

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

**IUVA WORKSHOP
NIST, MD**

January 14, 2020

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PATHOGEN TRANSMISSION MODES

Air handler/cooling coil

- aspergillus, pseudomonas aeruginosa...

Airborne transmission through HVAC ducts

- TB, MRSA, Influenza, Klebsiellapneumoniae, aspergillus, Acinetobacter baumannii, aspergillus...

Water-borne transmission

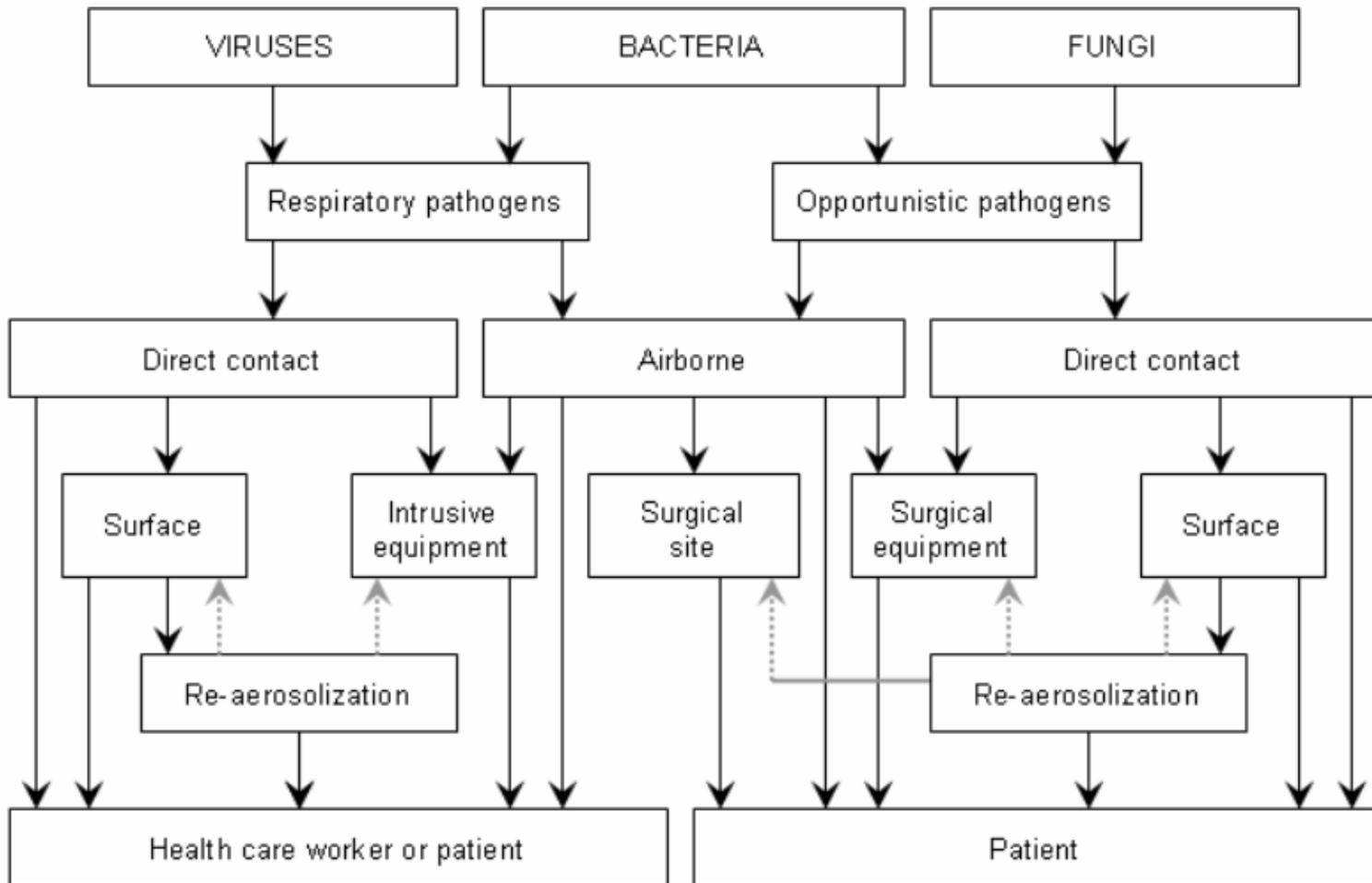
- Legionella, pseudomonas aeruginosa; mycobacteria; aspergillus, fusarium, cryptosporium, giardia, acanthamoebia...

Surface cross-contamination

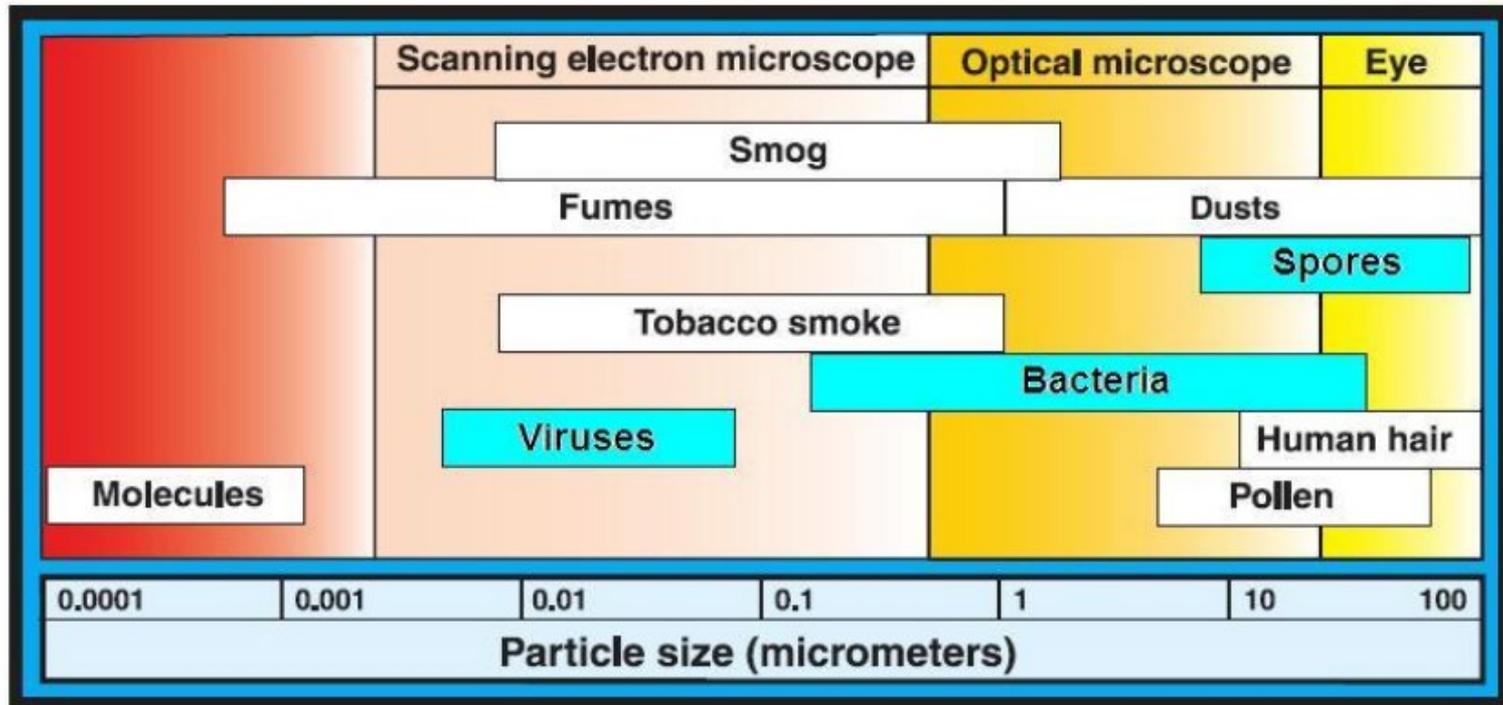
- MRSA, C-Diff, VRE, Candida auris, Ebola...

Hand cross-contamination

PATHOGEN TRANSMISSION ROUTES



AIR CONTAMINANTS



CONTROL STRATEGIES

- **Ventilation and Dilution**
- **Purging with Outside air**
 - **Increase Air changes per hour**
- **Pressurization control; isolation rooms**
- **Filtration**
- **Ultraviolet Germicidal Irradiation (UVGI)**

RELEVANT INDUSTRY GUIDELINES

GUIDELINES	AGENCY
Guidelines for Environmental Infection Control in Healthcare Facilities	HICPAC
Guidelines for Construction and Equipment of Hospital and Medical Facilities	AIA
HVAC Design Manual for Hospitals and Clinics	ASHRAE
General Requirements: Purpose of the Facilities Standard for Public Buildings Service	GSA
Guidelines for Preventing the Transmission of Mycobacterium Tuberculosis in Health Care Settings	CDC
Environmental Control for Tuberculosis: Upper-Room Ultraviolet Germicidal Irradiation Guidelines for Health Care	NIOSH
Guidelines on the Design and Operation of HVAC Systems in Disease Isolation Areas	CHPPM
Unified Facilities Criteria UFC 4-510-01 design: Medical Military Facilities	UFC 2001

ASHRAE UVGI GUIDELINES AND STDS.

Position Document on Airborne Infectious Diseases

Position Document on Filtration and Air Cleaning

ASHRAE/ASHE Standard 170.1: Ventilation of Health Care Facilities

SYSTEMS and EQUIPMENT HANDBOOK
Chapter 12: Ultraviolet Lamp Systems

APPLICATIONS HANDBOOK
Chapter 60: Ultraviolet Air and Surface Treatment

ASHRAE Standard 185.1: Method of Testing UV-C Lights for use in Air Handling Units or Air Ducts to Inactivate Airborne Microorganisms

ASHRAE Standard 185.2: Method of Testing UV-C Lights for use in Air Handling Units or Air Ducts to Inactivate Microorganisms on Irradiated Surfaces

ASHRAE GPC 37: Guideline for the Application of Upper Air (Upper Room) Ultraviolet Germicidal (UV-C) Devices to Control the Transmission of Airborne Microorganisms

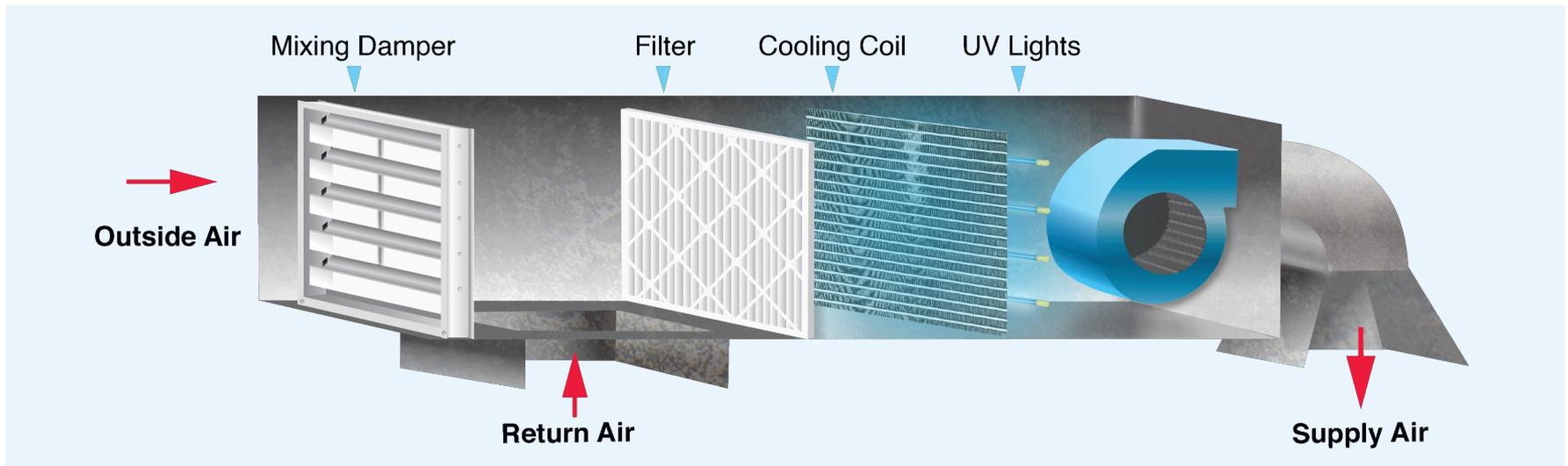
APPLICATION OF UVC IN AIR HANDLERS



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



UVGI AIR STREAM DISINFECTION

“Kill on the Fly”

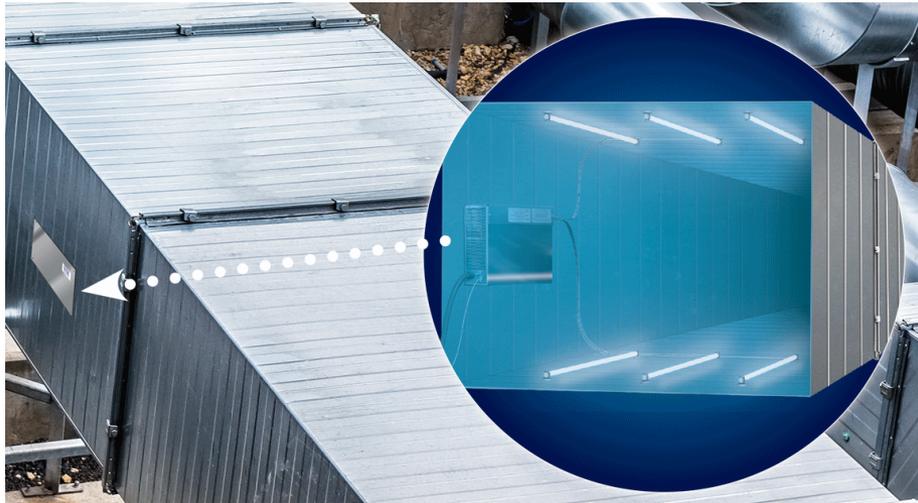
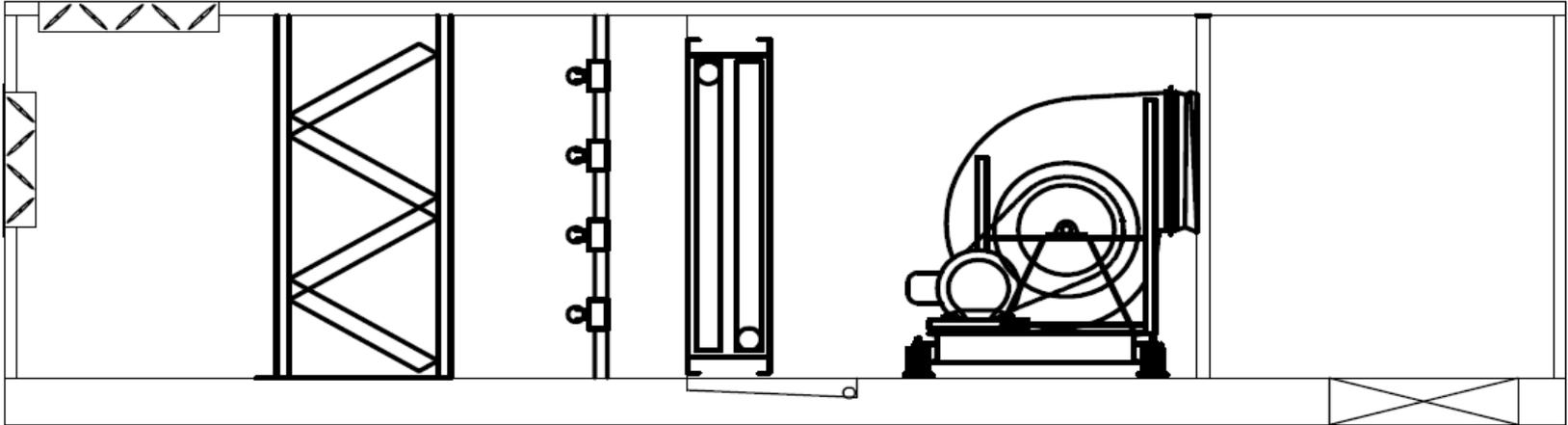


Moving Air Streams

COMMON AIRBORNE MICROORGANISMS

INFLUENZA (COMMON COLD)	TUBERCULOSIS
SARS, HIN1	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



CORRECT APPLICATION OF UVC DOSE



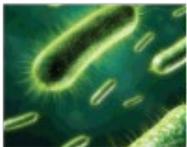
Bacteria

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



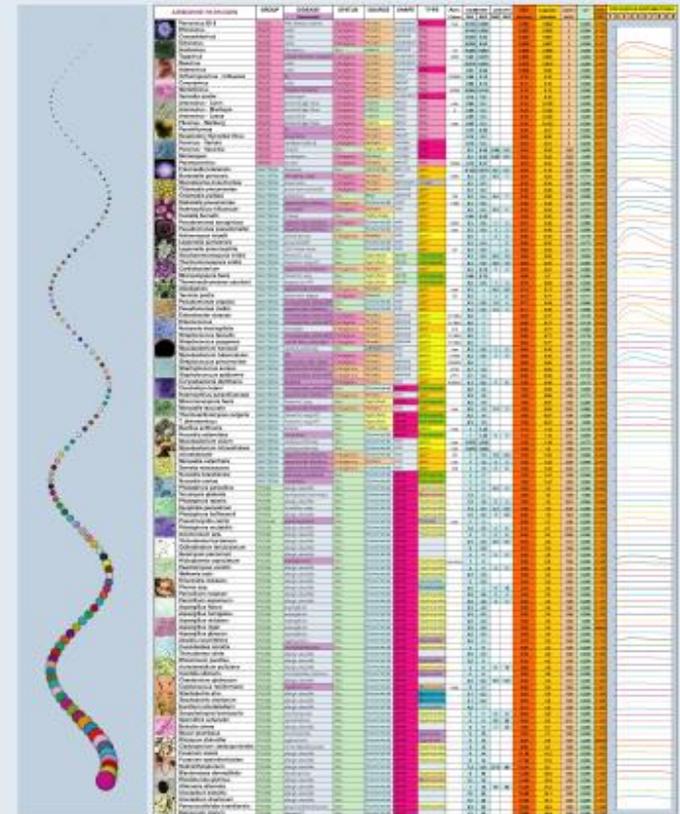
Mold

Aspergillus flavus	99,000
Aspergillus niger	330,000

THE WORLD'S MOST WANTED FELONS

Altru-V applies the Power of the V to seek out and destroy the nastiest felons—bacteria, viruses, and molds hiding in your equipment and circulating through your ductwork. Rely on Altru-V to drive out the felons and drive efficiency and performance back into your HVAC system while you enhance your air quality.

ALTRU-V The Optimal Solution for HVAC Maintenance



Call your sales representative or distributor for more information on UV products from Altru-V. Tel: 877-781-3983 Fax: 951-257-4600 www.altru.com ALTRU-V A Division of UVDI 39232 Industry Drive Valencia, CA 91355 UVDI

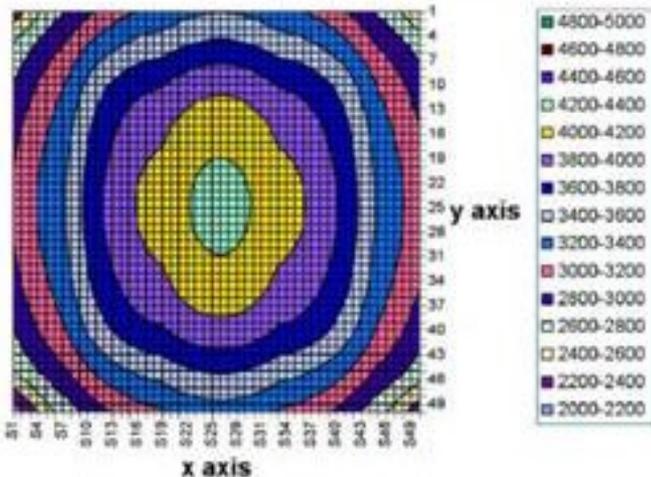
UV DOSE CRITICAL TO SYSTEM EFFICACY

Application Specific! Correct Intensity = Dose per Solution

Coil Disinfection:

- Surface fixed
- Unlimited Time
- Low UV dose

Coil Surface Intensity Distribution ($\mu\text{W}/\text{cm}^2$)

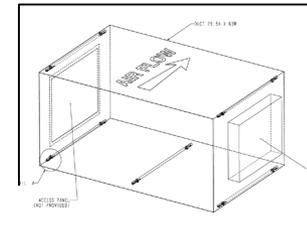


Air Disinfection: High Dose

- Fast moving microbes
- Fractions of seconds
- High UV Dose

Target Microbe and Dose for 90% Inactivation		
Microbe	<i>Influenza A virus</i>	
Microbe Rate Constant	0.0011870	$\text{cm}^2/\mu\text{J}$
Dose for 90% Kill (D90)	1940	$\mu\text{W}/\text{cm}^2$

UV Exposure Dose =	1589	$\mu\text{W}/\text{cm}^2$
URV =	12	



Lamp model	V-MAX-33	
Lamp UV power, W	27.00	
Lamp arc length, cm	76.2	
Lamp Diameter, cm	1.58	
Number of Lamps	5	
Total UV Power, W	135	
Duct Width	167.64	cm
	66.00	in
Duct Height	53.340	cm
	21.00	in
Duct Length	101.6	cm
	40.00	in
Airflow	339.802	m^3/min
	11999.9	cfm
Velocity	6.3	m/s
	1246.7	fpm
Exposure Time	0.160	sec
Air Temperature	55	F
Reflectivity	57	%

Cooling Coil's Impact On Energy Use

ASHRAE Journal

Study Verifies Coil Cleaning Saves Energy

By Ross D. Montgomery, PE, 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 budget can be self-defeating.

Through our privately funded testing, monitoring and analysis, we believe we found a methodology and regimen that proves maintaining air-handler components in a clean condition can save energy dollars and improve other building parameter changes and efficiencies such as improved dehumidification and comfort, along with less mold and bacteria. Thus, we are encouraging IAQ environmental parameter improvements, better tenant satisfaction, and increased worker effectiveness.

It is difficult to find a building such a study can be held. For owner and managers of a 12 floor building on Times Square, New York City wanted to see why dramatic change in coil cleanliness and frequency might have. It has only four large air handlers (SF-7, SF-8, SF-9; 250 [880 kW], 121 [425 kW] and 81 ton [285 kW] respectively) to service its 1.1 million sq ft (111,900 m²) of air-conditioned space throughout the year.

future data readings will measure and document O&M program designed to maintain the enhanced performance.

No direct way of measuring energy use or demand because instruments cannot measure the energy or demand. However, the absence of energy use can be calculated by comparing measurements of and/or demand before and after an energy conservation (ECM) (see ASHRAE Guideline 14, 2002, *Method of Energy and Demand Savings* for details and testing criteria and methods).

The ECM data collection was started on August 21, 2005. The ECM cleaning of the coils occurred on Aug. 26 and 28. During the study, specific operational parameters SF-8 and 9 were monitored with energy balance and humidity data points being recorded for one of the ECM. The recording was restored for an additional following the ECM. Several critical data points: differential pressure, air and water temperatures after the coil, condenser temperature, supply air outside air temperature, humidity before and after were measured on SF-8 and 9 and both units were completely cleaned.

To add reliability to our instrumentation call accuracy, a certified and independent testing, air balancing (TAB) firm was used to test and calibrate instrumentation that logged pressure, temperature, velocity and volumetric flow rates, voltage and at the course of our study period. In all, some 54 data continuously logged throughout the study period.

The daily variation in outside air temperature the same in the first span of this ECM (Figure 2) observed in the various charts, the building HVAC are operated in this building only during 6 a.m. Monday through Friday.

The study has yielded the following overall conclusions:

- Restoration of the one air handler resulted in a net will lead to energy savings of up to \$40,000 in accordance with the results and assumptions study. (The coil is 30 years old, and its last clean-up year ago, so the coil was in a dirty state).
- Restoring the air handler resulted in a decrease in energy use across the coil of approximately 14% resulted in a corresponding increase in airflow is that the fan is producing that much more ton of cooling.
- Restoring the air handler resulted in an increase to 22 tons (67 kW to 77 kW) of cooling

increased Aug. 26 to 28). This represents a significant increase in least heat transfer ability of the coil in the range of 10%. This indicates the ability of the coil "after cleaning" to being able to provide for better building dehumidification capacity control by delivering sub-dew-point air temperatures across the cooling coil.

In addition to the test results presented in this article, many other "soft" positive results came out of cleaning and normal maintenance operations and its resultant energy savings and airflow increases. The HVAC system performance is increased and can more closely perform to its original intended specified operation (38,150 cfm [14,500 L/s] design data from 30 years before). After coil cleaning and regular maintenance, the HVAC systems are cleaner, and do not provide an environment for fungal, bacterial and microbial growth in their coils, ducts, and pipes. IAQ and the presence of good IAQ are increased in the building, and the overall comfort and work effectiveness can be greatly enhanced. Overall energy satisfaction with the building environment has been improved as evidenced by the property manager's communications and positive feedback.

Furthermore, not only will the owner benefit from the obvious energy savings and comfort increase, we also would like to optimize some other building maintenance and operation processes and help enhance energy and maintenance efficiencies for years to come.

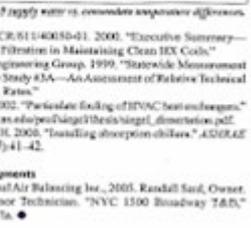
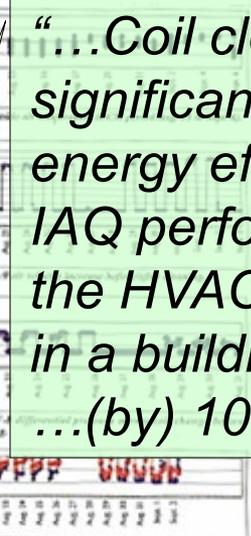
The building management had considered upgrading the environmental control systems to a modern building management system but could not clearly demonstrate an economic value to that investment. The data developed during this study allowed them to more accurately calculate a payback, so they scheduled this upgrade. In addition, communication had not been given to operation of the controls and the building supply and return fan from constant speed operation to VFD. The economic analysis allowed through this study has suggested for such a conversion might have significant economic value.

Good maintenance and operation policies including coil cleaning can significantly improve energy efficiency and IAQ performance of the HVAC/R systems in a building, such as reported here of 10% to 15%. Most importantly, this study identified several key mentioned and adjusted data points, such as pressure, humidity, and temperature, that can quickly and accurately provide a performance of the potential for energy savings in any building. It is anticipated that such measurements will become a valuable tool for measuring the economic impact of various building maintenance strategies.

A risk set of this study's data remains to be fully analyzed. It is possible that full analysis of all of this data will lead to even more additional opportunities for operational economy and improvements in this and other similar buildings.

Bibliography

ASHRAE. 1999. "Water Test and Measure Facts Manual." Cleveland, Ohio.



"...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

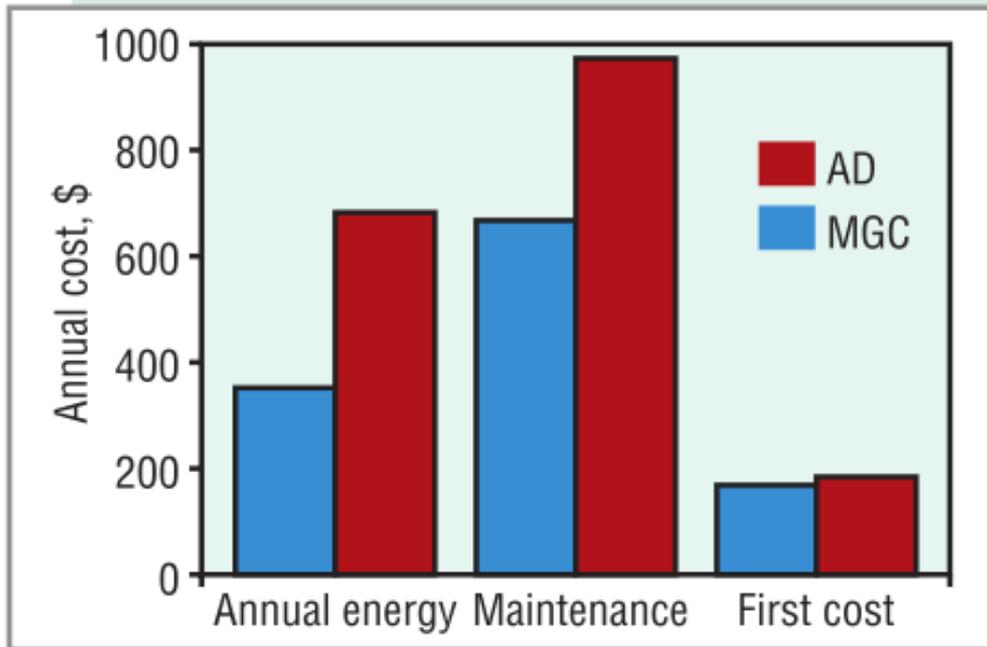


FIGURE 7. A comparison of UVGI air-stream-disinfection (AD) and microbial-growth-control (MGC) systems for a 20-year life cycle.

Economic evaluation of typical UVGI systems		
Type of Application	Air-stream disinfection	Microbial-growth control
Design airflow	10,000 cfm	10,000 cfm
Velocity	413 fpm	413 fpm
Predicted disinfection	90 percent <i>Serratia</i>	99.99 percent <i>Aspergillus</i>
UVGI lamp model	GPH436T5	TUV18W
Number of lamps	2	1
Height	150 cm	150 cm
Width	150 cm	150 cm
Length	150 cm	150 cm
Lamp total power (each)	36 W	18 W
Hours of operation	3744 hr	8760 hr
Energy costs		
Heat generated	0.072 kW	0.018 kW
Cooling load	189 kWh	110 kWh
Total dP (lamps, fixtures, filters)	0.560 in. WG	0.290 in. WG
Total fan energy (80 percent eff.)	8016 kWh	4151 kWh
Electrical energy	270 kWh	158 kWh
Cooling load energy	189 kWh	110 kWh
Total energy	8475 kWh	4419 kWh
Rate	8 cents per kWh	8 cents per kWh
Annual energy cost	\$678	\$354
Maintenance costs		
Average tube life	9000 hr	9000 hr
Tube hours per year	7488 hr	8760 hr
Replacements per year	0.83	0.97
Cost per tube	\$85	\$85
Annual cost	\$71	\$89
Annual filter-replacement cost	\$33	\$6
Maintenance (assumed)	\$200	\$200
Annual maintenance cost	\$949	\$642
First costs		
UVGI system (AU prices)	\$765	\$550
Labor (estimated)	\$1000	\$1000
Total installation cost	\$1765	\$1550
Life cycle	20 years	20 years
Interest rate	8 percent	8 percent
Life cycle cost	\$180	\$158
Total annual cost	\$1806	\$1154

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UVGI COSTS and ENERGY CONSUMPTION HVAC Systems

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.

Baseline	Upper Air UV	Increased Air Changes (9.2ACH)	UVGI in AHU
\$6792	\$10847	\$10,900	\$6675

SYSTEM DESIGN	Baseline System	Upper-Room UVGI	HVAC System with Increased 9.2 ACH	UVGI in AHU
System	AHU - 1	AHU - 1	AHU - 2	AHU - 1
Design Airflow (CFM)	3,900	3,900	8,240	3,900
Velocity (FPM)	520	520	495	520
ACH (Exam & Treatment Rooms)	6	15.2 (Equivalent)	15.2	6
Predicted disinfection in room	99%	99%	99%	99%
Predicted time required for room disinfection	46	18	18	46
Predicted coil disinfection	0%	0%	0%	99.99%
UVGI Fixture Model	-	#WM-136	-	#EXTV-60-1R4
Number of UVGI Fixtures per space	-	2	-	-
Number of Lamps per fixture	-	1	-	4
Nominal Power per Lamp (W)	-	36	-	60
Number of spaces with UVGI fixtures	-	14	-	-
UVGI hours of operation	-	8,760	-	8,760
FIRST COSTS (Installed costs)				
AHU	\$11,548	\$11,548	\$24,867	\$11,548
Ductwork	\$23,509	\$23,509	\$35,727	\$23,509
Exhaust Fan	\$734	\$734	\$764	\$734
UVGI system	\$0	\$25,018	\$0	\$1,567
Life cycle	20 years	20 years	20 years	20 years
Interest rate	8%	8%	8%	8%
<i>Annualized first cost¹</i>	<i>\$3,645</i>	<i>\$6,193</i>	<i>\$6,249</i>	<i>\$3,805</i>
ENERGY COSTS				
AHU hours of operation	8,760	8,760	8,760	8,760
Total fan energy (KWH)	37,446	37,446	57,888	33,102
Electrical energy - UVGI lamps (KWH)	0	8,830	0	2,102
Total energy (KWH)	37,446	46,276	57,888	35,204
Energy rate (\$/KWH)	0.078	0.078	0.078	0.078
<i>Annual energy cost</i>	<i>\$2,921</i>	<i>\$3,610</i>	<i>\$4,515</i>	<i>\$2,746</i>
MAINTENANCE COSTS				
UVGI replacement lamp cost	-	\$25	-	\$25
Total UVGI replacement lamp costs	-	\$700	-	\$100
Lamp replacements per year	-	1	-	1
Labor hours per UVGI lamp replacement	-	0.31	-	0.25
Total labor hours for UVGI lamp replacement	-	8.68	-	1
Labor rate (\$/Hr)	-	\$23.95	-	\$23.95
Total maintenance cost for UVGI	-	\$908	-	\$124
Chemical costs	\$40	\$40	\$40	-
Chemical cleanings per year	1	1	1	-
Labor hours for chemical cleaning	4	4	4	-
Labor rate (\$/Hr)	\$23.95	\$23.95	\$23.95	-
Total maintenance cost for chemical cleaning	\$136	\$136	\$136	-
<i>Annual maintenance cost</i>	<i>\$136</i>	<i>\$1,044</i>	<i>\$136</i>	<i>\$124</i>
COMPARATIVE ANNUAL COST	\$6,702	\$10,847	\$10,900	\$6,675

UVGI Value Proposition versus Mechanical Air Cleaning

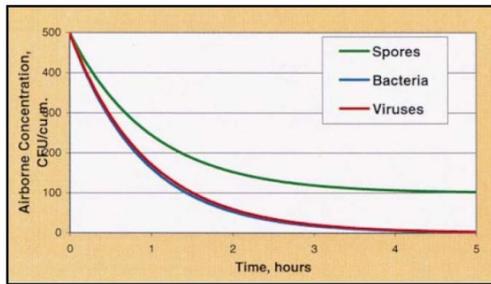


Figure 4.6 Outside Air Effectiveness

(W. J. Kowalski, 1997)

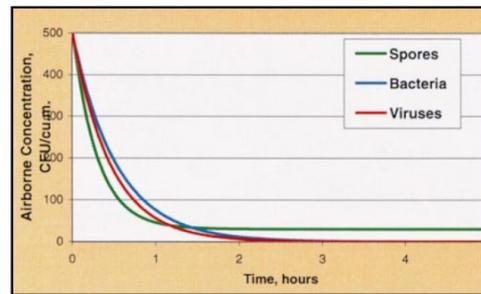


Figure 4.7 MERV 13 Filter Effectiveness

(W. J. Kowalski, 1997)

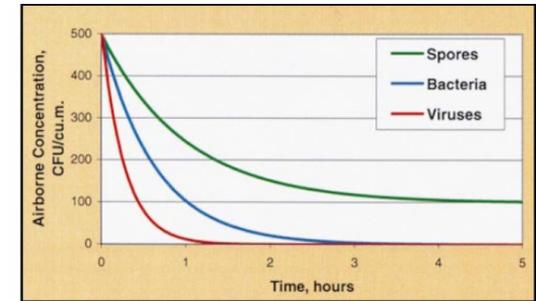


Figure 4.8 UVGI Effectiveness

(W. J. Kowalski, 1997)

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

Source: CDC

SSI (often MRSA): \$11,874 - \$34,670

Thank You