UVC IN THE BUILDING ENVIRONMENT:
Perspectives on Building Codes, Energy Consumption & Cost Benefits

IUVA WORKSHOP
NIST, MD
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VP, Innovation & Technology
Ultraviolet Devices Inc.
PATHOGEN TRANSMISSION MODES

**Air handler/cooling coil**
- aspergillus, pseudomonas aeruginosa...

**Airborne transmission through HVAC ducts**
- TB, MRSA, Influenza, Klebsiella pneumoniae, aspergillus, Acinetobacter baumannii, aspergillus...

**Water-borne transmission**
- Legionella, pseudomonas aeruginosa; mycobacteria; aspergillus, fusarium, cryptosporium, giardia, acanthamoeba...

**Surface cross-contamination**
- MRSA, C-Diff, VRE, Candida auris, Ebola...

**Hand cross-contamination**
AIR CONTAMINANTS

![Air Contaminants Diagram](image)

- **Molecules**
- **Viruses**
- **Tobacco smoke**
- **Fumes**
- **Smog**
- **Dusts**
- **Spores**
- **Bacteria**
- **Human hair**
- **Pollen**

**Particle size (micrometers):**

- 0.0001
- 0.001
- 0.01
- 0.1
- 1
- 10
- 100

**Microscopes:**

- Scanning electron microscope
- Optical microscope
- Eye
CONTROL STRATEGIES

- Ventilation and Dilution
- Purging with Outside air
  - Increase Air changes per hour
- Pressurization control; isolation rooms
- Filtration
- Ultraviolet Germicidal Irradiation (UVGI)
<table>
<thead>
<tr>
<th>GUIDELINES</th>
<th>AGENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guidelines for Environmental Infection Control in Healthcare Facilities</td>
<td>HICPAC</td>
</tr>
<tr>
<td>Guidelines for Construction and Equipment of Hospital and Medical Facilities</td>
<td>AIA</td>
</tr>
<tr>
<td>HVAC Design Manual for Hospitals and Clinics</td>
<td>ASHRAE</td>
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<tr>
<td>General Requirements: Purpose of the Facilities Standard for Public Buildings Service</td>
<td>GSA</td>
</tr>
<tr>
<td>Guidelines for Preventing the Transmission of Mycobacterium Tuberculosis in Health Care Settings</td>
<td>CDC</td>
</tr>
<tr>
<td>Environmental Control for Tuberculosis: Upper-Room Ultraviolet Germicidal Irradaition Guidelines for Health Care</td>
<td>NIOSH</td>
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<tr>
<td>Guidelines on the Design and Operation of HVAC Systems in Disease Isolation Areas</td>
<td>CHPPPM</td>
</tr>
<tr>
<td>Unified Facilities Criterai UFC 4-510-01 design: Medical Military Facilities</td>
<td>UFC 2001</td>
</tr>
<tr>
<td>Document/Standard</td>
<td>Description</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Position Document on Airborne Infectious Diseases</td>
<td></td>
</tr>
<tr>
<td>Position Document on Filtration and Air Cleaning</td>
<td></td>
</tr>
<tr>
<td>ASHRAE/ASHE Standard 170.1: Ventilation of Health Care Facilities</td>
<td></td>
</tr>
<tr>
<td>SYSTEMS and EQUIPMENT HANDBOOK</td>
<td>Chapter 12: Ultraviolet Lamp Systems</td>
</tr>
<tr>
<td>APPLICATIONS HANDBOOK</td>
<td>Chapter 60: Ultraviolet Air and Surface Treatment</td>
</tr>
<tr>
<td>ASHRAE Standard 185.1: Method of Testing UV-C Lights for use in Air Handling Units</td>
<td>or Air Ducts to Inactivate Airborne Microorganisms</td>
</tr>
<tr>
<td>ASHRAE Standard 185.2: Method of Testing UV-C Lights for use in Air Handling Units</td>
<td>or Air Ducts to Inactivate Microorganisms on Irradiated Surfaces</td>
</tr>
<tr>
<td>ASHRAE GPC 37: Guideline for the Application of Upper Air (Upper Room) Ultraviolet</td>
<td>Germicidal (UV-C) Devices to Control the Transmission of Airborne Microorganisms</td>
</tr>
</tbody>
</table>
UVGI COIL CLEANING

Coil Cleaning Systems Save Energy and Money!
UV Destroys the Microbiological Biofilm that Thrives in the Moist Coil Environment

UV coil systems are typically installed downstream of the evaporator coil to destroy bacteria, mold and organic matter that grows and collects on cooling coils and surrounding areas.
UVGI COIL CLEANING

- UV systems destroy bacteria, mold and organic matter that grows and collects on cooling coils

- The resulting increase in HVAC cooling capacity and decreased pressure drop results in energy savings of up to 15% in some systems

- UV is a 24/7 maintenance system that eliminates the need for periodic mechanical coil cleaning

![Clogged Coil](image1)

![UV destroys biofilm](image2)

![Clean Coil after 3 months](image3)
UVGI AIR STREAM DISINFECTION

“Kill on the Fly”

Moving Air Streams

COMMON AIRBORNE MICROORGANISMS

INFLUENZA (COMMON COLD)  TUBERCULOSIS
SARS, H1N1            MEASLES
MERS                CHICKEN POX
MOLD SPORES          LEGIONELLA
UVGI AIR DISINFECTION

AHU Mounted

Duct Mounted
UVGI UPPER AIR ROOM DISINFECTION

Courtesy: Dr. Richard Vincent Mt. Sinai School of Medicine, NY
UVGI WHOLE ROOM SURFACE DISINFECTION
### Bacteria

- Bacillus anthracis: 8,700
- Bacillus anthracis spores: 46,200
- Escherichia coli: 6,600
- Legionella pneumophila: 12,300
- Mycobacterium tuberculosis: 10,000
- Salmonella typhi - Typhoid Fever: 7,000
- Staphylococcus aureus: 6,458
- Vibrio comma - Cholerae: 6,500
- Clostridium difficile - C-diff: 38,500
- Vancomycin-Resistant Enterococci - VRE: 12,600

### Virus

- Infectious Hepatitis: 8,000
- Influenza A: 4,558

### Mold

- Aspergillus flavus: 99,000
- Aspergillus niger: 330,000
UV DOSE CRITICAL TO SYSTEM EFFICACY

Application Specific! Correct Intensity = Dose per Solution

Coil Disinfection:
- Surface fixed
- Unlimited Time
- Low UV dose

Air Disinfection: High Dose
- Fast moving microbes
- Fractions of seconds
- High UV Dose

<table>
<thead>
<tr>
<th>Target Microbe and Dose for 90% Inactivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microbe</td>
</tr>
<tr>
<td>Rate Constant</td>
</tr>
<tr>
<td>Dose for 90% Kill (D90)</td>
</tr>
</tbody>
</table>

| UV Exposure Dose | 1589 µW/cm² |
| URV | 12 |

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamp model</td>
<td>V-MAX-35</td>
</tr>
<tr>
<td>Lamp UV power, W</td>
<td>27.00</td>
</tr>
<tr>
<td>Lamp arc length, cm</td>
<td>76.2</td>
</tr>
<tr>
<td>Lamp Diameter, cm</td>
<td>1.58</td>
</tr>
<tr>
<td>Number of Lamps</td>
<td>5</td>
</tr>
<tr>
<td>Total UV Power, W</td>
<td>135</td>
</tr>
<tr>
<td>Duct Width</td>
<td>187.64 cm</td>
</tr>
<tr>
<td>Duct Height</td>
<td>53.340 cm</td>
</tr>
<tr>
<td>Duct Length</td>
<td>101.6 cm</td>
</tr>
<tr>
<td>Airflow</td>
<td>335.802 m³/min</td>
</tr>
<tr>
<td>Velocity</td>
<td>6.3 m/s</td>
</tr>
<tr>
<td>Exposure Time</td>
<td>0.160 sec</td>
</tr>
<tr>
<td>Air Temperature</td>
<td>55 F</td>
</tr>
<tr>
<td>Reflectivity</td>
<td>87 %</td>
</tr>
</tbody>
</table>
Cooling Coil’s Impact On Energy Use

ASHRAE Journal

Study Verifies
Coil Cleaning
Saves Energy

By Ross D. Montgomery, P.E., Member ASHRAE; and Robert Baker, Member ASHRAE

Although it’s known theoretically that cleaning a coil can result in energy savings, little actual testing data and research exist to prove the point. As a result, building managers often ignore or reduce resources devoted to air-handler maintenance when faced with budget constraints. If proper maintenance is an important consideration in overall energy costs, conserving in that but can be self-defeating.

Through our privately funded testing, monitoring and analysis, we believe we found a methodology and isolates that proven maintaining air-handler components to a clean condition can save energy dollars and improve other building performance parameters such as indoor air quality and comfort, along with less mold and bacteria. Thus, we are evaluating. IAQ environmental parameter improvements, better tenant satisfaction, and increased maintenance

“...Coil cleaning can significantly improve energy efficiency and IAQ performance of the HVAC&R systems in a building ...(by) 10 – 15%.”
UVGI COSTS and ENERGY CONSUMPTION

HVAC Systems

FIGURE 7. A comparison of UVGI air-stream-disinfection (AD) and microbial-growth-control (MGC) systems for a 20-year life cycle.

By W.J. KOWALSKI, PE, and WILLIAM P. BAHNFLETH, PhD, PE,* Department of Architectural Engineering, The Pennsylvania State University, University Park, Pa.

By W.J. KOWALSKI, PE, and WILLIAM P. BAHNFLETH, PhD, PE,* Department of Architectural Engineering, The Pennsylvania State University, University Park, Pa.

Economic evaluation of typical UVGI systems

<table>
<thead>
<tr>
<th>Type of Application</th>
<th>Air-stream disinfection</th>
<th>Microbial-growth control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design airflow</td>
<td>10,000 cfm</td>
<td>10,060 cfm</td>
</tr>
<tr>
<td>Velocity</td>
<td>413 tpm</td>
<td>413 tpm</td>
</tr>
<tr>
<td>Predicted disinfection</td>
<td>90 percent Serratia</td>
<td>99.99 percent Aspergillus</td>
</tr>
<tr>
<td>UVGI lamp model</td>
<td>GFH436TS</td>
<td>TUV18W</td>
</tr>
<tr>
<td>Number of lamps</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Height</td>
<td>150 cm</td>
<td>150 cm</td>
</tr>
<tr>
<td>Width</td>
<td>150 cm</td>
<td>150 cm</td>
</tr>
<tr>
<td>Length</td>
<td>150 cm</td>
<td>150 cm</td>
</tr>
<tr>
<td>Lamp total power (each)</td>
<td>36 W</td>
<td>18 W</td>
</tr>
<tr>
<td>Hours of operation</td>
<td>3744 hr</td>
<td>8760 hr</td>
</tr>
<tr>
<td>Energy costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat generated</td>
<td>0.072 kW</td>
<td>0.018 kW</td>
</tr>
<tr>
<td>Cooling load</td>
<td>189 KWH</td>
<td>110 KWH</td>
</tr>
<tr>
<td>Total DP (lamps, fixtures, filters)</td>
<td>0.560 in Wh</td>
<td>0.296 in Wh</td>
</tr>
<tr>
<td>Total fan energy (80 percent eff.)</td>
<td>8016 KWH</td>
<td>4151 KWH</td>
</tr>
<tr>
<td>Electrical energy</td>
<td>270 KWH</td>
<td>158 KWH</td>
</tr>
<tr>
<td>Cooling load energy</td>
<td>189 KWH</td>
<td>110 KWH</td>
</tr>
<tr>
<td>Total energy</td>
<td>8475 KWH</td>
<td>4419 KWH</td>
</tr>
<tr>
<td>Rate</td>
<td>8 cents per KWH</td>
<td>8 cents per KWH</td>
</tr>
<tr>
<td>Annual energy cost</td>
<td>$678</td>
<td>$354</td>
</tr>
<tr>
<td>Maintenance costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average tube life</td>
<td>9000 hr</td>
<td>9000 hr</td>
</tr>
<tr>
<td>Tube hours per year</td>
<td>7438 hr</td>
<td>8760 hr</td>
</tr>
<tr>
<td>Replacements per year</td>
<td>0.83</td>
<td>0.97</td>
</tr>
<tr>
<td>Cost per tube</td>
<td>$85</td>
<td>$85</td>
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<tr>
<td>Annual cost</td>
<td>$71</td>
<td>$89</td>
</tr>
<tr>
<td>Annual filter-replacement cost</td>
<td>$33</td>
<td>$6</td>
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<tr>
<td>Maintenance (assumed)</td>
<td>$200</td>
<td>$200</td>
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<tr>
<td>Annual maintenance cost</td>
<td>$949</td>
<td>$642</td>
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<tr>
<td>First costs</td>
<td></td>
<td></td>
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<tr>
<td>UVGI system (AU prices)</td>
<td>$765</td>
<td>$550</td>
</tr>
<tr>
<td>Labor (estimated)</td>
<td>$1000</td>
<td>$1000</td>
</tr>
<tr>
<td>Total installation cost</td>
<td>$1765</td>
<td>$1550</td>
</tr>
<tr>
<td>Life cycle</td>
<td>20 years</td>
<td>20 years</td>
</tr>
<tr>
<td>Interest rate</td>
<td>8 percent</td>
<td>8 percent</td>
</tr>
<tr>
<td>Life cycle cost</td>
<td>$100</td>
<td>$150</td>
</tr>
<tr>
<td>Total annual cost</td>
<td>$1806</td>
<td>$1154</td>
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</tbody>
</table>
Annual costs of employing UVGI systems for air stream disinfection is significantly lower than the cost associated with mechanical ventilation controls, such as increasing air changes or purging with more outside air.

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Upper Air UV</th>
<th>Increased Air Changes (9.2 ACH)</th>
<th>UVGI in AHU</th>
</tr>
</thead>
<tbody>
<tr>
<td>$6792</td>
<td>$10847</td>
<td>$10,900</td>
<td>$6675</td>
</tr>
</tbody>
</table>
The combination of UV and Merv 13-15 filters may be able to provide a performance equivalent to HEPA filtration thus reducing energy costs. Energy savings are due to the fact that the fan energy required to overcome static pressure loss of the HEPA filters is far greater than the energy consumed by UVGI lamps.
ENERGY CONSUMPTION: WHOLE ROOM DISINFECTION DEVICES

- Limited by current availability in room
  - 15 Amp typical
  - Not continuously on

Low Energy consumption, relatively
HEALTHCARE ASSOCIATED INFECTIONS
COST IMPACT

- CDC estimates 1.7 million HAI infections per year
  - Almost 100,000 deaths annually caused by HAIs
  - Estimated cost of $30+ billion

- HAI hospital length of stay is increased 5 + days

- Range of cost for a single HAI:
  - C. diff: $6,408 - $9,124
  - SSI (often MRSA): $11,874 - $34,670

Source: CDC
Thank You