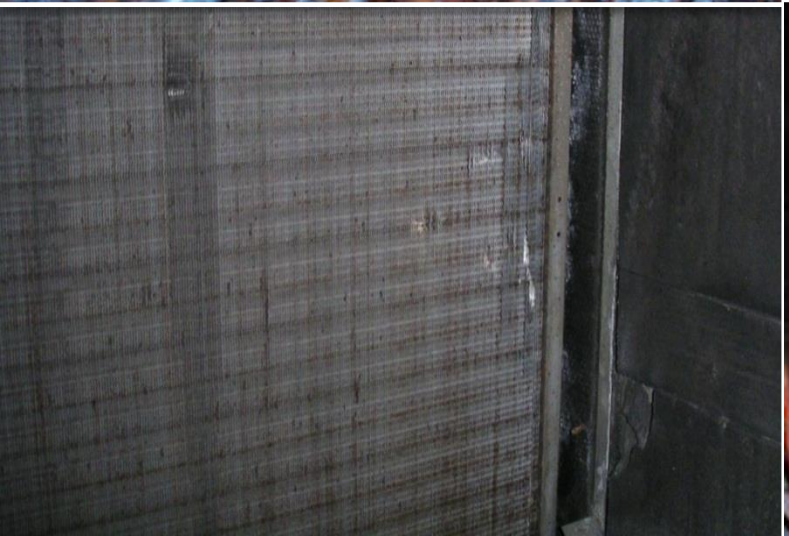
Approved by ASHRAE Board of Directors
January 29, 2015

Reaffirmed by Technology Council
January 13, 2018

Expires January 23,
2021

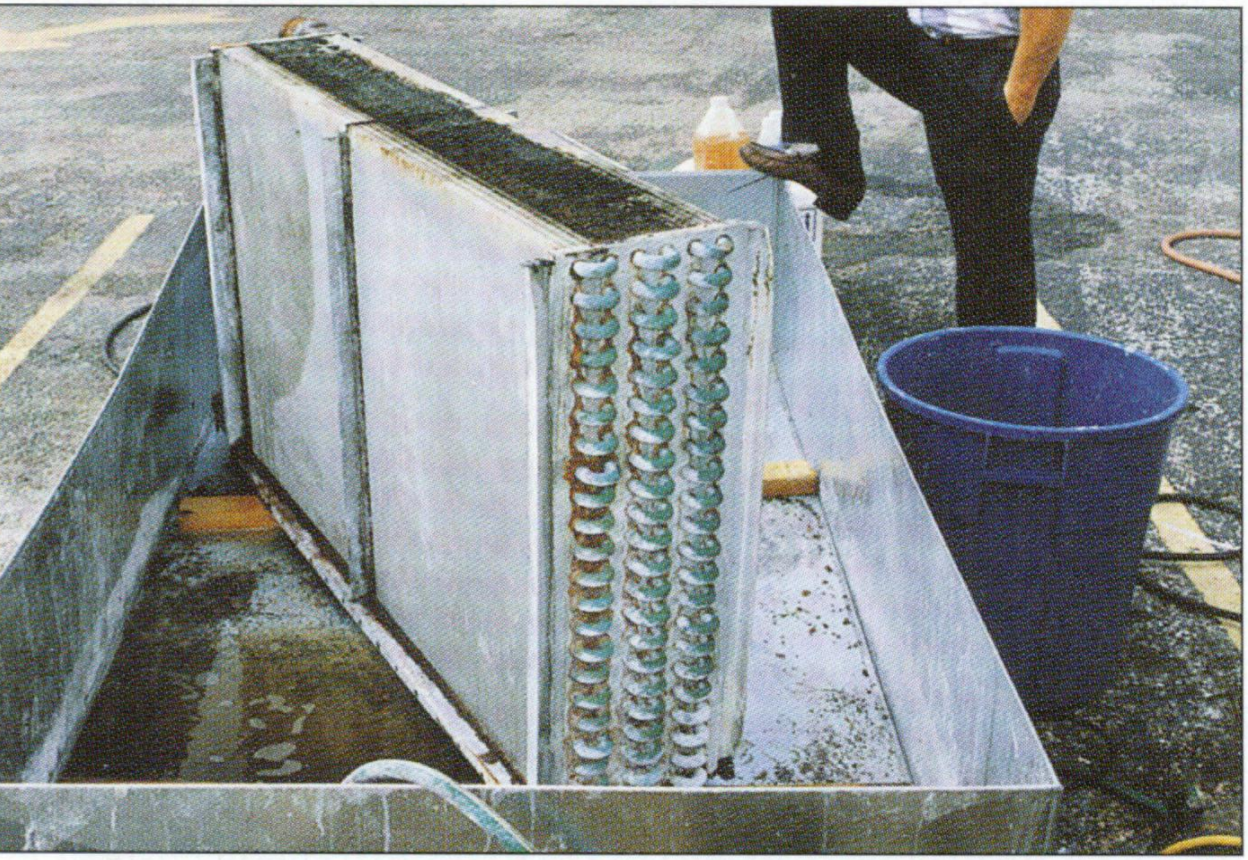

THERMAL EXPANSION VALVE 1
TXV1 L00322
FILTER/DRYER 1

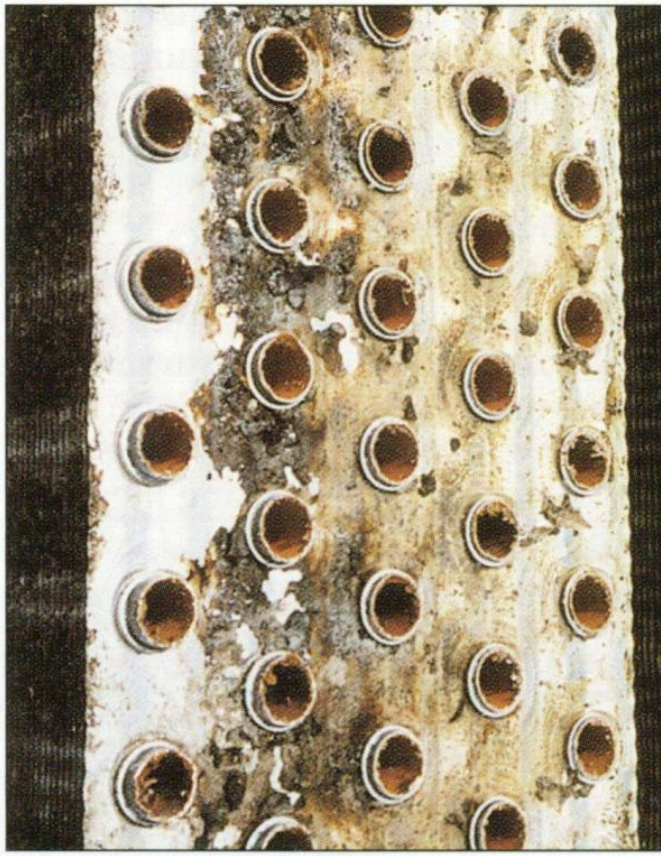
Fouled Cooling Coils and Drain Pans



Mold Growth in Filter

Mechanical & Chemical Cleaning Methods Don't Always Work





Case Studies

Bayview (AtlanTech) Case Study

- 12-story building built in 1973
- 412,000 sq. ft. Class A
- 3-chillers, 250, 430 & 750-ton
- 24 AHUs – 2 – per floor
- Houses 13 tenants, including:
  - » AT&T,
  - » Whole Foods and
  - » Landmark Worldwide
- UV install was to correct poor IAQ

CASE STUDY:
BAYVIEW TOWERS

As seen in:

- Engineered Systems – Nov. 2013
- RSES Journal – Jan. 2014
- BD+C – Feb. 2014
- Building Operating Management – Feb. 2014
- Mechanical Hub – Jul. 2014
- ACHR- Sept. 2014
- Retrofit-Sept/Oct 2014

The Bayview Report :

MECHANICAL SOLUTIONS, INC.

RECEIVED JAN 24 2012

2050 Tigertail Blvd., Bay O • Dania Beach, FL 33004 • Phone: 954-921-0979 • Fax: 954-921-0964

Quotes from the K & P report:

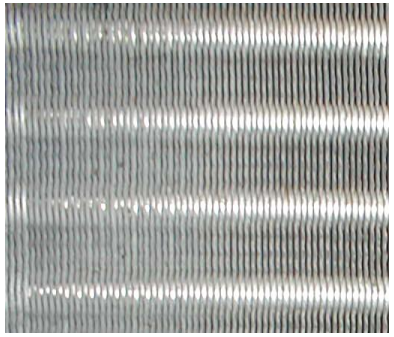
1. Another big item is not only the increase of air flow, but the significant decrease in pressure drop across the cooling coils.
2. There's a slight increase in coil pressure drop on **12B**, however for the amount of air increase, pressure drop should have been **1.21" but it's only a 0.611".**
3. In **5B** not only did the **air flow increase by 46.8%, the pressure drop decreased by 10%**. **This is typical of most all of the AHU's.**
4. Also, the air leaving the coils has a lower dew point. This is amazing because the increases air flow through the coils would normally raise the dew point.
5. **System capacity "increases" were more than 35% on average!**

The Problem

So What Happens?

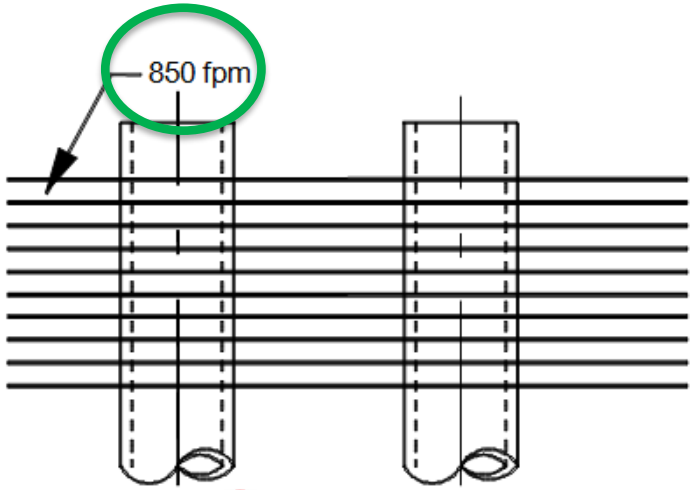
Organic Matter Lowers Coil Eff. & CFM / Increases Coil ΔP

New Clean Coil:



500 fpm

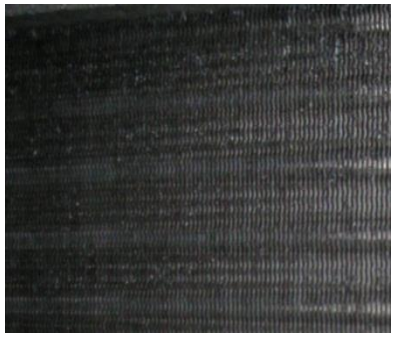
APPROACH



60% OPEN = **Optimum cooling / Design**

~54° WB

Add only .006" of bio film:



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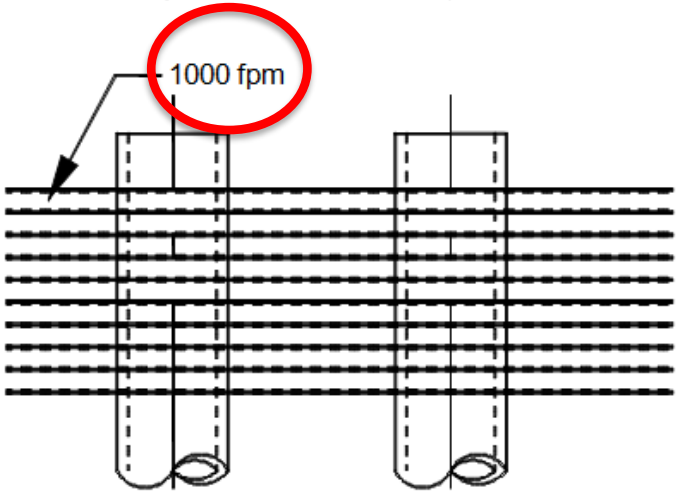
APPROACH

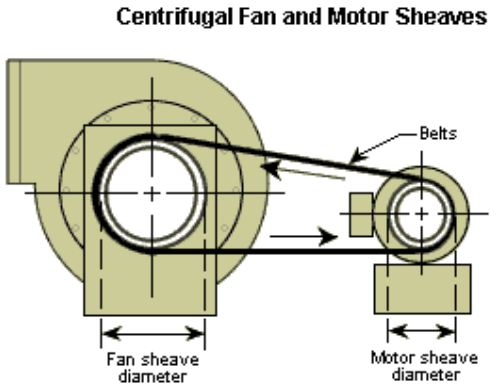


51% OPEN = **Decreased efficiency**

~58° WB

Typical Responses To The Problem

Speed up Fan



Pump More Chilled Water

Lower Coil Water Temp

= **Increased kWh Usage on Fan Motors**

= **Increased kWh Usage on Pump Motors**

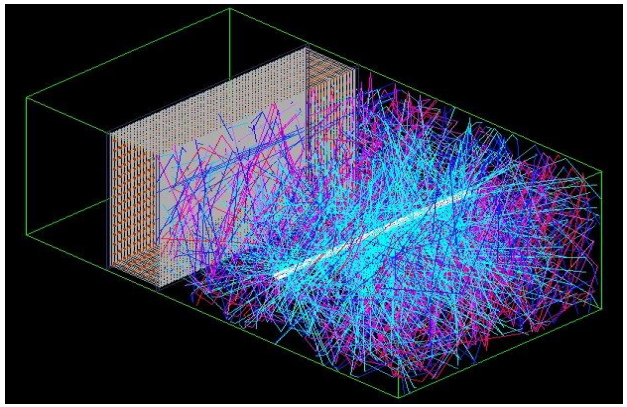
= **Significantly Increases kWh Usage on Chiller**

INCREASED ENERGY COSTS

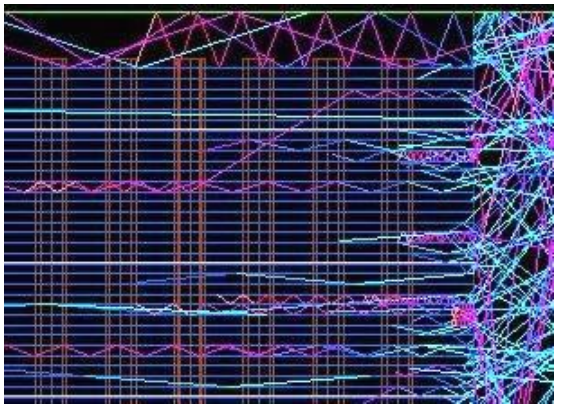
Restoring Coil Efficiency

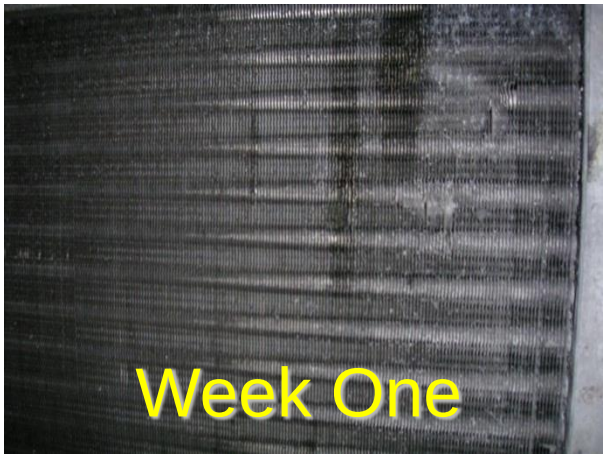
UV-C on the coil

UV-C energy degrades organic matter



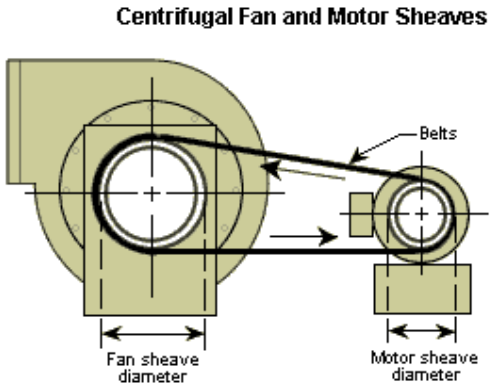
Energy is reflected through the coil





Harvesting Energy Savings From A Restored Cooling Coil

Slow Down Fan



Pump Less Chilled Water

Raise Coil Water Temp

= **Restored kWh Usage** **=** **Restored kWh Usage** **=** **Restores Significant kWh Usage**

SUSTAINABLE ENERGY SAVINGS

Univ of AR

Georgia Tech

Florida Atlantic University

ASHRAE RP-1738

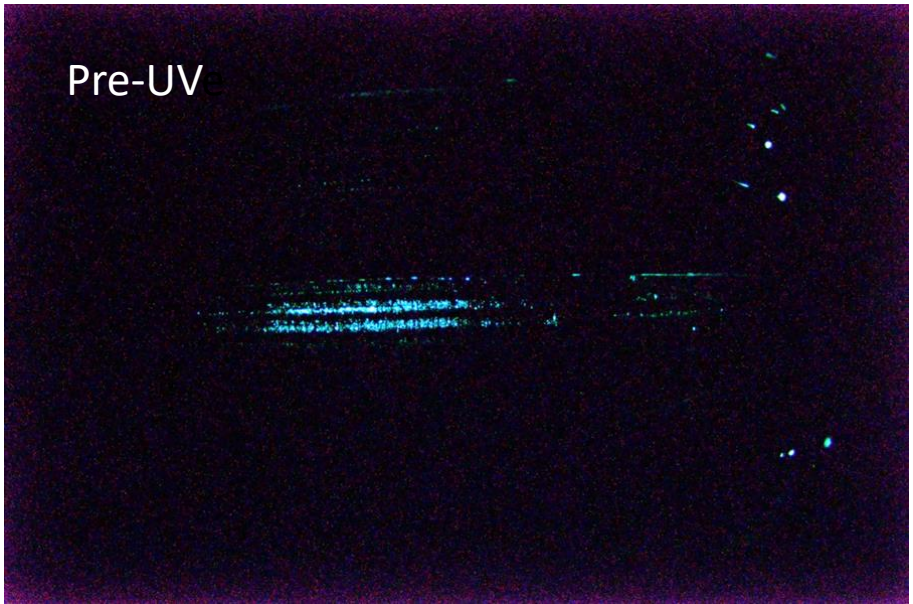
Field Measurement and Modeling of UVC Cooling Coil Irradiation for HVAC Energy Use Reduction

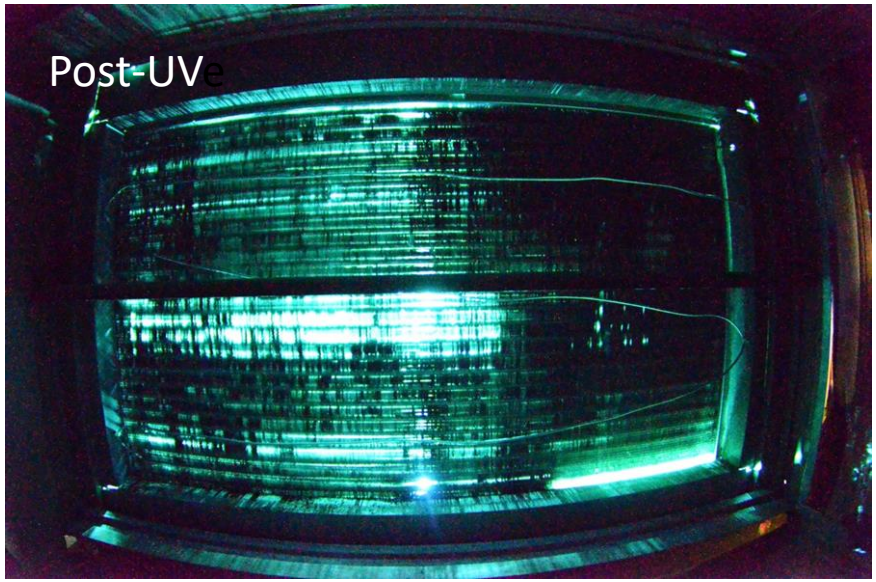
Final Report

November, 2016

Results

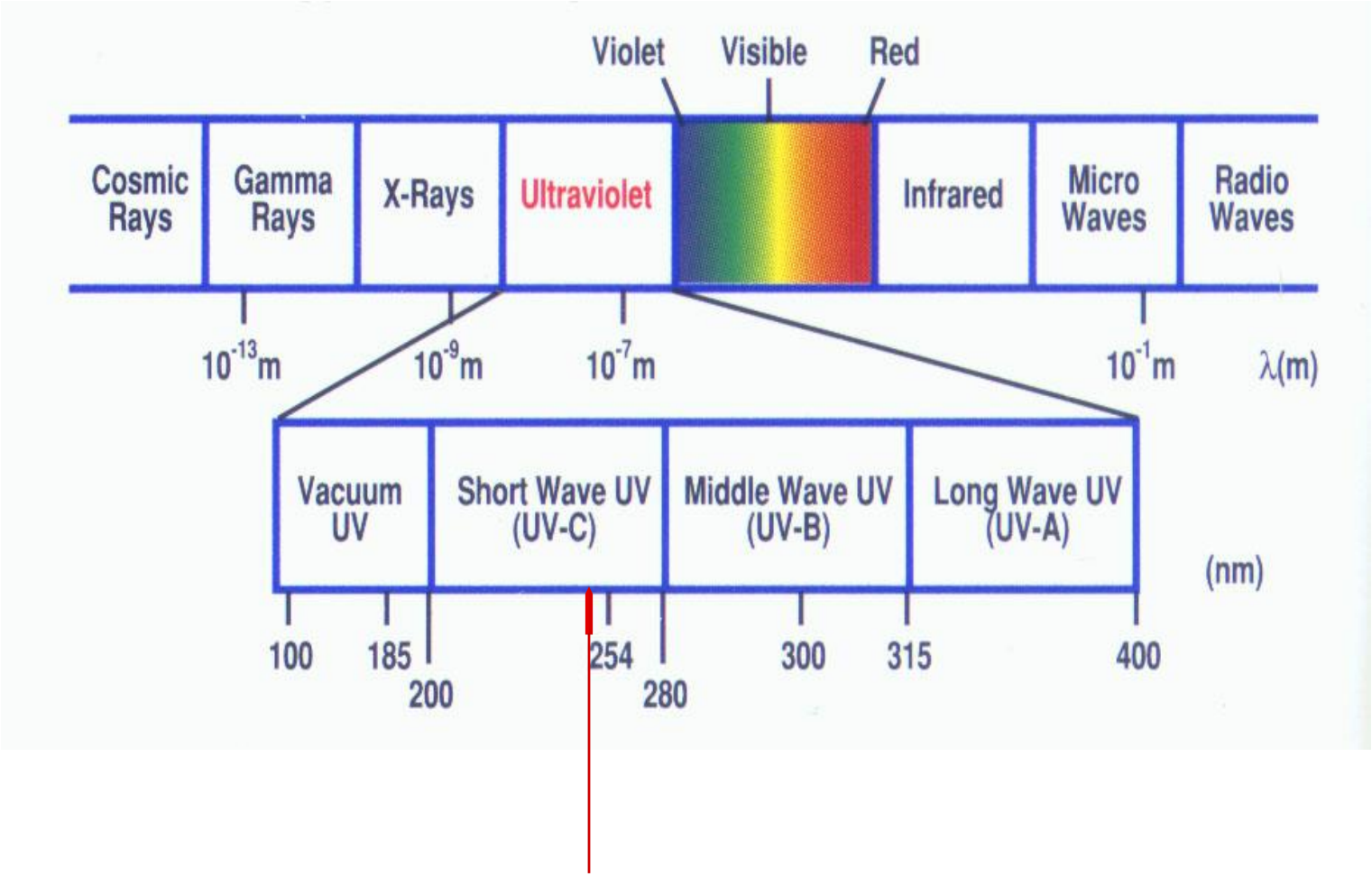
- 21.65% to 21.70% **decrease** (95% confidence) in mean coil airside pressure drop
- 14.5% to 14.8% (95% confidence) **increase** in mean overall heat transfer coefficient (UA)





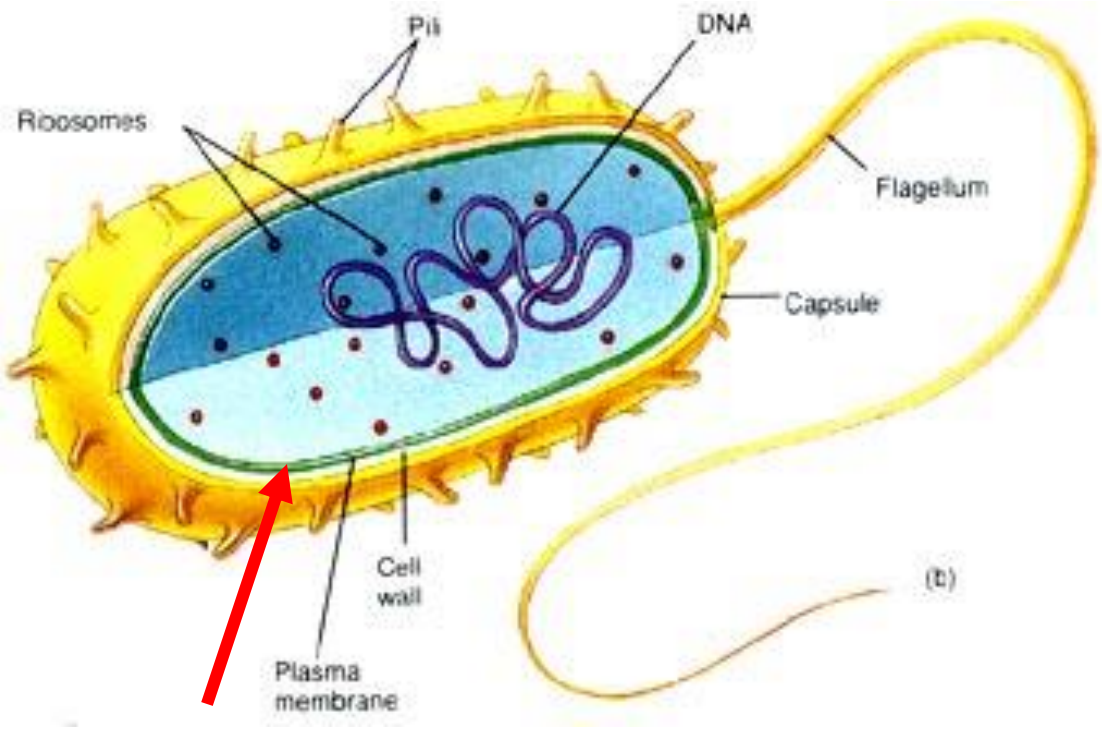
UV-C Energy Basics

Light Spectrum



Germicidal UV-C Lamp @ 253.7 nm

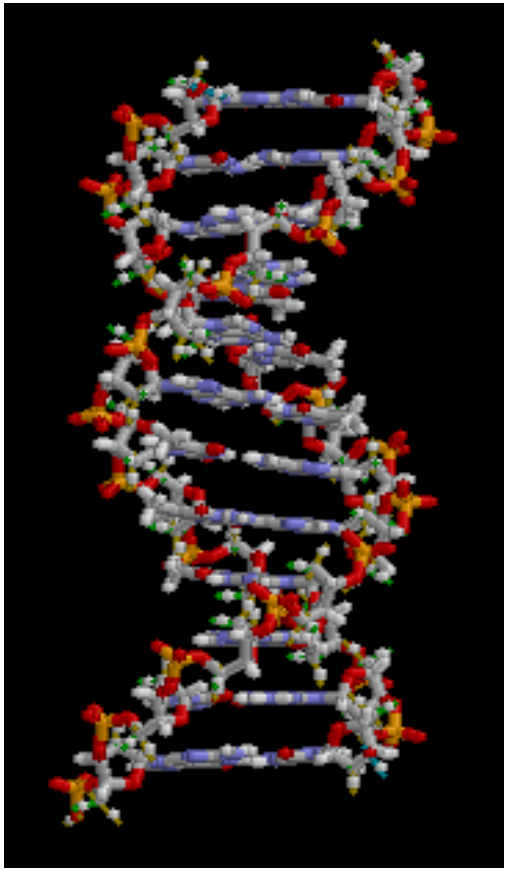
Cell Destruction

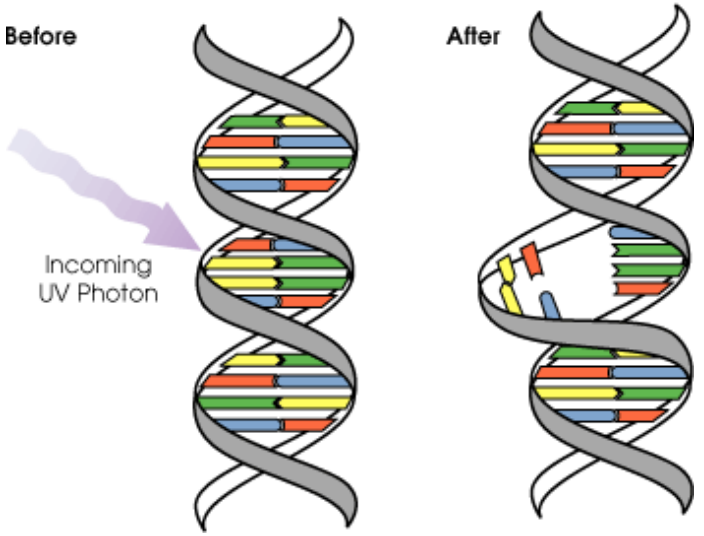


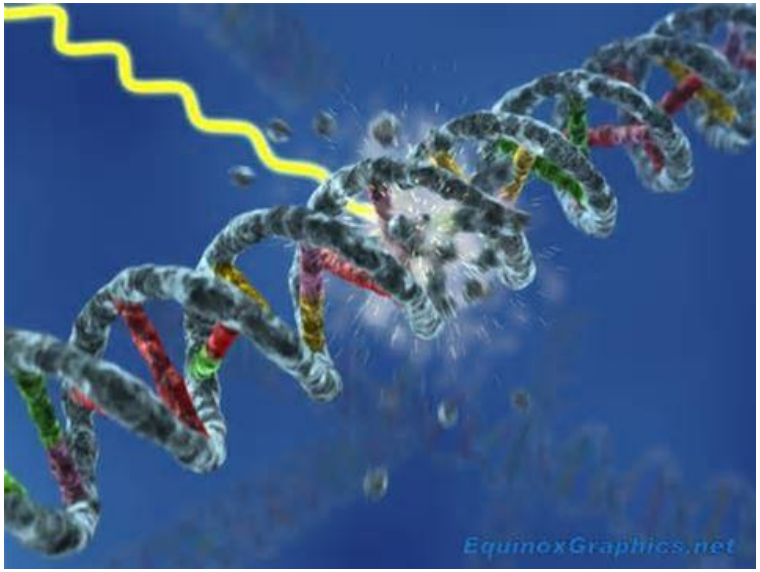
UV-C energy enters the cell

- Electromagnetic energy breaks through cell wall
- Damages DNA
- Cannot reproduce or feed
- Cell “Dies”

DNA Damage



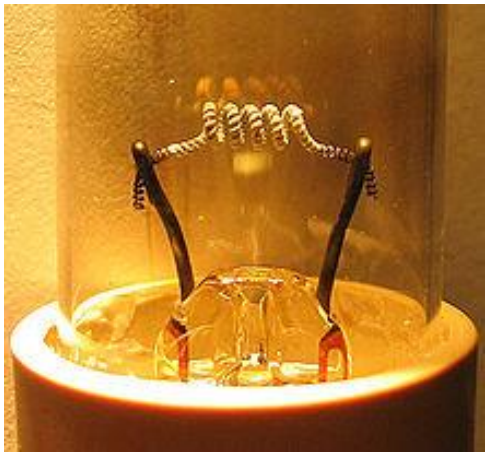




Fluorescent Lamps

- Impure or “junk” glass; does not transmit UV-C
- Contains Mercury (Hg)
- Contains Phosphor
- Contains Noble gases - Argon

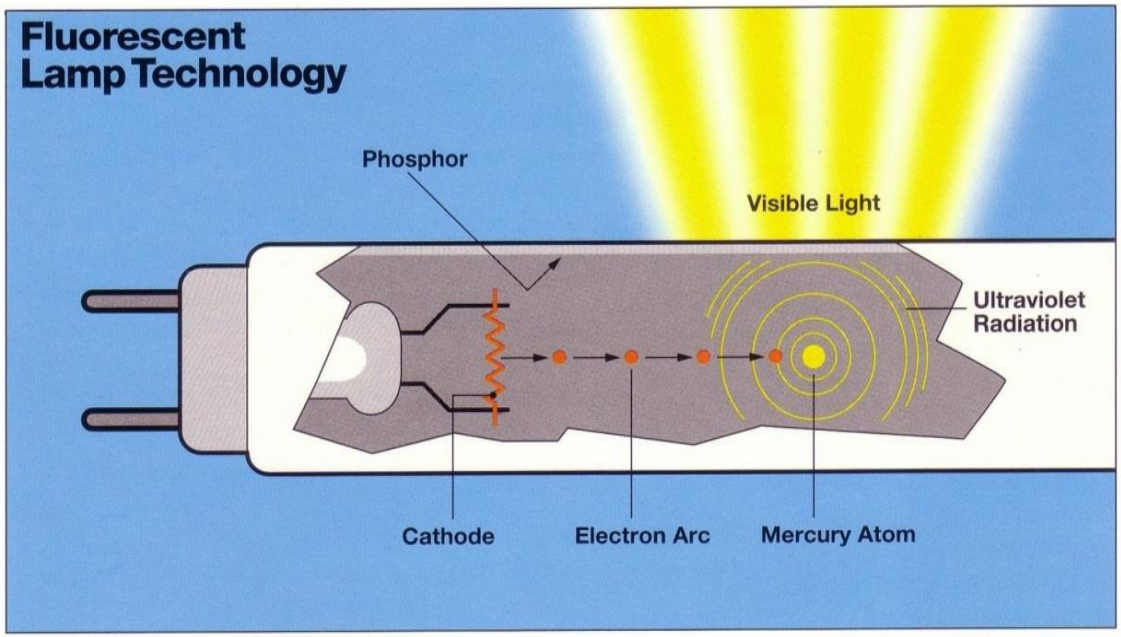
UV-C Lamps



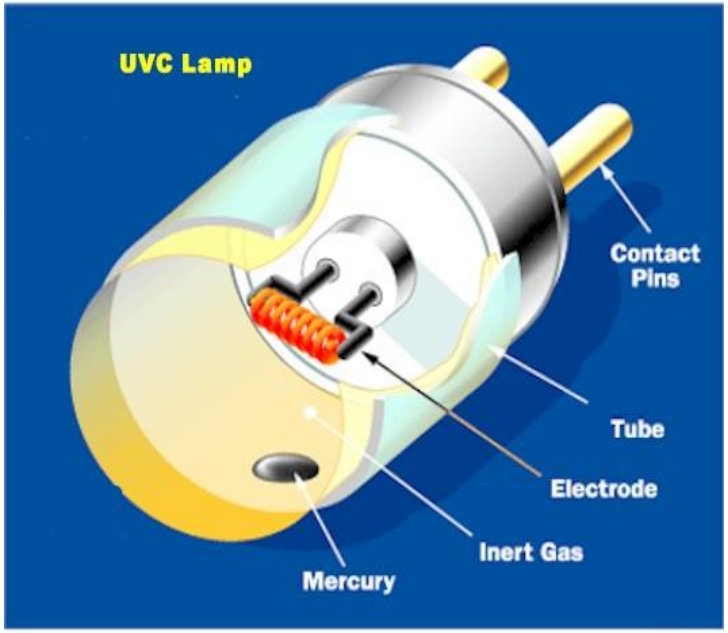
- Glass that transmits UV-C
  - Quartz
  - Sodium- Barium Silicate (“soft glass”)
- Internal Phosphor is not used
- Contains Some Mercury (Hg)

Contains Noble gases – Typically Argon or Neon / Argon mix

Fluorescent vs. UV-C Lamps



All fluorescent lamps generate an arc between two cathodes at opposite ends of a glass tube which excites atoms of mercury. This generates ultraviolet radiation which causes a phosphor coating to fluoresce and produce visible light.



UV-C Lamps

- 9,000 -18,000 hrs of useful life (ASHRAE recommends 9,000 hrs)
- Similar to fluorescent lamps
  - < 5.5 mg of mercury
  - Made on same machines
- Blue hue is only visible light
  - ~ 5% of lamp output is visible light (blue)
  - Blue light is not an indicator of the invisible UV-C wavelength!

UV-C Lamp Manufacturers

- “Off the Shelf” (Limited Sizes)
  - Philips
  - GE
  - Osram/ Sylvania
- Custom manufactures (Any Size, Any Cap)
  - Light Sources
  - First Light
  - Several Chinese sources

Philips Lamp Description	Lamp Wattage	Diameter	Microwatt/CM2
Philips TUV 4W	4	T5	9
Philips TUV PL-S 5W/2P	5	PLS	9
Philips TUV 6W	6	T5	15
Philips TUV PL-S 7W/2P	7	PLS	15
Philips TUV 8W	8	T5	21
Philips TUV PL-S 9W/2P	9	PLS	22
Philips TUV 10W	10	T8	23
Philips TUV 11W	11	T5	26
Philips TUV PL-S I I W/2P	11	PLS	33
Philips TUV PL-S I 3W/2P	13	PLS	31
Philips TUV 15W	15	T8	48
Philips TUV 16W	16	T5	45
Philips TUV FI7T8	17	T8	88
Philips TUV PL-L I 8W/4P	18	PLL	51
Philips TUV PL-L 24W/4P	24	PLL	65
Philips TUV 25W	25	T5	69
Philips TUV 25W	25	T8	69
Philips TUV 30W	30	T8	100
Philips TUV PL-L 35W/4P HO	35	PLL	105
Philips TUV 36W	36	T8	145
Philips TUV PL-L 36W/4P	36	PLL	110
Philips TUV 36T5	40	T5	144
Philips TUV PL-L 55W/4P HF	55	PLL	156
Philips TUV PL-L 60W/4P	60	PLL	166
Philips TUV 64T5	75	T5	280
Philips TUV 36T5 HO	75	T5	230
Philips TUV PL-L 95W14P HO	95	PLL	250
Philips TUV 64T5 HO	145	T5	442

Lamp Wattage/ Output

For a variety of low pressure mercury TUV lamps, the irradiance values at I meter distance are expressed below.

What Does ASHRAE say…
2015 Handbook Chapter 60.8

- **Coil surface irradiance levels on the order of 1 µW/cm² can be effective (Kowalski 2009) although 50-100 µW/cm² is more typical.**

- **The use of reflectors to focus lamp output on surfaces can reduce the power required for surface treatment, but at the expense of reducing air treatment effectiveness.**

- Modeling shows that applying **7.5 watts*** per square foot of coil surface exceeds ASHRAE recommendations.

*HPAC Magazine; *Right Sizing UV-C Lamps for HVAC Applications*; October 2013

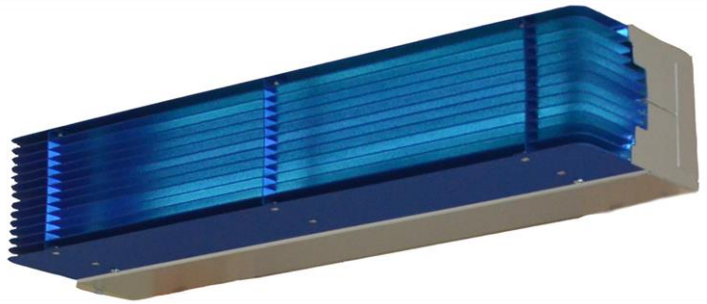

Whole Building UV-C Protection
UV-C for roof-top units
UV-C for exhaust systems
Upper Air UV-C for waiting rooms
Upper Air UV-C for patient rooms & surgical suites
UV-C for A/C Systems
Hospital
ERGENCY

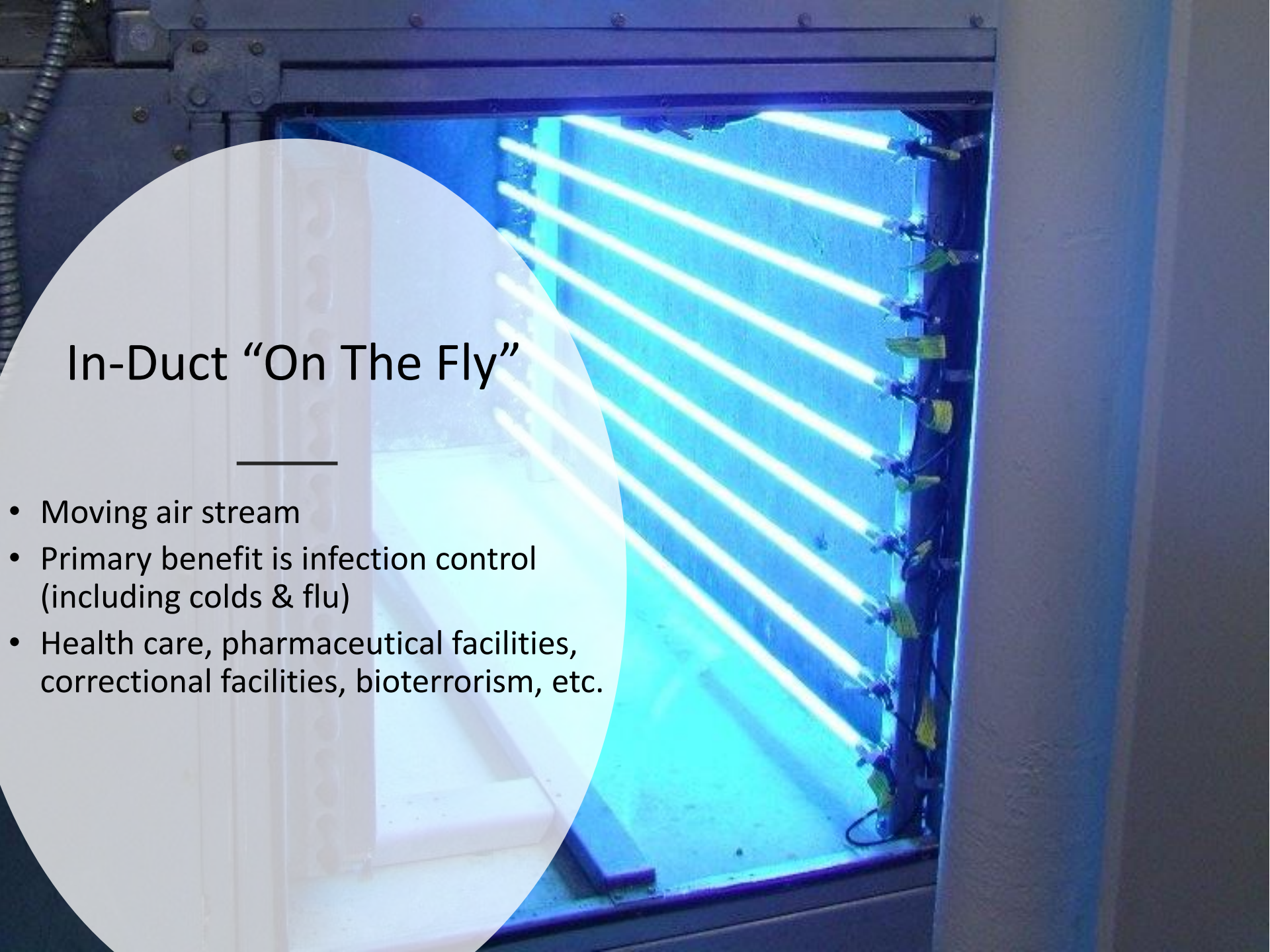
HVAC Applications

- Surface: Irradiation-Coils

- In-Duct: “On The Fly”

- Air/ In Room





In-Duct “On The Fly”

- Moving air stream
- Primary benefit is infection control (including colds & flu)
- Health care, pharmaceutical facilities, correctional facilities, bioterrorism, etc.

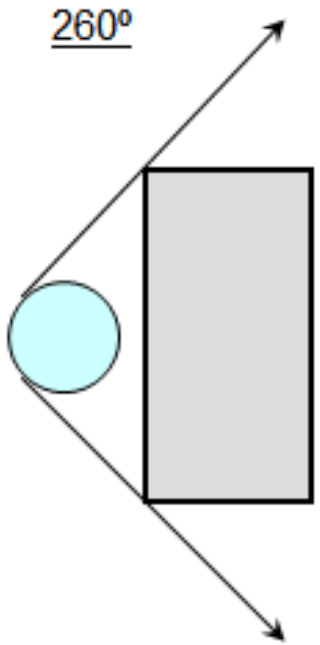
Surface Irradiation

95-98% of **ALL** UV-C applied in HVAC Systems is for Coil Irradiance and System Maintenance

- ☑ Coils, drain pans, fans, filters, plenum box, etc.
- ☑ Continuous & restorative cleaning
- ☑ Maintains as-built performance
- ☑ Energy savings, improved IAQ, & comfort benefits

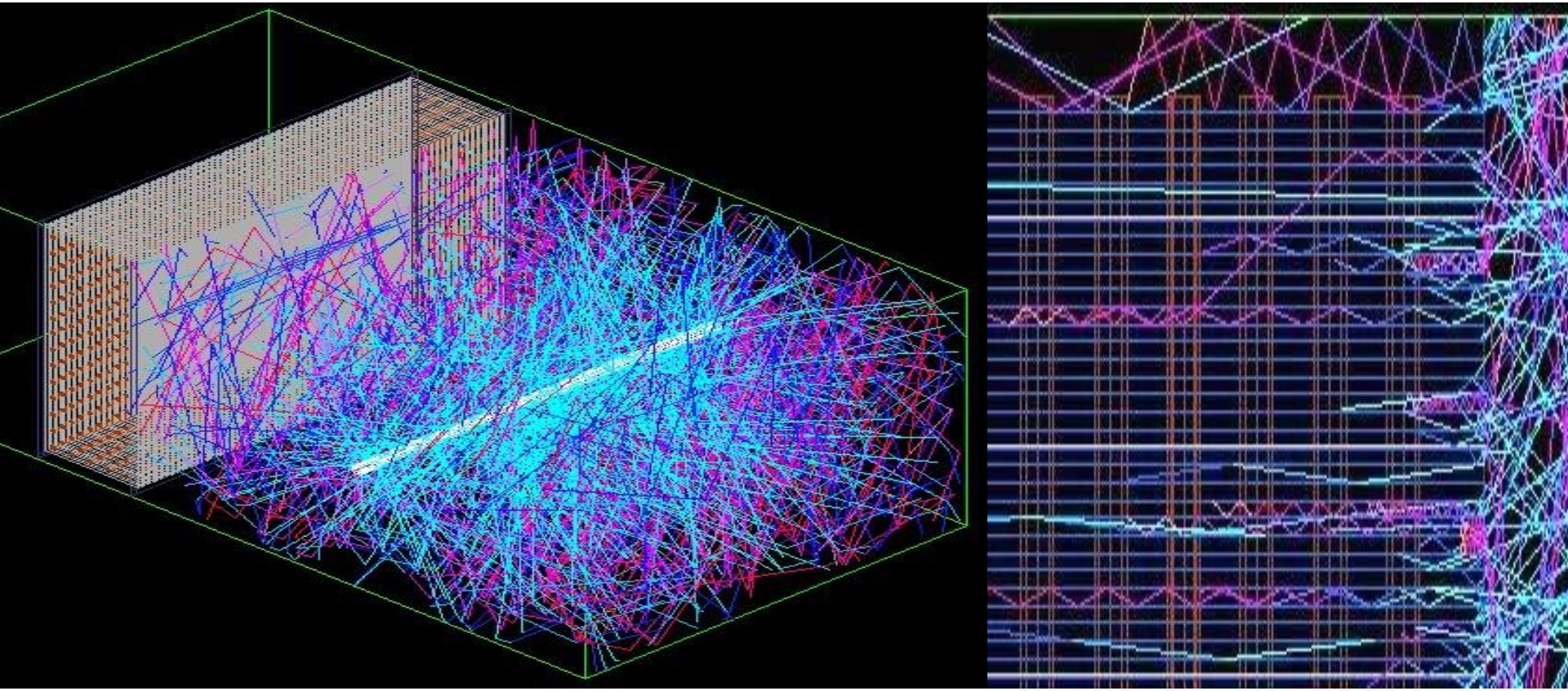
360^{o} UV-C Distribution

- Provides best energy distribution
- Easier fit-up with fewest lamp lengths
- Remote ballasts
- Highest efficacy
- Lowest possible cost of ownership



Notice the light distribution.

360° Reflections Increase Dosage



Ray-tracing models – Penn State University

HVAC Surface Cleaning

- New construction…
  - Preventive measure
  - Maintains as-built conditions and IAQ
- Retrofit
  - Problem-solving measure

    (then)
  - Maintains as-built conditions and improves IAQ

Safety Considerations: Engineering Controls

- All access panels or doors to the lamp section, and panels or doors to adjacent AHU sections where UV radiation may penetrate or be reflected should have warning labels posted

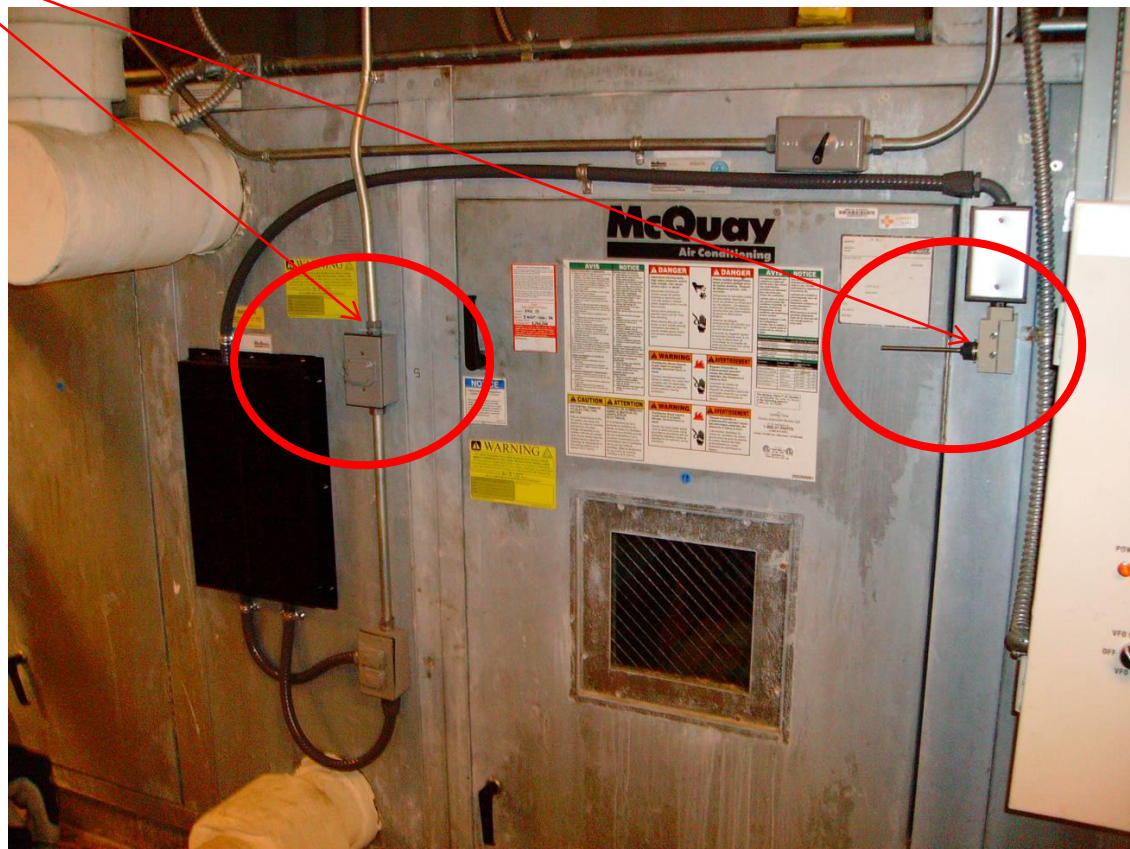
How to view UV-C

- Recommend not to enter a plenum with UV-C lamps on
- If it is absolutely necessary, Personal protective equipment (PPE) should be used:
  - UV safety goggles
  - UV face shields
  - Long-sleeved, tightly-woven clothing that covers much of the body, and
  - Gloves

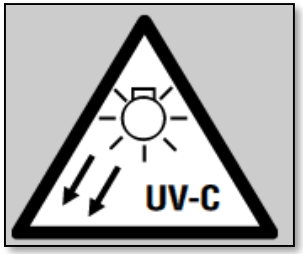
Safety Considerations: Engineering Controls

- Lamp sections of an AHU should have electrical disconnect devices

- Switches should be wired in series so that opening any access de-energizes the lights.



Exposure to UV-C Energy

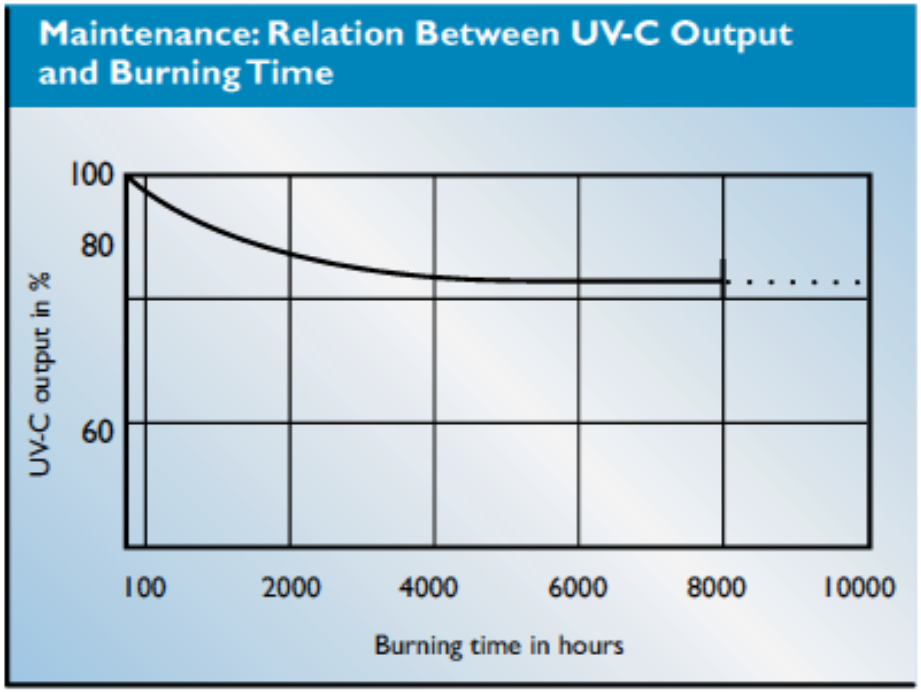


- UV-C, while not causing “permanent” damage in small doses can cause temporary corneal damage
- The cornea is like the skin in that it can be "sunburned" by exposure to too much UV radiation. This is called keratoconjunctivitis (snow blindness or welders flash)
- This condition usually does not present until **6 to 12 hours following** the UV exposure
- Although very painful (often described as having sand in the eyes) this condition is usually temporary (a few days) because the corneal cells will grow back

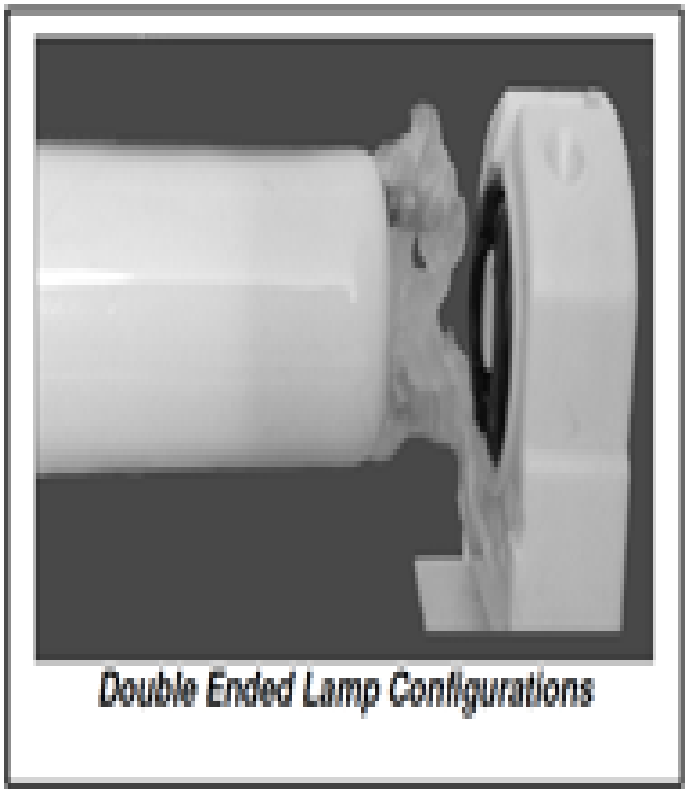
System Maintenance

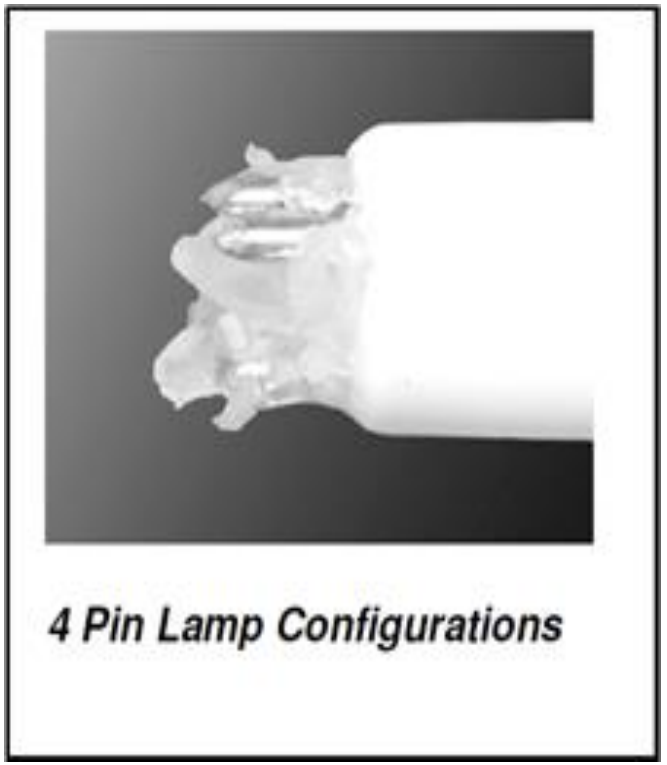
- Annual Lamp Replacement
  - Lamps are rated for 9000 operation hours or 1 year

- Recommend lamps be replaced annually to ensure desired performance and to protect against equipment failure



Re-lamp

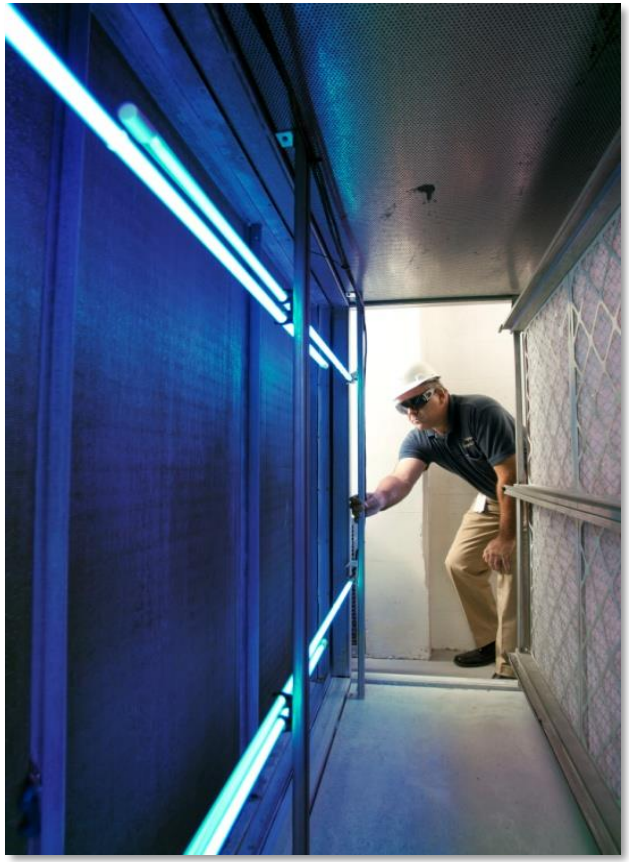

Double Ended Lamp Configurations


4 Pin Lamp Configurations

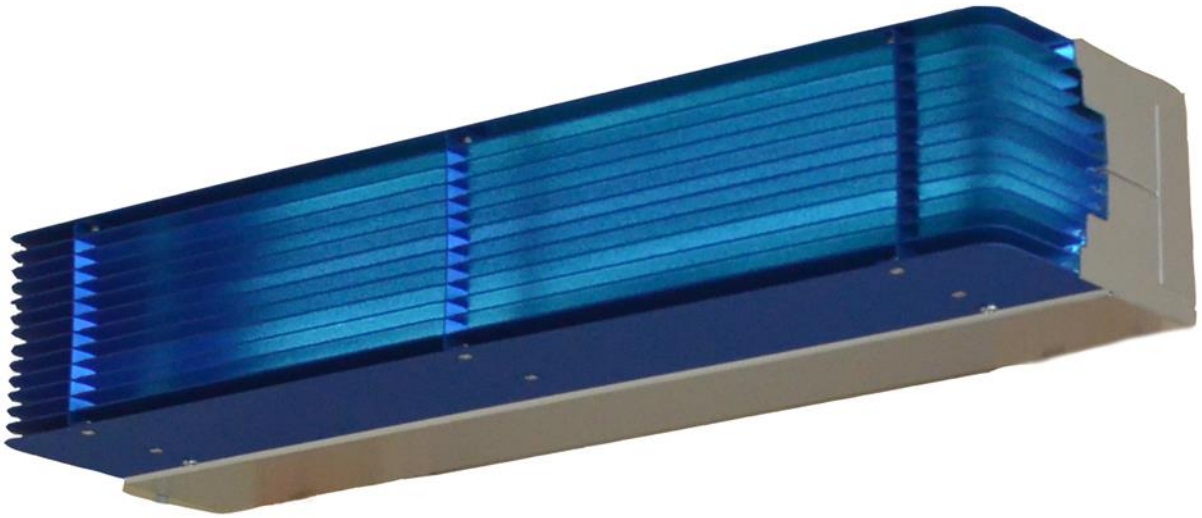
Make sure to add di-electric grease to prongs and seat lamp properly

Controls

- Toggle switch or Lock Out/Tag Out
  - Eliminates accidental operation
- Door interlocks (UL 1995)
  - Turns lights off when doors open
- Lamp/ Ballast Monitoring
  - Signals lamps on/off to BMS
- Radiometer
  - Usually seen for infection control or security applications



Upper Air UV-C



History Of Upper Air UV

FIG. 2. Class room, Swarthmore Public Schools—side wall fixtures.

ENVIROMENTAL CONTROL OF EPIDEMIC SPREAD OF CONTAGION[1]

By W. F. WELLS, M. W. WELLS

LABORATORIES FOR THE STUDY OF AIR-BORNE INFECTION,[2] UNIVERSITY OF PENNSYLVANIA SCHOOL OF MEDICINE, PHILADELPHIA, PA.

and T. S. WILDER

DEPARTMENT OF PEDIATRICS, UNIVERSITY OF PENNSYLVANIA, AND GERMANTOWN FRIENDS SCHOOL, PHILADELPHIA, PA.

THE peculiar vulnerability of air-borne microorganisms to ultraviolet radiation (Wells and Fair 1935) has been offered as a basis for sanitary control of air-borne infections (Wells 1935). Radiant disinfection of air in operating rooms has since become recognized in surgical antisepsis (Hart 1936; Overholt and Betts 1940) and ultraviolet barriers in wards (Wells 1939) have reduced hospital cross-infections (del Mundo and McKhann 1941).

The studies discussed here were planned nearly 5 years ago to test the hypothesis that epidemic spread of contagion could be

[1] This discussion is a condensation of a paper which appeared in the *American Journal of Hygiene for January, 1942*, 35: 97–121, and is presented here with its permission.

[2] Supported by a grant from the Commonwealth Fund to the University of Pennsylvania School of Medicine.

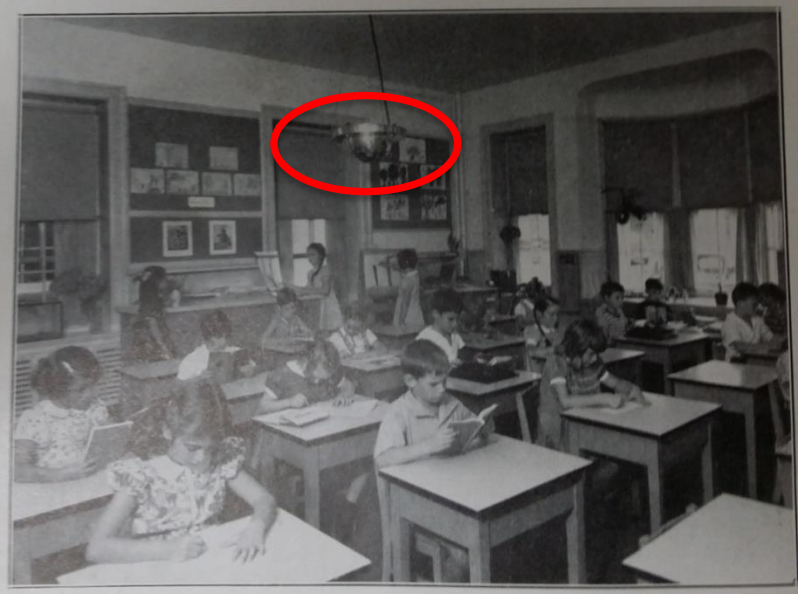


FIG. 1. Class room, Germantown Friends School—central radiant sources.

Why Upper Room UV-C Now?

- Epidemic spread of TB and AIDS world wide.
  - 2 billion people are infected with TB of which 12 million are co-infected with HIV and AIDS.
  - Resulting in 1.5 million TB deaths per year.
- Resurgent spread of tuberculosis in the USA in the late 1980s.
  - Tuberculosis is the most common cause of death from infectious disease (1.5 million) with HIV/AIDS in second (1.2 million).
- Pandemic Influenza
- Measles

Why Upper Room UV-C Now?

- Certain airborne pathogens have become antibiotic resistant and others are continuously mutating
- Large volumes of room air can be treated for less energy than any other method – especially the increase of dilution (OSA) ventilation rates
- UV-C works against “all” airborne pathogens
- Installation and maintenance is relatively simple, and first and operational costs are very low

*Table 1. Diseases Spread by Droplet or Airborne Transmission (*diseases are those where airborne transmission is reasonably certain even if it is not the primary mode)*

Influenza*	Influenza virus	Fever, chills, malaise, headache cough, coryza, myalgias	All, especially physicians and nurses
Measles (Rubeola)*	Rubeola virus	Fever, rash, malaise, coryza, conjunctivitis, Koplik's spots, adenopathy, CNS complications	All
Mumps*	Mumps virus	Painful/swollen salivary glands orchitis, meningoencephalitis	All, especially pediatricians, dentists, daycare workers
Tuberculosis*	Mycobacterium species	Fever, weight loss, fatigue, night sweats, pulmonary disease, extra pulmonary involvement including lymphatic, genitourinary, bone, meningeal, peritoneal, miliary	All, especially nurses, pathologists, laboratory workers, housekeeping staff

Applications

ASHRAE Position Document on Airborne Infectious Diseases

Approved by ASHRAE Board of Directors
January 19, 2014

Reaffirmed by Technology Council
January 31, 2017

Expires January 31, 2020

Table 1 Airborne Infectious Disease Engineering Control Strategies: Occupancy Interventions and Their Priority for Application and Research

Strategy	Occupancy Categories Applicable for Consideration*	Application Priority	Research Priority
Dilution ventilation	All	High	Medium
Temperature and humidity	All except 7 and 11	Medium	High
Personalized ventilation	1, 4, 6, 9, 10, 14	Medium	High
Local exhaust	1, 2, 8, 14	Medium	Medium
Central system filtration	All	High	High
Local air filtration	1, 4, 6, 7, 8 10	Medium	High
Upper-room UVGI	1, 2, 3, 5, 6, 8, 9, 14	High	Highest
Duct and air-handler UVGI	1, 2, 3, 4, 5, 6, 8, 9, 14	Medium	Highest
In-room flow regimes	1, 6, 8, 9, 10, 14	High	High
Differential pressurization	1, 2, 7, 8 11, 14	High	High

Note: In practical application, a combination of the individual interventions will be more effective than any single one in isolation.
*Occupancy Categories:

1. Health care (residential and outpatient)
2. Correctional facilities
3. Educational < age 8
4. Educational > age 8
5. Food and beverage
6. Internet café/game rooms
7. Hotel, motel, dormitory
8. Residential shelters
9. Public assembly and waiting
10. Transportation conveyances
11. Residential multifamily
12. Retail
13. Sports
14. Laboratories where infectious diseases vectors are handled

Upper Air (Room) Basics

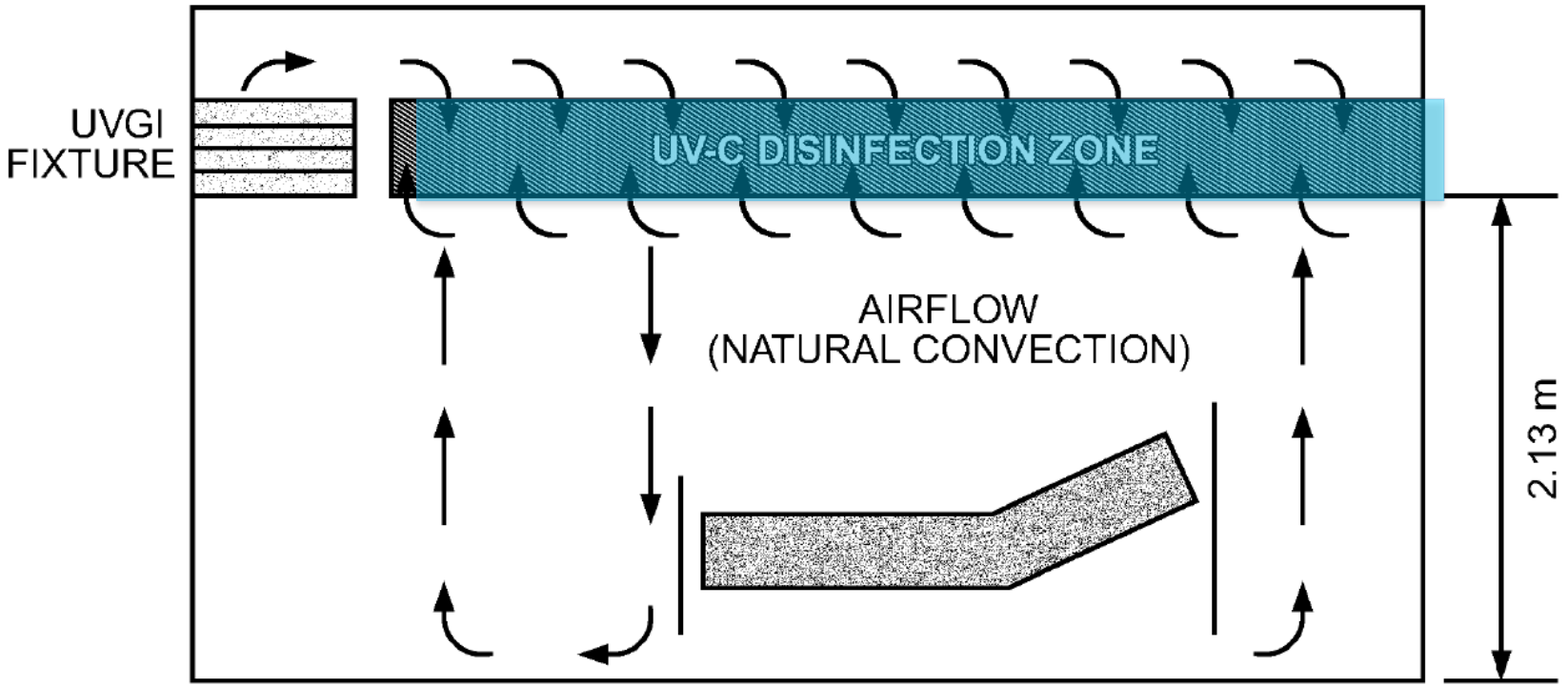


Fig. 5 Typical Elevation View of Upper-Room UV Applied in Hospital Patient Room

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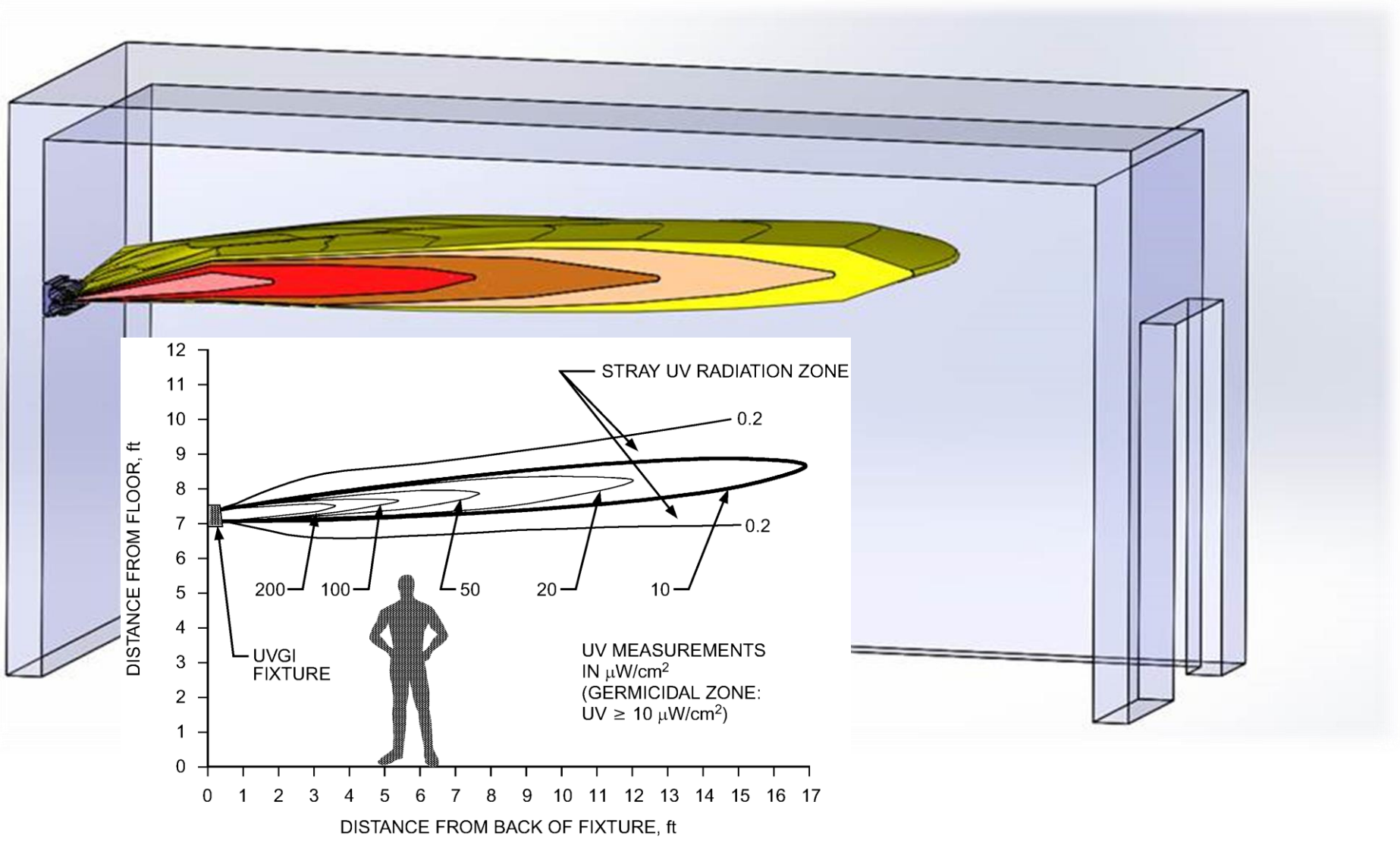
Modeling UV-C Distribution



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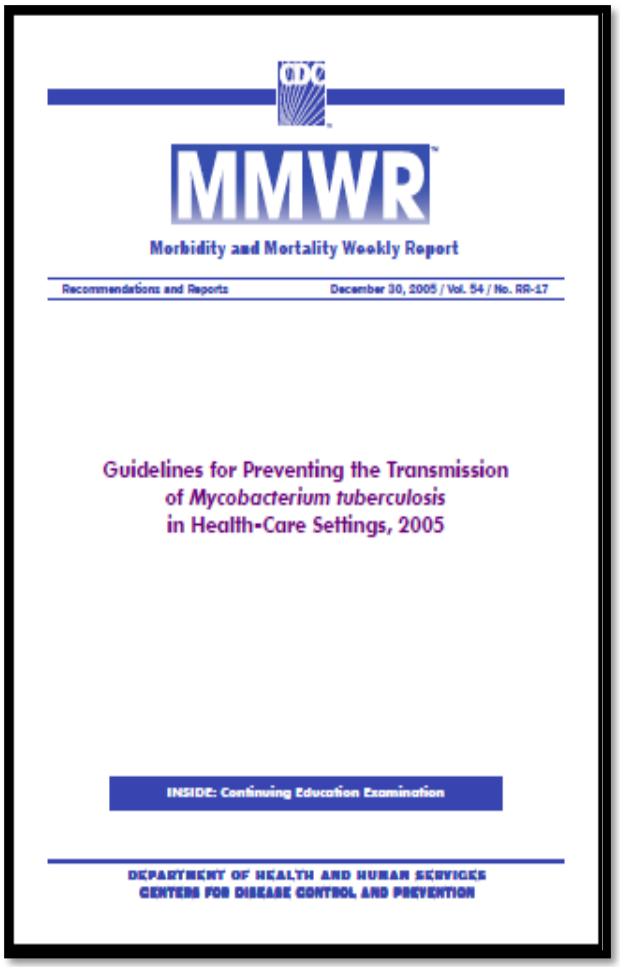
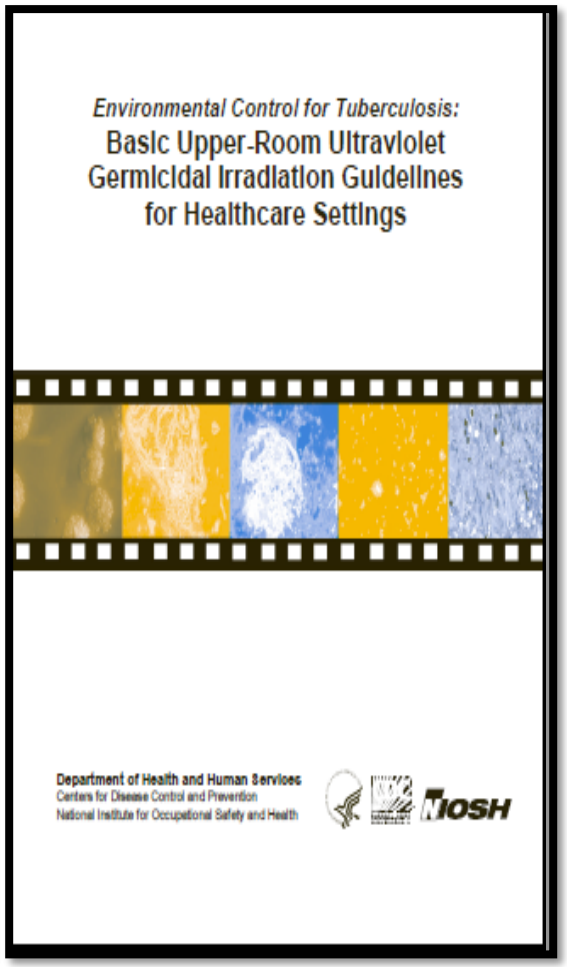
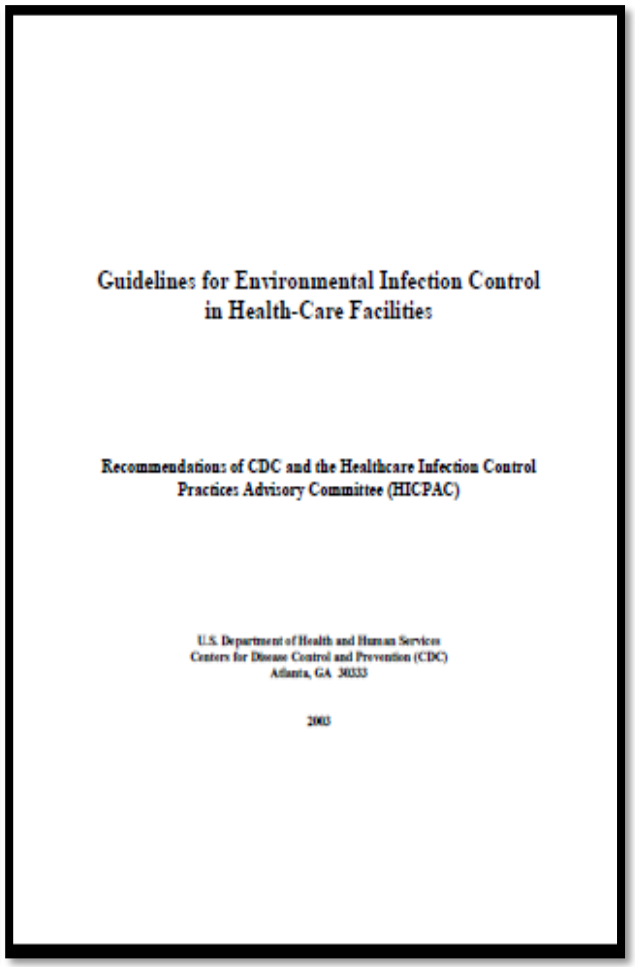
Current Reference Material

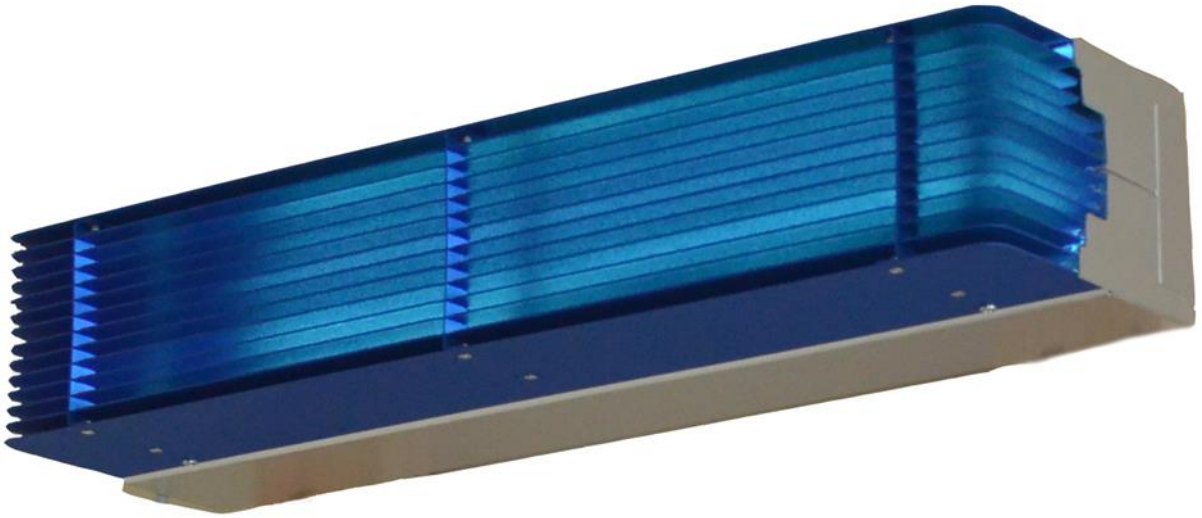




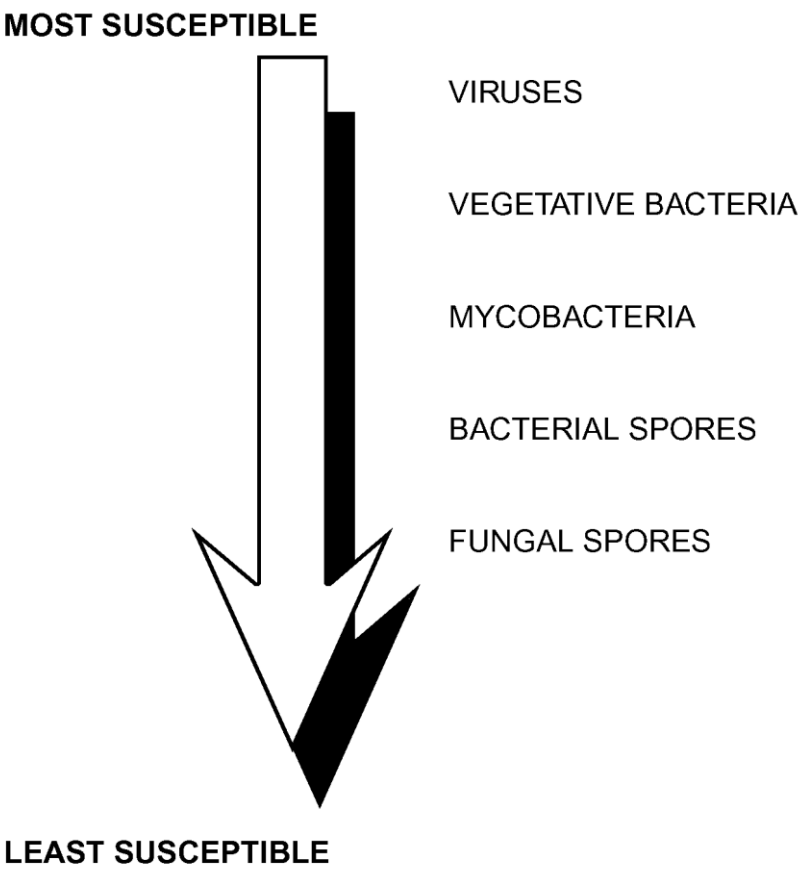


New ASHRAE Guideline – Upper Air

GPC 37P, *Guidelines for the Application of Upper-Air (Upper Room) Ultraviolet Germicidal (UV-C) Devices to Control the Transmission of Airborne Pathogens*



UV-C Inactivation of Microorganisms by Group



Representative Members of Organism Groups

Organism Group	Member of Group
Viruses	**Influenza viruses**
	Measles
	SARS
	Smallpox
Vegetative Bacteria	**Staphylococcus aureus**
	Streptococcus pyogenes
	Escherichia coli
	Pseudomonas aeruginosa
	Serratia marcescens
Mycobacteria	**Mycobacterium tuberculosis**
	Mycobacterium bovis
	Mycobacterium leprae
Bacterial Spore	Bacillus anthracis
	Bacillus cereus
	Bacillus subtilis
Fungal Spores	Aspergillus versicolor
	Penicillium chrysogenum
	Stachybotrys chartarum

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Upper Air Case Study

- 20 Upper Air Fixtures
- Daycare
- Student Lounge
- Cafe

“Anywhere you put thousands of people in close proximity, be it a hospital, airport, large office building or college, it’s advisable to try to eliminate disease transmission as much as possible…”

- Director of Facilities, Alan Yauney

Café, Day Care & Lounge

Questions?
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