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

Systems Handbook

2012- HVAC Systems and Equipment Handbook

CHAPTER 17

ULTRAVIOLET LAMP SYSTEMS

Application Handbook

2015 HVAC Applications Handbook

CHAPTER 60

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.**

Position Documents

ASHRAE Position Document on Filtration and Air Cleaning

Approved by ASHRAE Board of Directors
January 29, 2015

Expires
January 29, 2018

ASHRAE Position Document on Airborne Infectious Diseases

Approved by ASHRAE Board of Directors
January 19, 2014

Expires
January 19, 2017

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


THERMAL EXPANSION
VALVE 1
FILTER/DRYER 1

Plenums, Fans & Dampers

Fouled Cooling Coils and Drain Pans

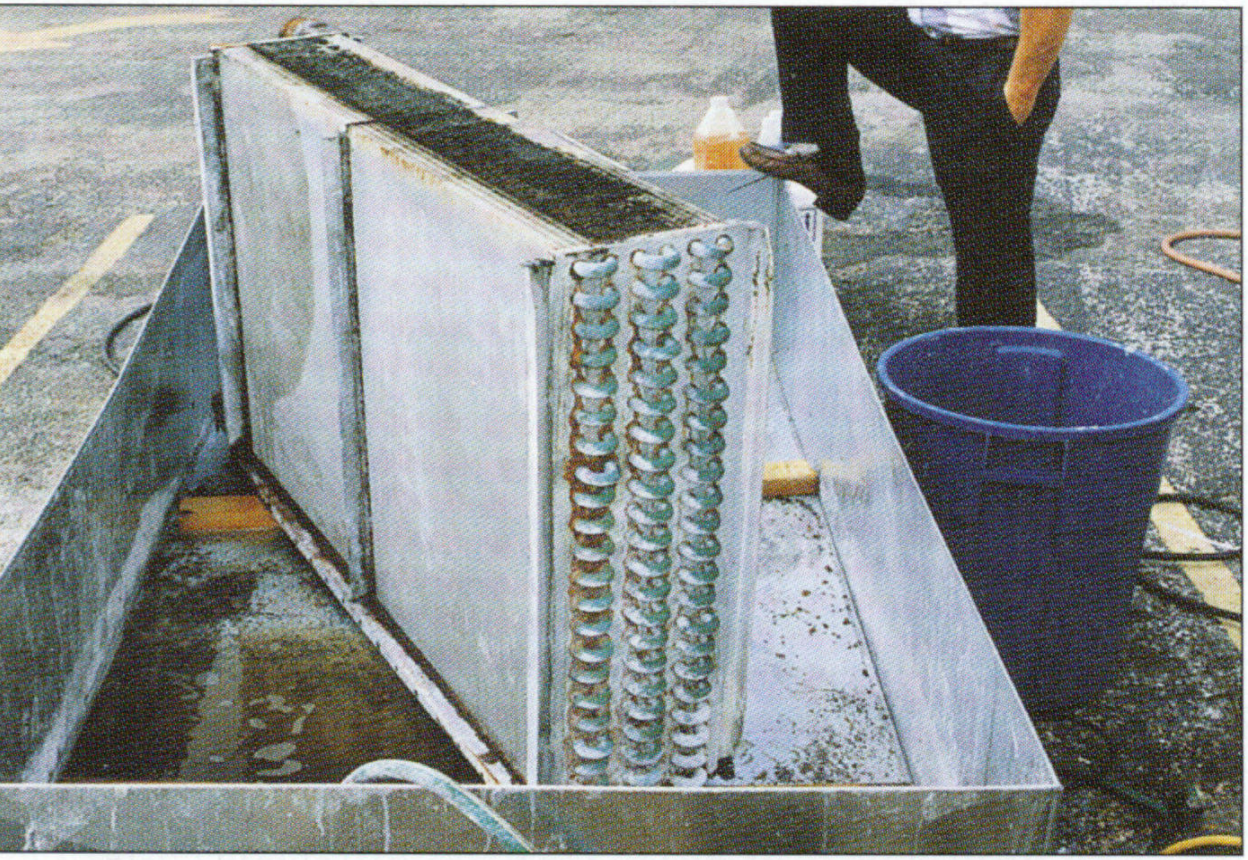
Mold Growth in Filter

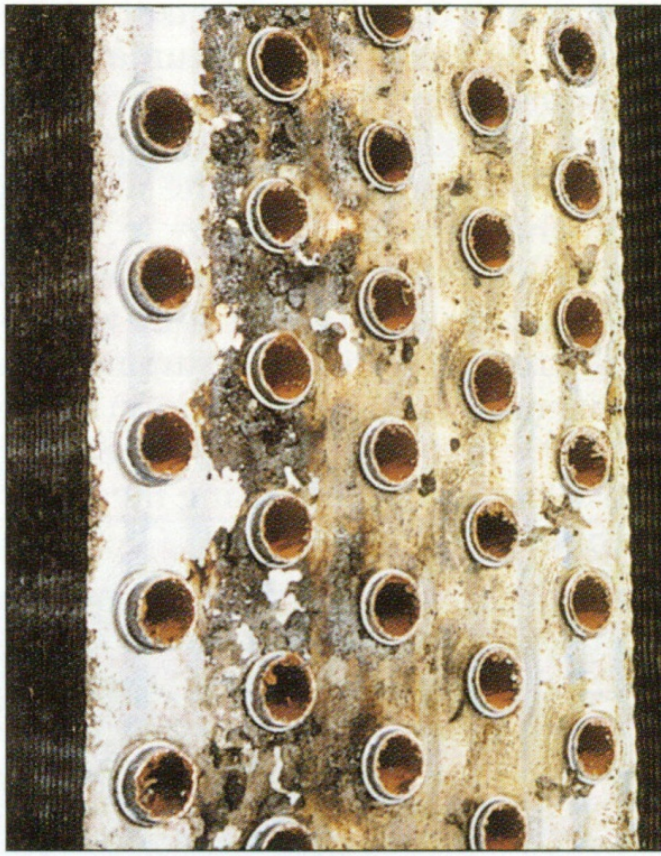
Coil Surface Samples

Before UV

After UV

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

ES Engineered Systems

RSES

BUILDING DESIGN +CONSTRUCTION

building OPERATING management

Air Conditioning | Heating | Refrigeration
the NEWS

Mechanical Hub
mechanical-hub.com

retrofit MAGAZINE

The Bayview Report :

MECHANICAL SOLUTIONS, INC.

RECEIVED JAN 24 2012

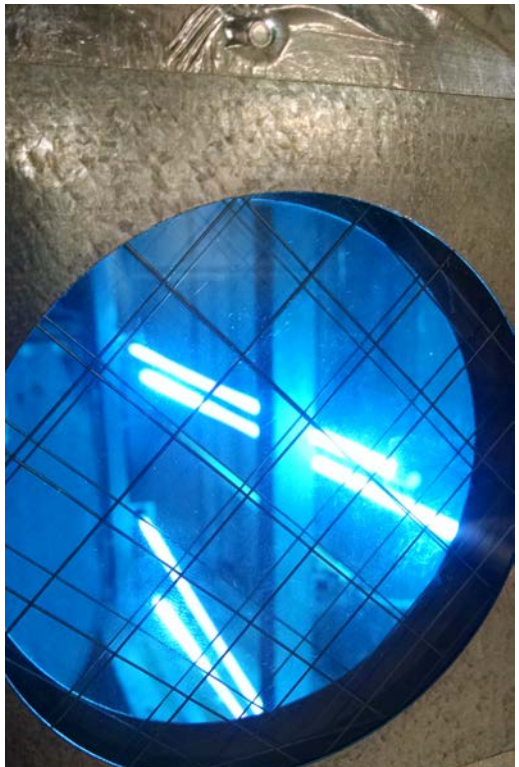
2050 Tigertail Blvd., Bay O • Dania Beach, FL 33004 • Phone: 954-921-0979 • Fax: 954-921-0964

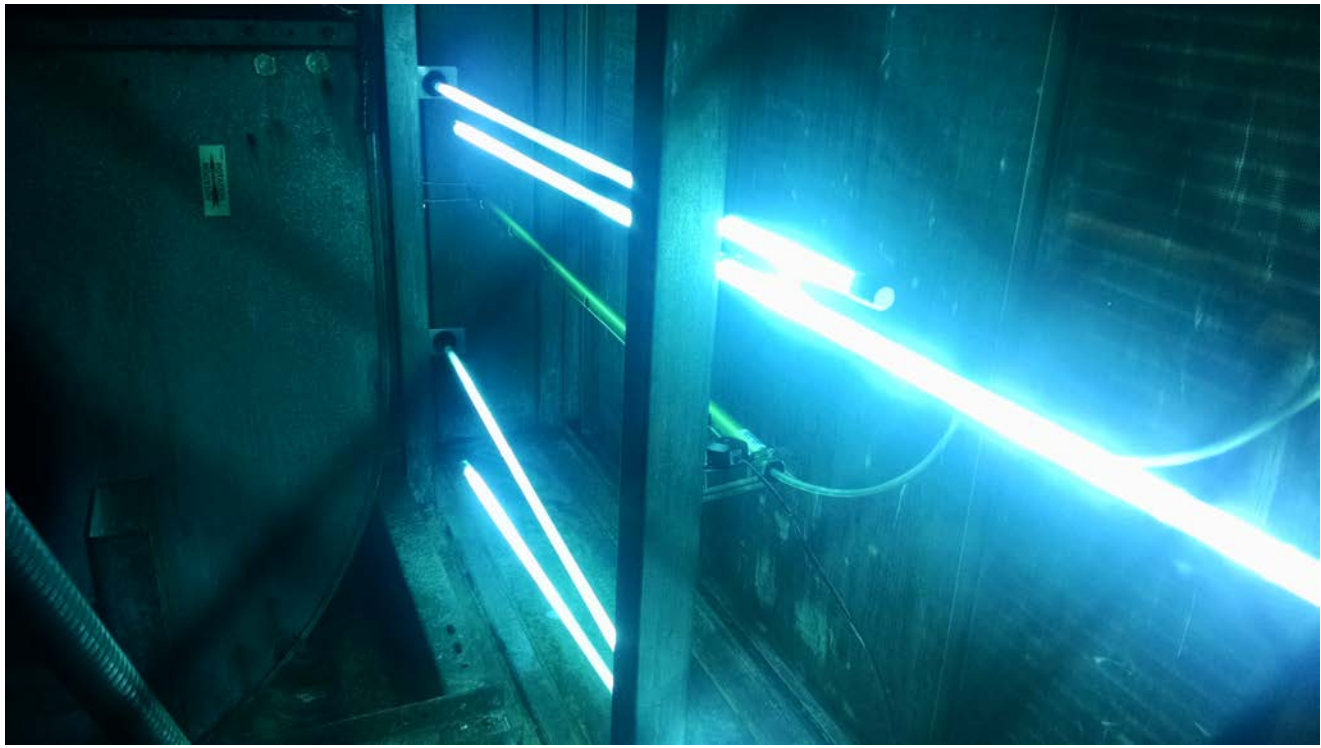
Quotes from the K & P report:

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!**

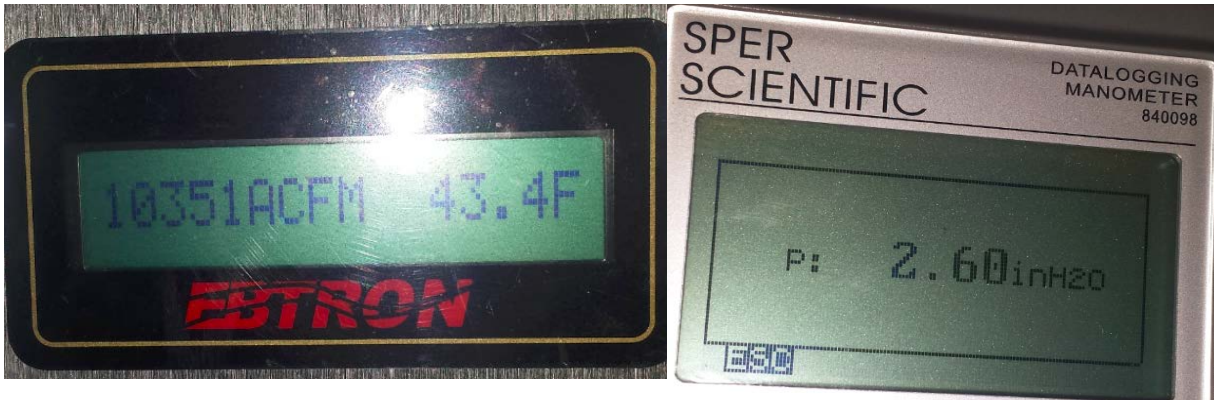
Hospital Case Study

REGIONAL MEDICAL CENTER SAVES $20,000 & RESTORES HVAC SYSTEM PERFORMANCE THROUGH ULTRAVIOLET-C TECHNOLOGY





Results



AHU - 9
Date: 9-12-2014
CFM: 10,351
Δ P: 2.60 in H2O

AHU - 9
Date: 12-02-2014
CFM: 14,307
Δ P: 0.69 in H2O

Results

"After a mere 90 days, airflow is back to design specs and we are able to maintain the desired temperature set points in the kitchen and cafeteria“

"The AHU motor is drawing less amps, saving the hospital energy. Based on this successful demonstration, we’ve decided to incorporate these performance-enhancing UV-C fixtures in more of the hospital's AHUs.”

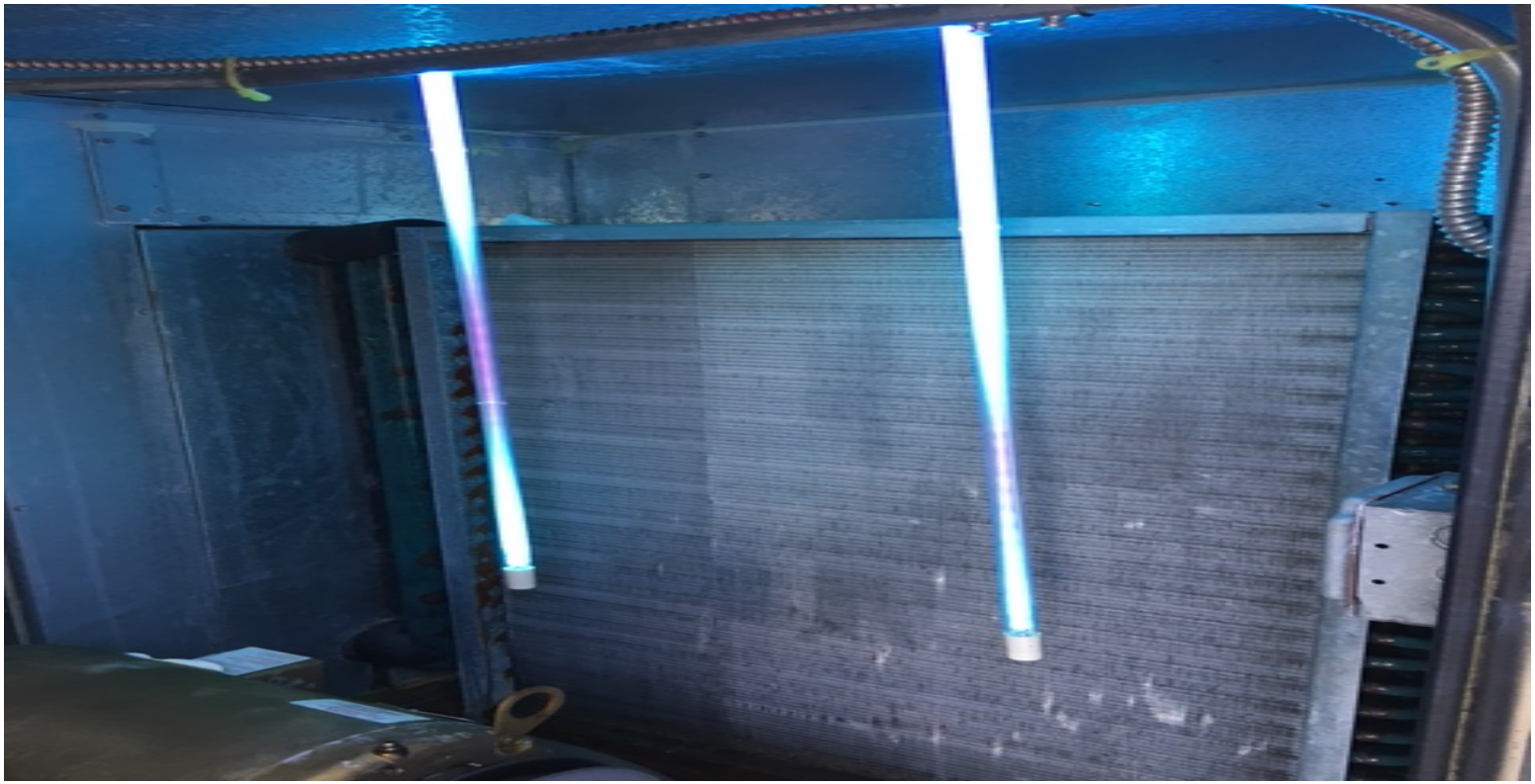
University of Arkansas
Brough Commons AHU South

96% Air Flow Increase With A Clean Coil

Florida Atlantic University

Emory University

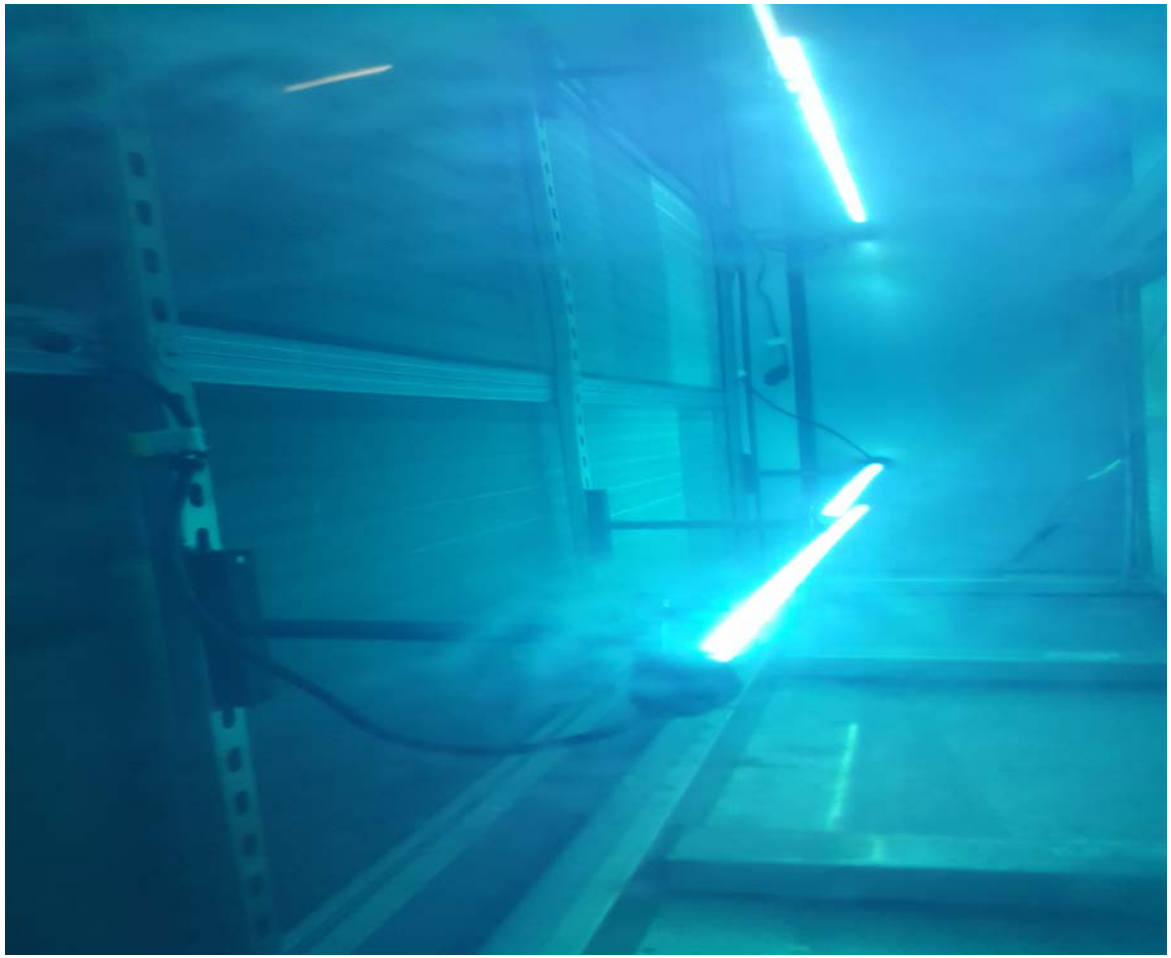
Georgia Tech



Georgia Tech

University of Louisiana - Monroe

University of Louisville Hospital



The Problem

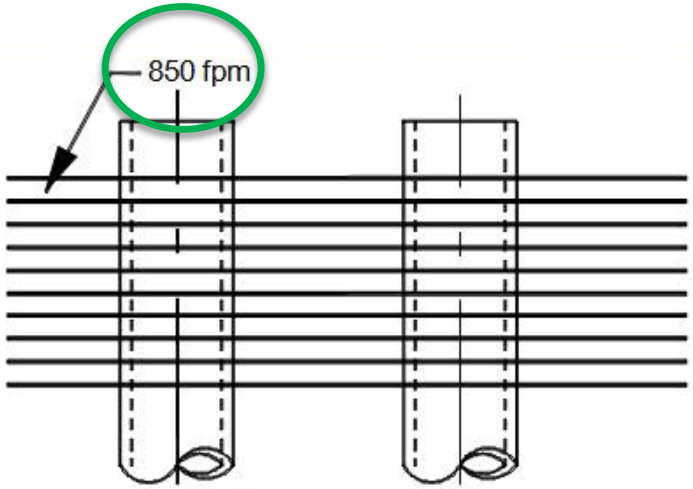
So What Happens?

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

New Clean Coil:

500 fpm

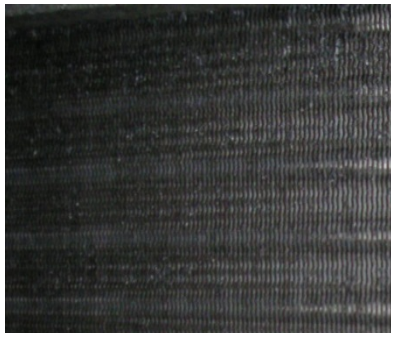
APPROACH



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

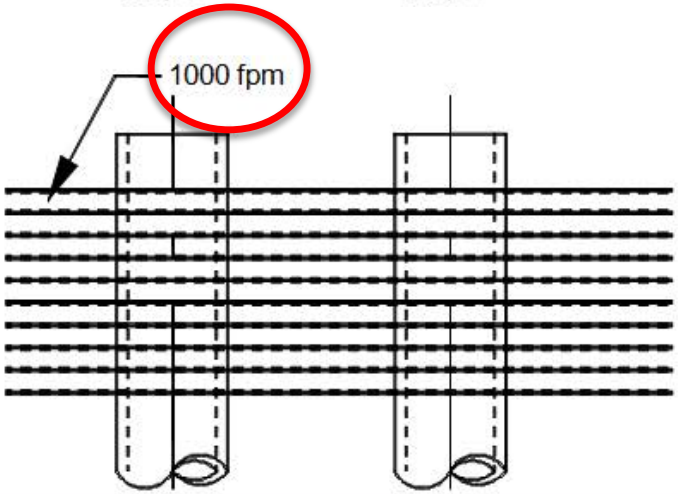
~54° WB

Add only .006" of bio film:



500 fpm

APPROACH

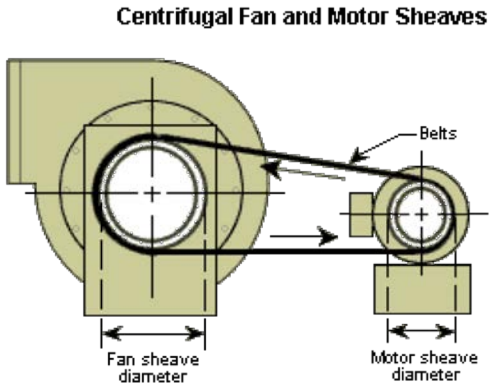


51% OPEN = **Decreased efficiency**

~58° WB

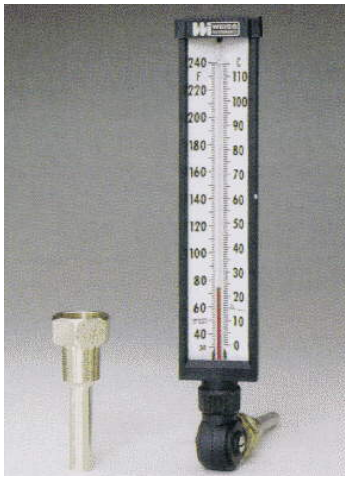
Typical Responses To The Problem

Speed up Fan



Pump More Chilled Water

Lower Coil Water Temp



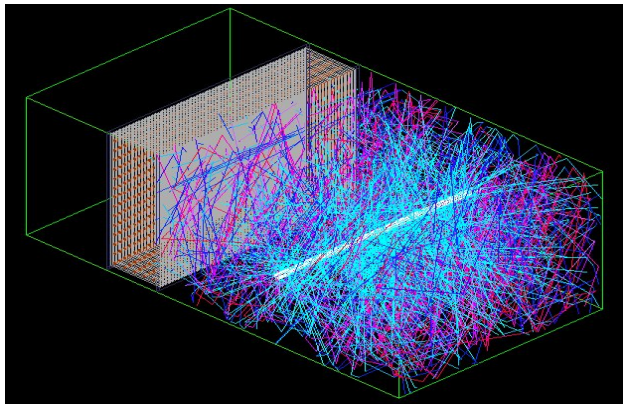
= **Increased kWh Usage on Fan Motors** = **Increased kWh Usage on Pump Motors** = **Significantly Increases kWh Usage on Chiller**

INCREASED ENERGY COSTS

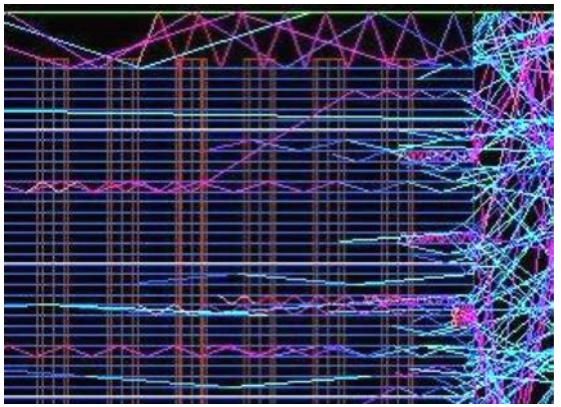
Restoring Coil Efficiency

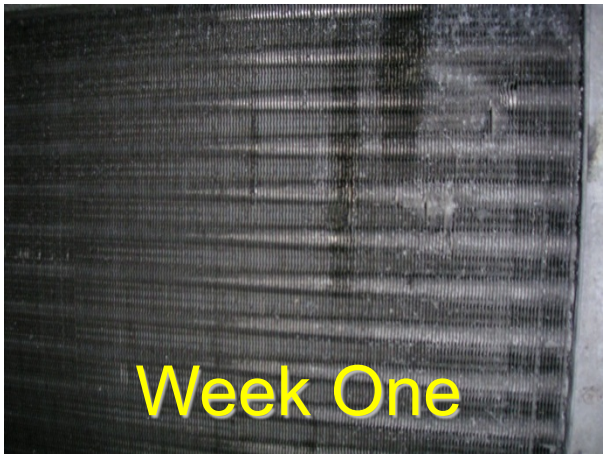
UV-C on the coil

UV-C energy degrades organic matter



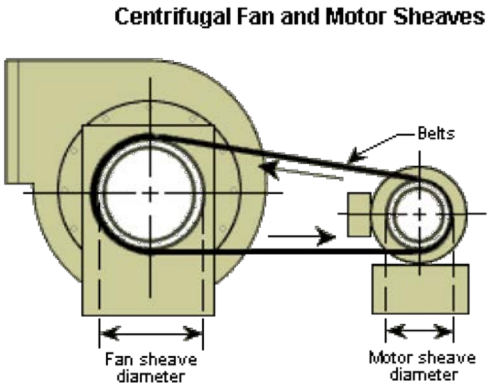
Energy is reflected through the coil





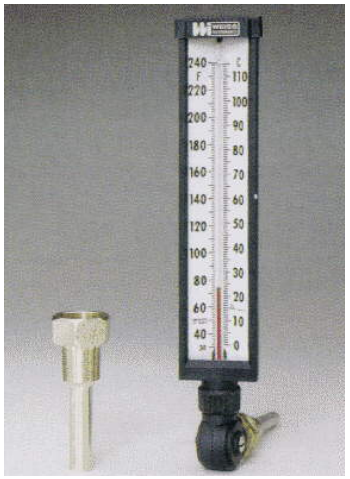
Harvesting Energy Savings From A Restored Cooling Coil

Slow Down Fan



Pump Less Chilled Water

Raise Coil Water Temp



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

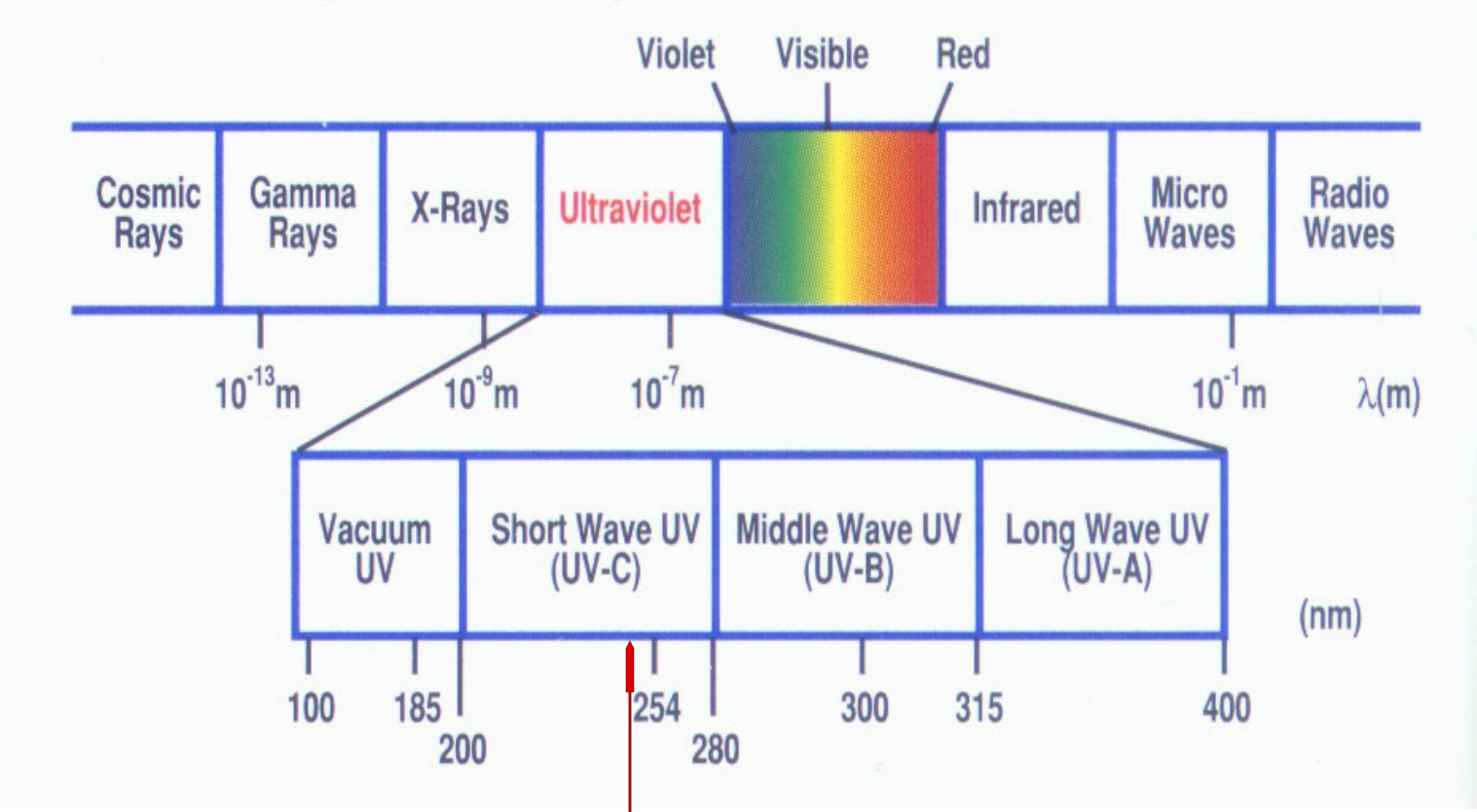
SUSTAINABLE ENERGY SAVINGS

Realizing Energy Savings (ROI)

	Before	After	Net Change
Date Sampled:	1/15/2015	2/15/2015	31 DAYS
CFM - Measured or Selected (VAV)	20,000	22,000	2,000
Entering Air Temperature - Dry Bulb °F	78.0	78.0	-
Entering Air Temperature - Wet Bulb °F	67.0	67.0	-
Leaving Air Temperature - Dry Bulb °F	63.0	63.0	-
Leaving Air Temperature - Wet Bulb °F	51.0	50.0	(1.0)
Total Cooling Capacity - Btuh	968,400	1,120,680	152,280
Sensible Heat -Btuh	324,000	356,400	32,400
Latent Heat - Btuh	644,400	764,280	119,880
Net Cooling Gain/Loss - Btuh →			152,280
Pressure Drop "Across Coil" ("WG)	1.1	0.9	0.20
Pressure Drop BHP Reduction			1.154
Annual Improvement (kWh cost)			$ 4,607.24
Total Annual Improvement			$ 4,607.24

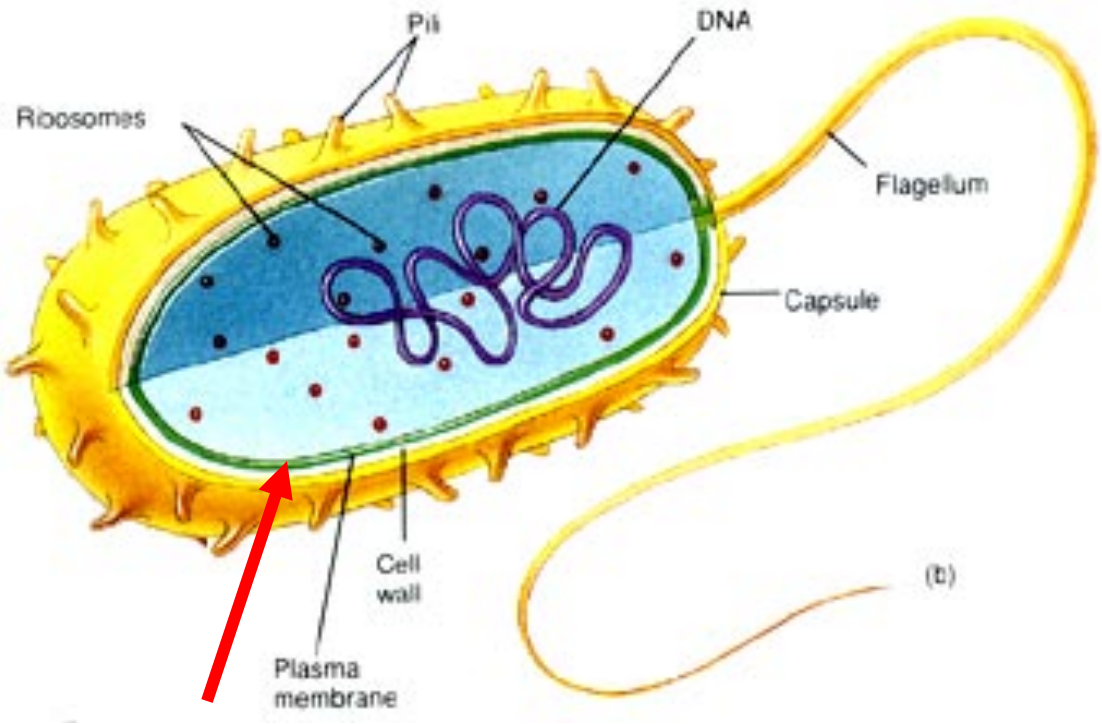
UV-C Energy Basics

Light Spectrum



Germicidal UV-C Lamp @ 253.7 nm

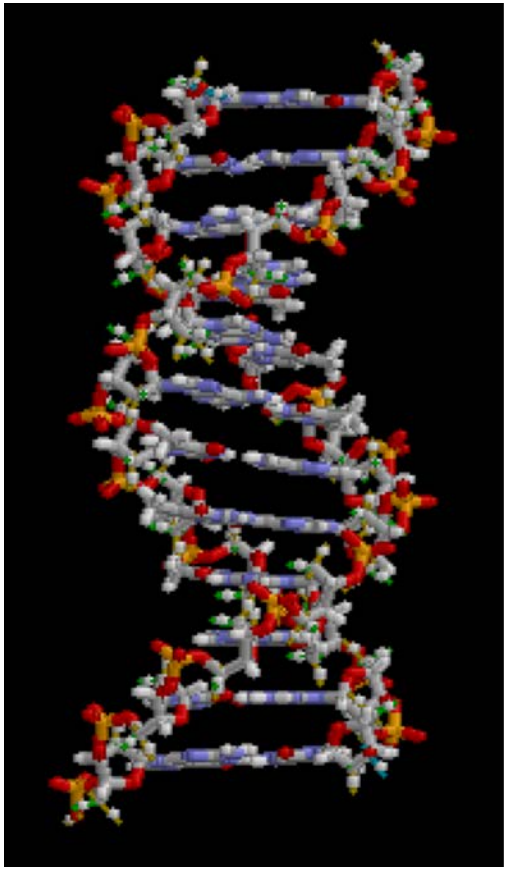
Cell Destruction

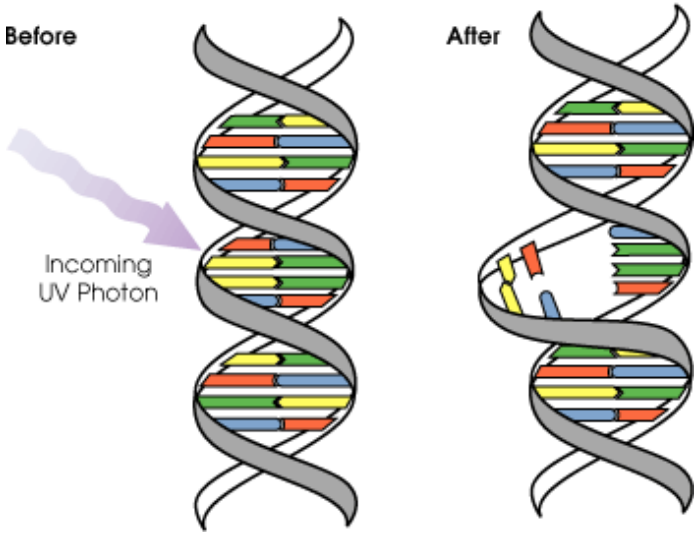


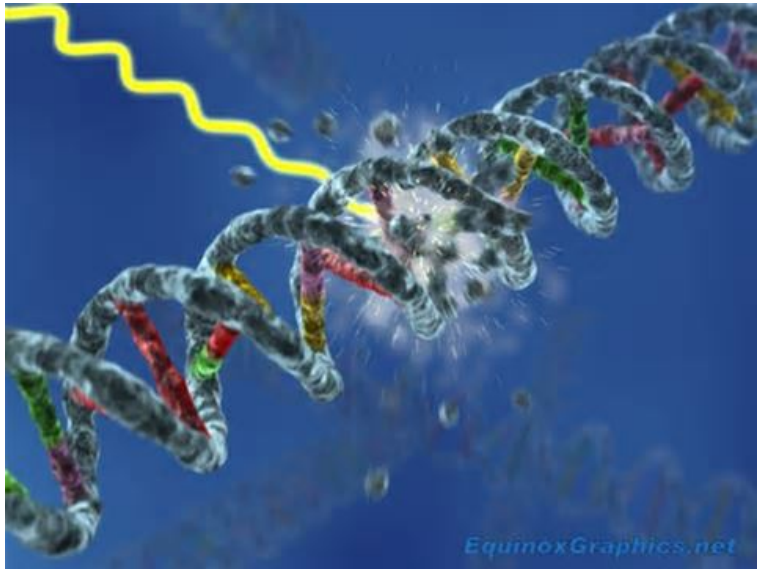
UV-C energy enters the cell

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

DNA Damage







Fluorescent

- 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

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 Lamps

- When it comes to replacement lamps, GUESSWORK should not be the path to finding a suitable replacement.
- Each lamp manufacturer supplies a Part number to the lamp.
- If that is not legible, check the fixture label.

You want to make sure that your lamp matches the prong configuration, length, and output (SO or HO).

What Does ASHRAE say…
2011 Handbook Chapter 60.8

- **Coil surface <u>irradiance</u> 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, <u>but at the expense of reducing air treatment effectiveness.</u>**

- 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

Schools Applications

Most often seen - small rooftop systems

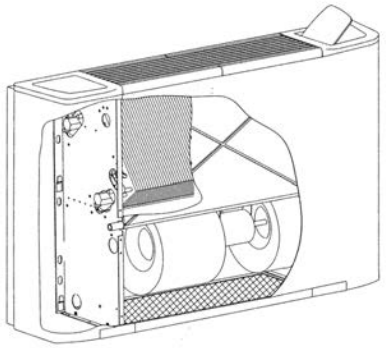

WARNING
UVR


American Standard

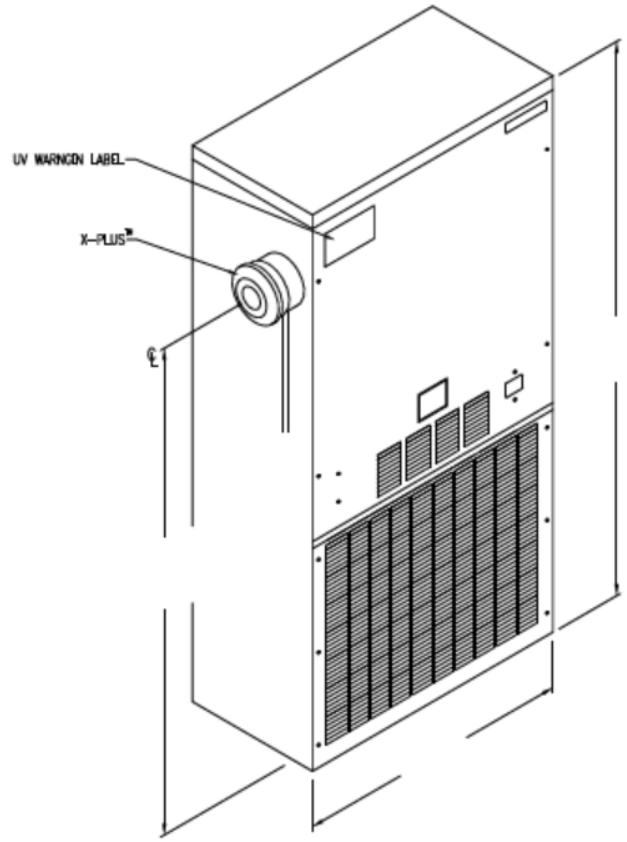
Large system – side access only

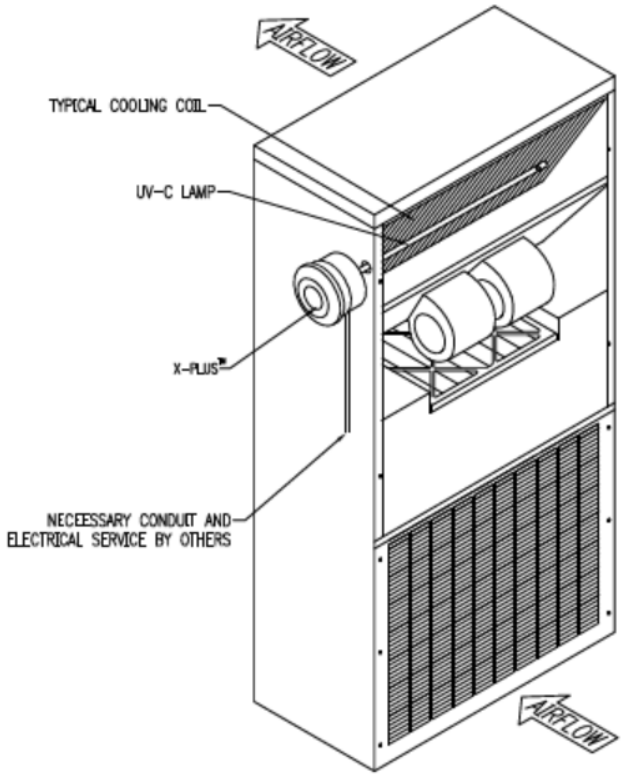
Large system – but with access issues

Fan Coil Applications



Modular Installation





On the exterior of a mobile trailer

HVAC Applications

- In-Duct- “On The Fly”
- Surface Irradiation-Coils
- Upper Air/ In Room

ASHRAE Position Document on Airborne Infectious Diseases

Approved by ASHRAE Board of Directors
January 19, 2014

Expires
January 19, 2017

Engineering Control Priority

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

In-Duct “On The Fly”

- Moving air stream or single-pass kill and requires more intensity, since you cannot change time, and this is split-second exposure
- Primary benefit is infection control (including colds & flu)
- Health care (isolation, special care, surgery), pharmaceutical facilities, correctional facilities, bioterrorism, etc.

Lackland Air Force Base
JOINT BASE SAN ANTONIO

Lackland AFB
San Antonio, TX

Infectious Disease Retrofit

Single Pass Kill Ratio = 99.98%

- 8 Dorm Buildings
- 20 AHU's / Building
- 160 AHU's Total
- Over 1500 Lamps

Surface Irradiation

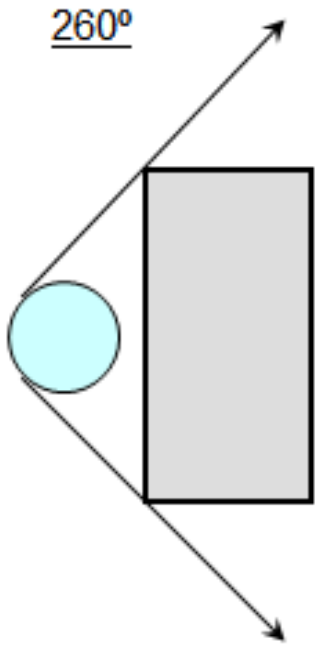
95-98% of **ALL** UV-C applied in HVAC Systems is for Coil Irradiance and System Maintenance

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

360° UV-C Distribution

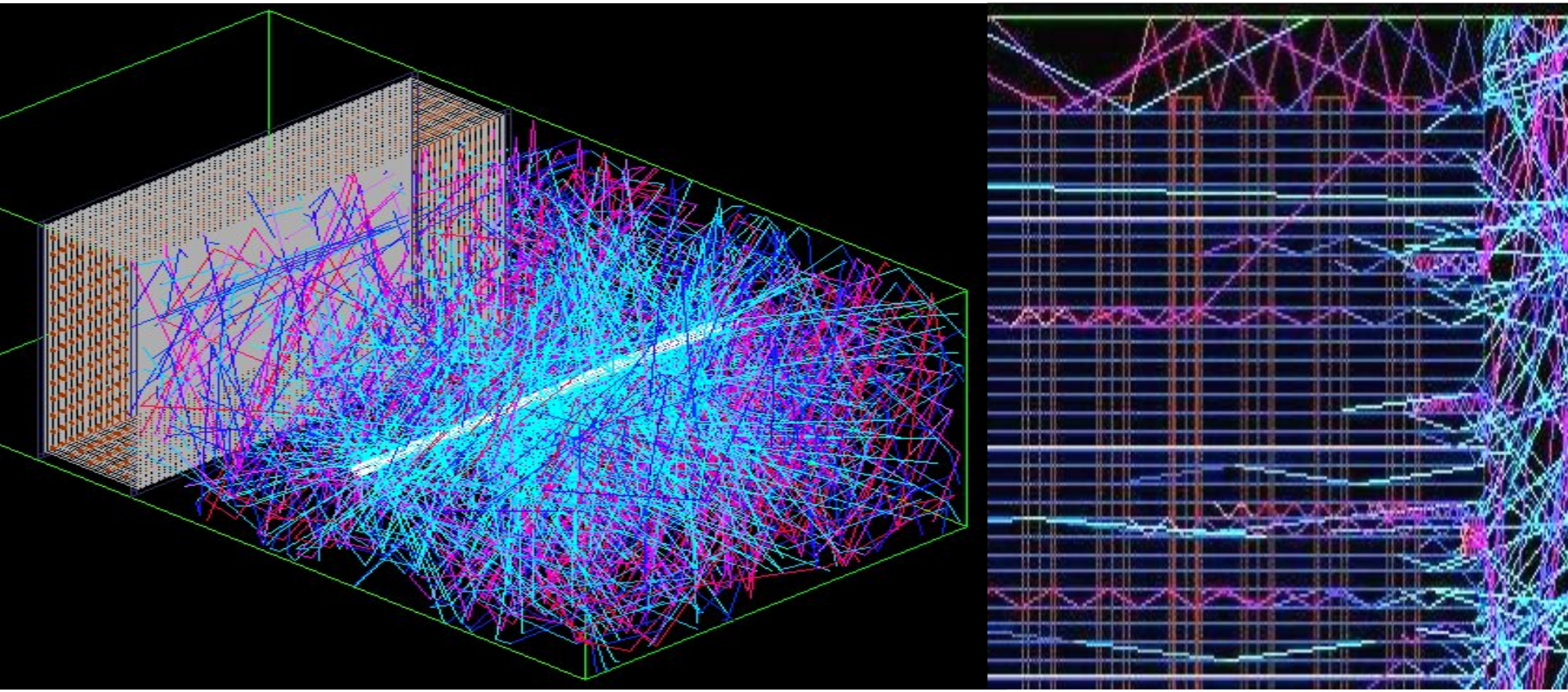
360^{o} UV-C Distribution

- 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

Upper Air/ In-Room

Strategy	Occupancy Categories Applicable for Consideration*	Application Priority	Research Priority
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

- Proven effective in killing airborne and surface microorganisms
- Perfect for healthcare, institutional, day care, food production, correctional facilities, ER, etc.
- Installs quickly and easily in “all” types of rooms

Upper Air Basics

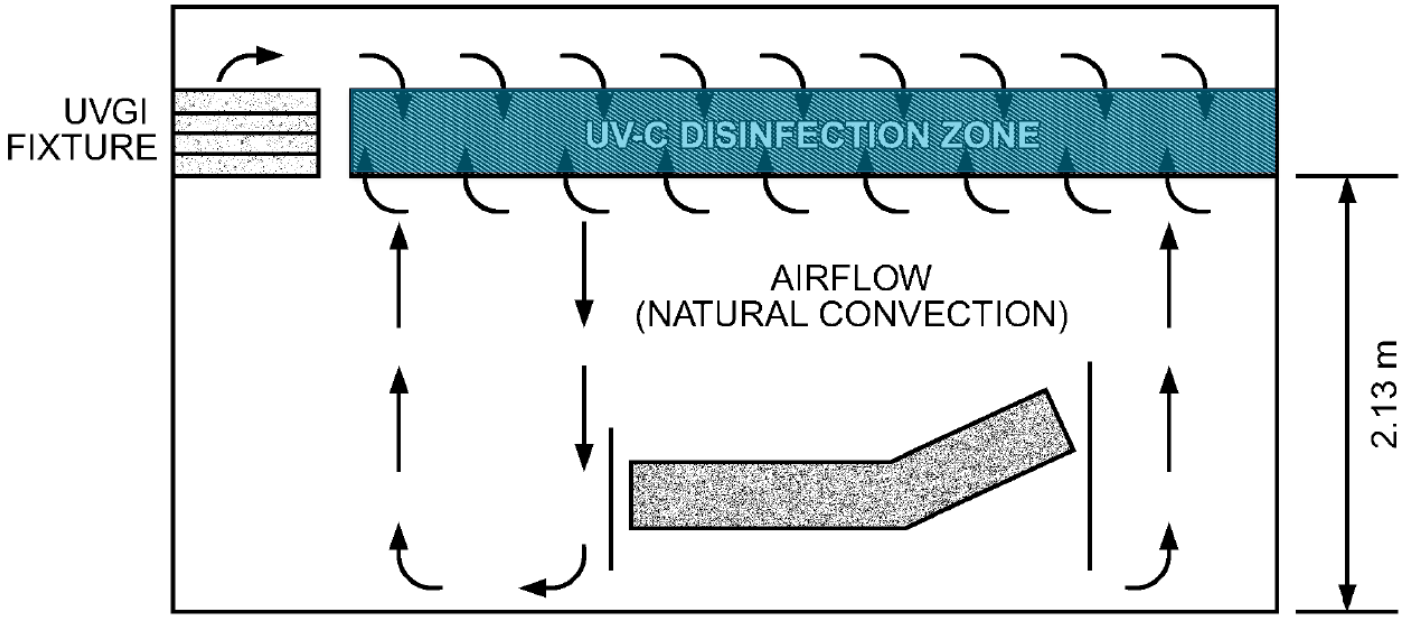
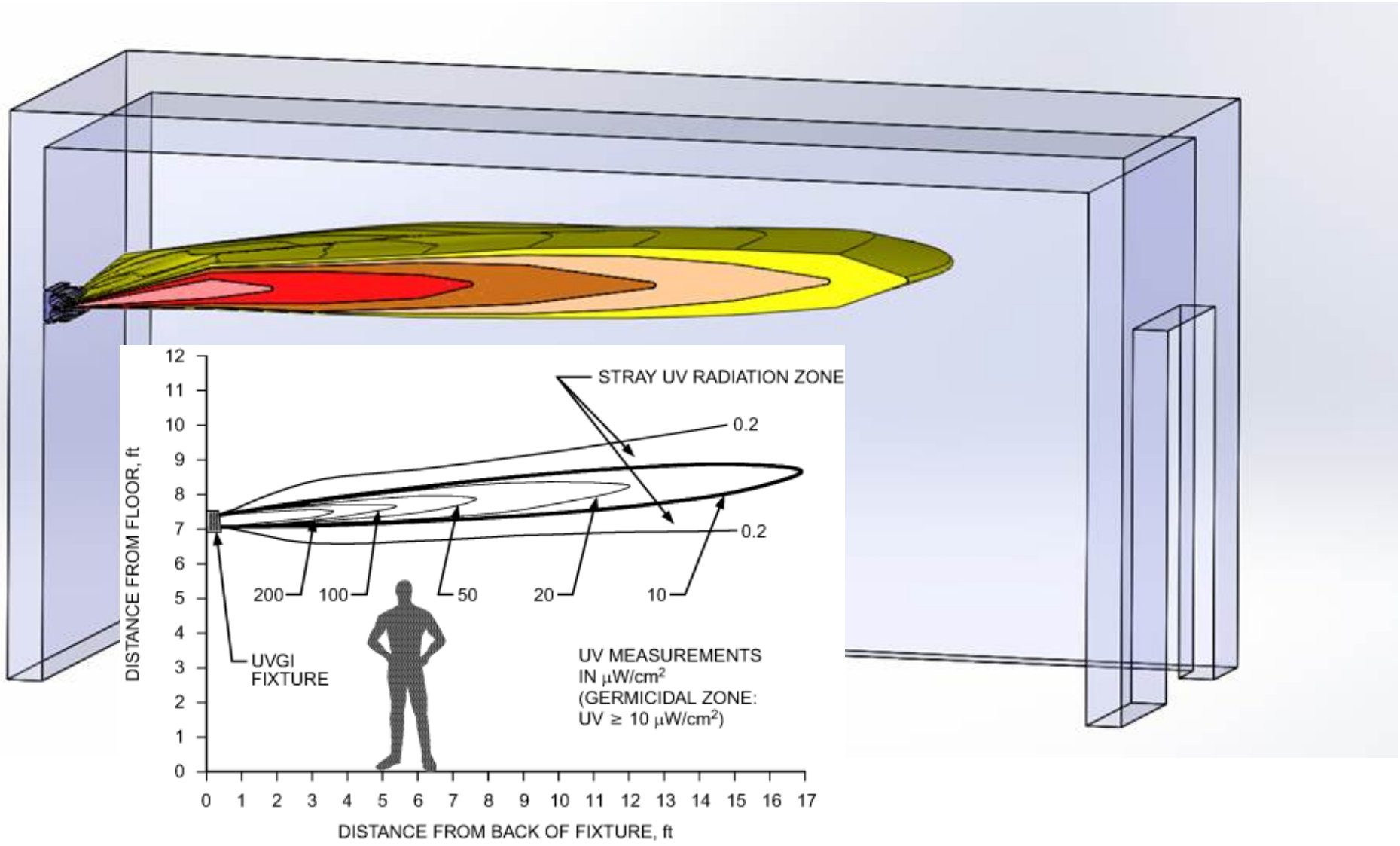


Fig. 5 Typical Elevation View of Upper-Room UV Applied in Hospital Patient Room

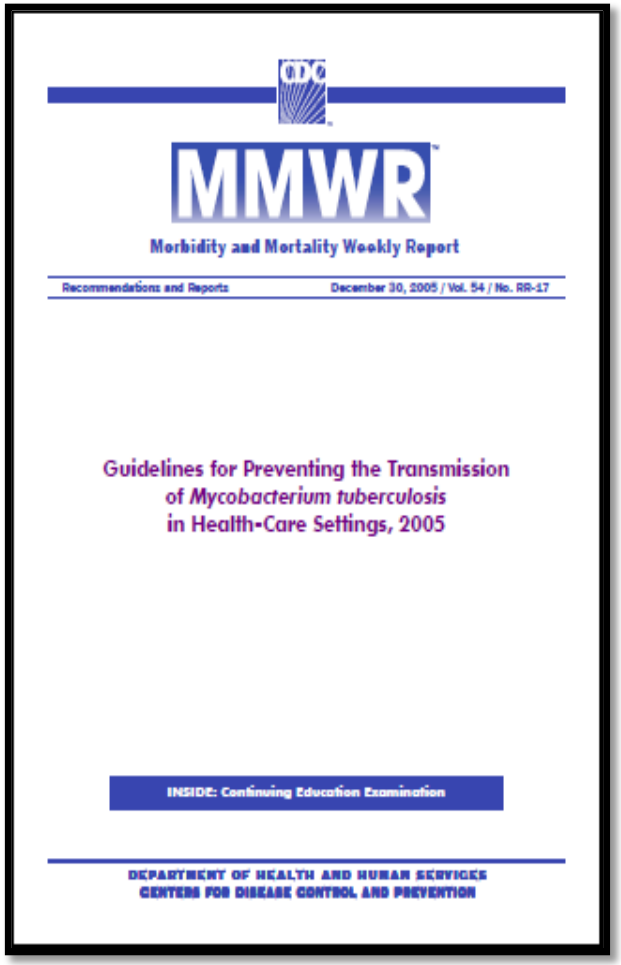
2011 ASHRAE Handbook—HVAC Applications

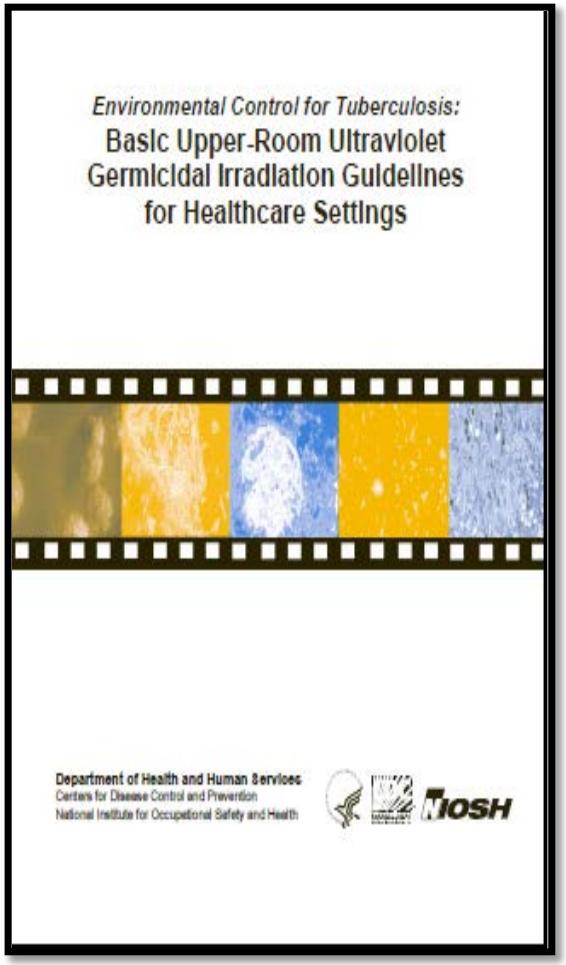
Modeling UV-C distribution

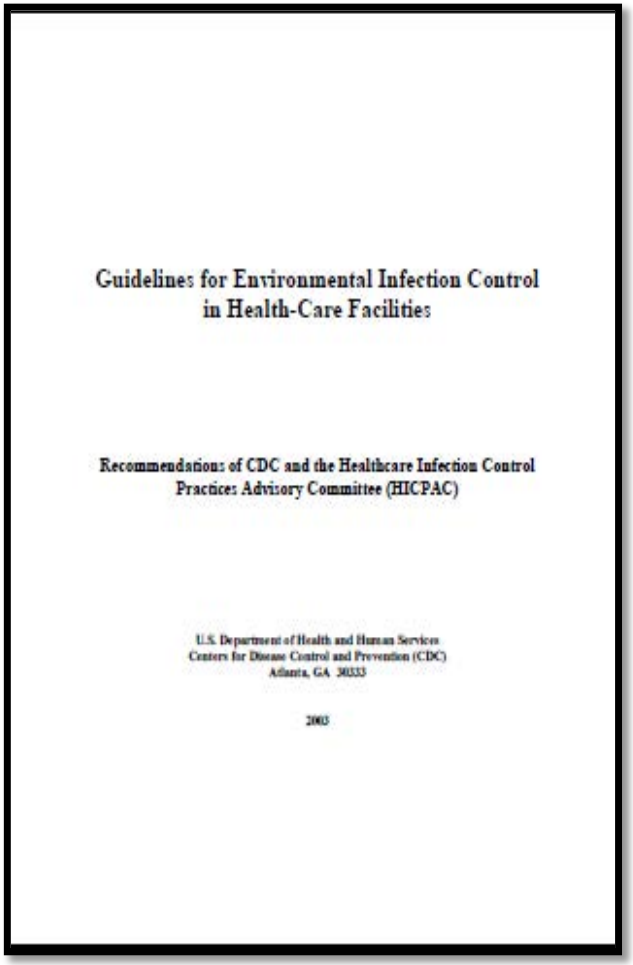


2011 ASHRAE Handbook—HVAC Applications-Chapter 60

Current Reference Material

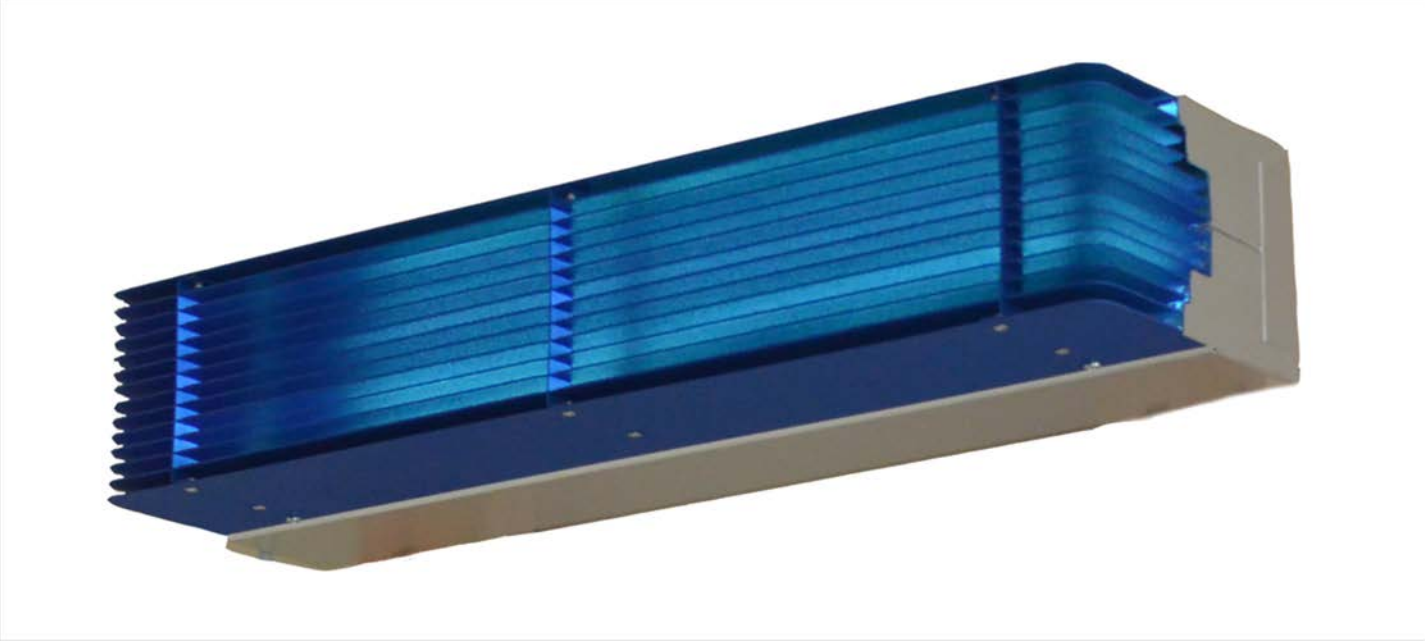




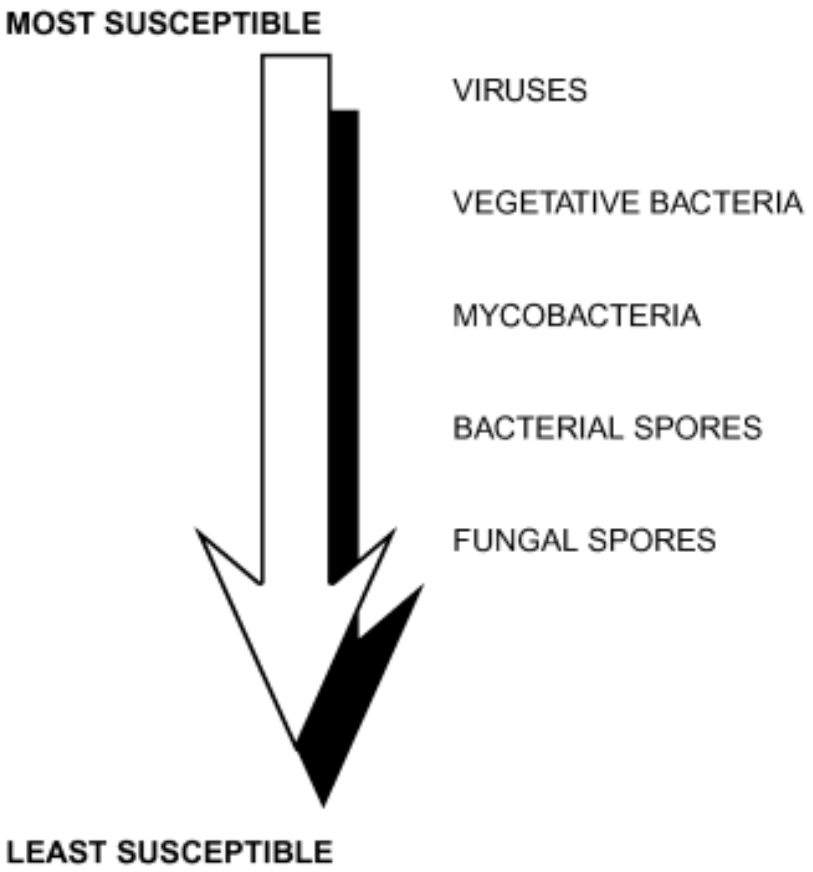


New ASHRAE Guideline – Upper Air

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

2011 ASHRAE Handbook—HVAC Applications-Chapter 60

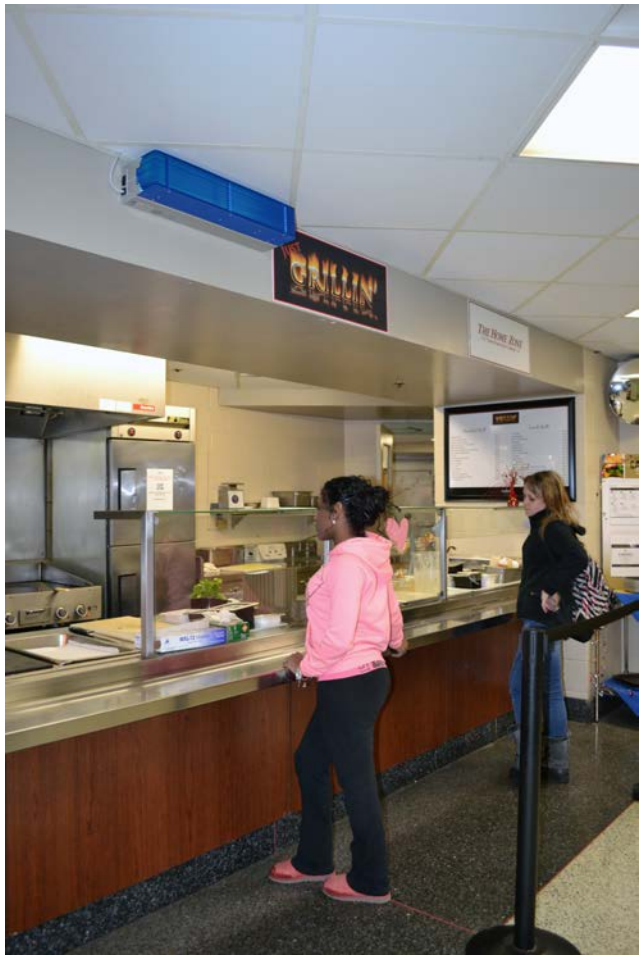
Upper Air Case Study

- 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



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


UVR

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- Summary
- Evaluations
  - Ultraviolet (Uv) Lamp Systems
  - Large Air-Handling Units And Plenums
  - Packaged Air-Handling Units And Unitary Systems
  - Controls
  - Accessories
  - Energy And Economic Considerations
  - Indoor Air Quality Considerations
  - Environmental Considerations

SUMMARY

SECTION 230566 - ANTIMICROBIAL ULTRAVIOLET LAMP SYSTEMS FOR HVAC

Version 13893

Section specifies ultraviolet-C (UV-C) lamp systems for mounting in air-handling units, fan-coil units, and packaged unitary HVAC equipment, for treatment of HVAC surfaces with ultraviolet germicidal irradiation (UVGI).

Section does not specify UVGI systems for in-duct airstream disinfection or in-room UV-C units.

Only Premium Section includes the following:

- UV-C lamp systems for large air-handling units, larger than 240,000 Btu/h (70 kW).

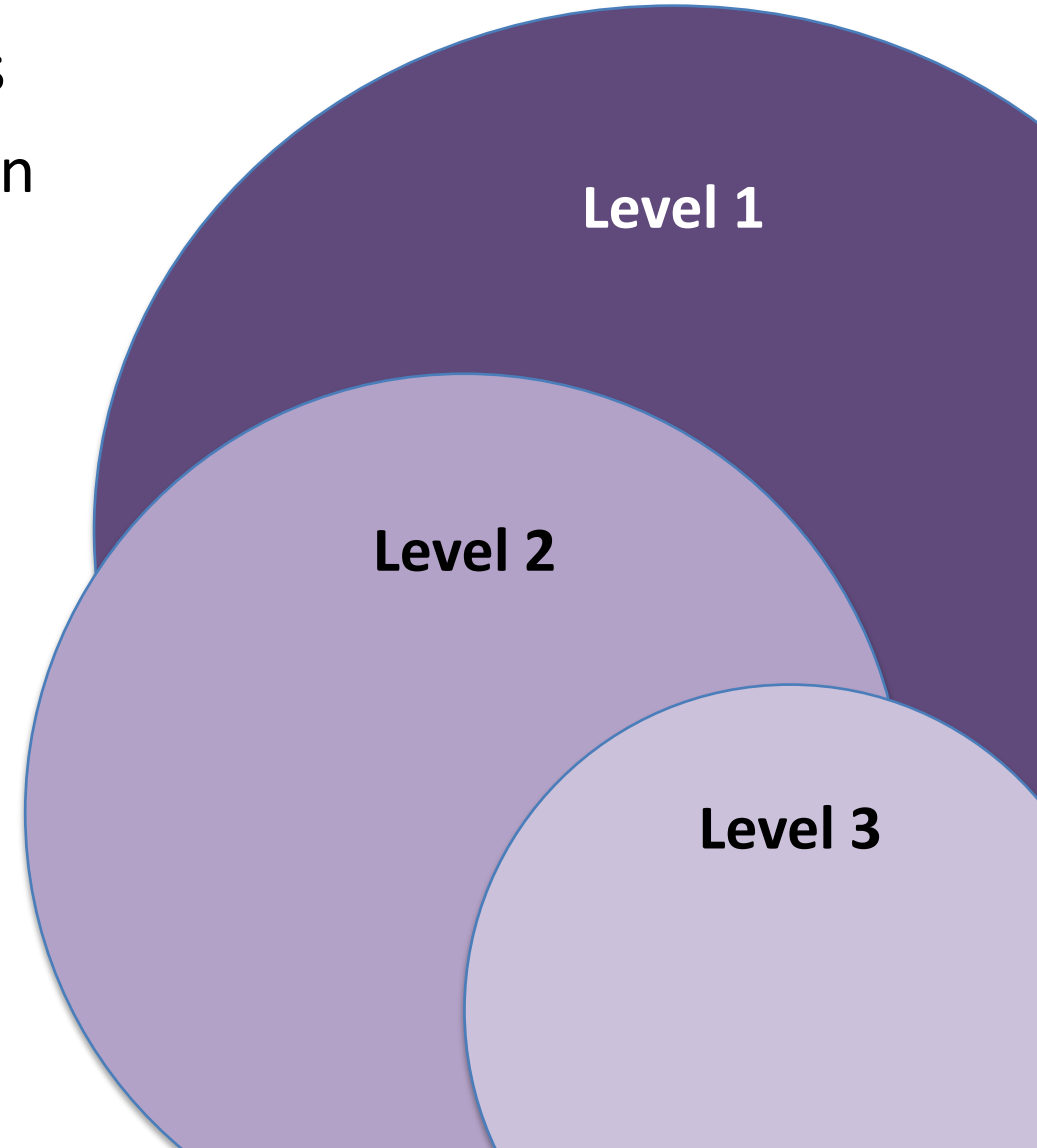
Related Sections:

- Section 260519 "Low-Voltage Electrical Power Conductors and Cables"
- Section 260523 "Control-Voltage Electrical Power Cables"
- Section 262816 "Enclosed Switches and Circuit Breakers"

Evaluations: References to the Section Text are to Premium Section.

Three Tiers of Benefits

- Level 1—HVAC systems
  - Cleaning & disinfection
- Level 2—People
  - IAQ & comfort
  - Easier maintenance
- Level 3—Budgets
  - Cost reduction
  - Cost avoidance



Level 1: HVAC Systems

- UV-C eliminates and/or prevents the buildup of organic material on surfaces, which:
  - Improves or maintains airflow
  - Returns and/or maintains heat-transfer levels
  - Reduces maintenance (coil cleaning)
- Gentler on coils than all other alternatives
- Maintained capacity prolongs system life
  - Less need to ‘tweak’ systems for same/similar performance

Level 2: People

- Clean coils and HVAC surfaces will:
  - Help improve indoor air quality (IAQ) by reducing mold products, pathogens and odors.
  - Boost comfort levels
  - Reduce sick time
  - Improve occupant productivity

Level 3: Budget

- Reduced energy consumption & cost
  - On average, UV-C cuts HVAC energy use by 10% - 25% and even more
  - Corresponding reduction in carbon footprint
- Fewer temperature complaints & responses
- Reduced system downtime & staff impacts
- Higher occupant/worker satisfaction
  - Reduces turnover and overhead

Questions?